Research Article

The Impact of Mangrove (*Rhizophora apiculata*) Leaves Hay and Fermented *Tithonia diversifolia* on Intake, Nutrient Digestibility and Body Weight Gain of Goat

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Abstract | The utilization of mangrove *(Rhizophora apiculata)* leaves aims to meet the needs of energy sources for goats and *Tithonia diversifolia* as a source of forage protein. This study aims to determine the intake, body weight gain, and digestibility of nutrients of goats fed mangrove leaves and *T. diversifolia* with different levels. The research employed 16 one-year-old goats and divided them into groups according to their body weight. The concentrate utilized in the study comprised tofu dregs, corn, rice bran, palm kernel cake, minerals, and salt. A randomized block design with four treatments and four groups of goat body weight as replicates was employed in the research. The four treatments were as follows: (T1 = mangrove leaves hay (MLH) 35% + fermented *T. diversifolia* (FTD) 5% + Concentrate (C) 60%, T2 = MLH 30% + FTD 10% + C 60%, T3= MLH 25% + FTD 15% + C 60%, T4= MLH 20% + FTD 20% + C 60%). Parameters measured included body weight gain, intake, and nutrient digestibility. After conducting the research, it was found that the difference in the levels of MLH and FTD significantly affected (P< 0.05) on body weight gain, intake, and nutrient digestibility. The ratio composition in the T4 treatment, namely mangrove leaves hay 20% + fermented *T. diversifolia* 20% + Concentrate 60% was able to increase body weight gain (65.25 g/head/day), and maintain dry matter intake (478.95 g/head/day).

Keywords | Body weight gain, Kacang goat, Mangrove leaves hay, Nutrient digestibility, *Tithonia diversifolia*

Received | May 24, 2023; **Accepted** | June 28, 2023; **Published** | July 23, 2023
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Citation | Jamarun N, Pazla R, Arief, Elihasridas, Yanti G, Sari RWW, Ikhlas Z (2023). The impact of mangrove (*Rhizophora apiculata*) leaves hay and fermented *Tithonia diversifolia* on intake, nutrient digestibility and body weight gain of goat. Adv. Anim. Vet. Sci., 11(9):1441-1450.
DOI | https://dx.doi.org/10.17582/journal.aavs/2023/11.9.1441.1450
ISSN (Online) | 2307-8316

INTRODUCTION

Mangroves are one of the many plants that grow in coastal areas that have the potential as alternative forages (Yanti et al., 2021; Sari et al., 2022a, b, c; Ikhlas et al., 2023). Mangrove leaves contain nutrients, among others, 13.37% crude protein (CP), 92.83% organic matter, 3.18 crude fat, 12.18% crude fiber, 79% total digestible nutrients (TDN), 0.38% Ca minerals, 0.51% P, Mg 0.20%, Zn 164 ppm, and S 0.01% (Jamarun et al., 2020). Rahardian et al. (2019) reported that mangrove forests are the most extensive in the world, and Indonesia, they cover 3.3

million ha. This potential must be utilized to increase the productivity of goats in the mangrove area by introducing mangroves as an alternative feed to replace field grass. Mangrove plant leaves have been used as camel fodder in the Red Sea, India, and Australia (Baba et al., 2016). This potential shows that mangroves can be used as animal feed. Sari et al. (2021) said that mangrove (*Rhizophora apiculata*) leaves have a complete nutritional content, including a source of carbohydrates and calories.

Tithonia diversifolia plants are usually harvested to produce 4.10-10.20 tonnes/ha/year in the form of dry matter, with a harvest of 6 times/per year (Hafis, 2019). The nutritional content of *T. diversifolia* contains 25.57% dry matter, 22.98% crude protein, 4.57 lignin, 18.17% crude protein, dan 84.01% organic matter (Jamarun et al., 2019). The crude protein content of *T. diversifolia* is high, so this forage can be used as a source of protein for livestock. One of the problems with *T. diversifolia* is that it has a limiting factor, namely the presence of anti-nutritional substances, such as phytic acid, which is the most anti-nutritional content in *T. diversifolia* of 79.1 mg/100g and other anti-nutritional substances (Onyeunago et al., 2013; Aye, 2016; Oluwasola and Dairo., 2016).

Phytic acid can reduce the palatability of livestock (Pazla et al., 2021a, 2022a, b). Phytic acid binds with minerals and proteins to form complex insoluble compounds, which reduce the availability of minerals and proteins, thereby reducing the nutrition of feed ingredients. This causes a decrease in the bioavailability (absorption) of minerals and protein in the body, thus reducing the nutritional quality of food (Samtiya et al., 2020). One way to reduce the limiting substances in *T. diversifolia* can be done through various processing methods, one of which is fermentation. Fermentation is an effective way to reduce the levels of phenolic compounds and phytic acid in the ingredients. The microbe used for *T. diversifolia* fermentation is *Aspergillus ficuum*, capable of producing phytase enzymes (Pazla et al., 2021b). In general, *A. ficuum* is most widely used in fermentation because it adapts to higher fermentation temperatures than other fermenting bacteria. Garcia et al. (2016) and Pazla et al. (2021c) said phytase enzymes that can hydrolyze phytic acid into inositol and organic phosphate. Fermented *T. diversifolia* combining with avocado waste can optimize bodyweight gain kacang goat (Pazla et al., 2023a). Using *T. diversifolia* in dairy goats can increase the fat content of goat's milk and optimize milk production (Pazla et al., 2022c; Arief and Pazla, 2023). Combining mangrove leaves and *T. diversifolia* are expected to optimize goats weight gain. This study aims to determine the best goat ration formulation from a combination of mangrove leaves and *T. diversifolia*.

MATERIALS AND METHODS

Materials and research tools

The individual cage was constructed using a 1X0.75X1 m iron frame and included provisions for eating and drinking. The materials employed in this study encompassed mangrove leaves, *tithonia*, Potato Dextrose Agar media, *Aspergillus ficuum*, concentrates, and aquades composed of palm kernel cake, corn, tofu dregs, salt, minerals, and rice bran. Additionally, various equipment such as mold rejuvenation tools, glass beakers, cotton, autoclaves, aluminum foil, analytical scales, test tubes, ropes, plastic, and bench containers were utilized in the research for chemical composition analysis.

Research methods

The *in vivo* study was conducted at experimental cage of the Animal Husbandry Faculty of Andalas, University, located in Padang City, West Sumatra. The geographical position of this area is 0° 54' 52.2648" S, 100° 27' 34. 2936" E at an elevation of 200-255 meters above sea level. The region experiences an average rainfall of 44 mm^3, humidity ranging from 73-75%, and wind speeds of 5-6 km/h. The temperature in the area ranges between 27-28 °C. A total of 16 goats, aged one year, were utilized in the study. The goats were grouped according to the weight of their body: Group I. 13.41±0.51 (CV= 3.80%), II. 11.95±0.47 (CV= 3.93%), III. 10.51±0.25(CV= 2.35%), IV. 9.71±0.27(CV= 2.77%). The treatment consisted of four ration formulations, namely:

T1. 35% mangrove leaves + 5% *T. diversifolia* + 60% Concentrate

T2. 30% mangrove leaves + 10% *T. diversifolia* + 60% concentrate

T3. 25% mangrove leaves + 15% *T. diversifolia* + 60% concentrate

T4. 20% mangrove leaves + 20% *T. diversifolia* + 60% concentrate

The mathematical model employed in the design is as follows: (Steel and Torrie, 2002).

$$Yij = \mu + \tau i + \beta j + \Sigma ij$$

Information

Yij = the results of the observation of the i-th treatment and the j-th replication; μ = general mean; τi = the effect of treatment i; Σij= random error; i = treatments (T1,T2,T3,T4); βj = the effect of treatment j; j = repetition (1, 2, 3, and 4).

The concentrate used in the study consisted of corn, rice bran, tofu dregs, minerals, and palm kernel cake. The design of the research employed a randomized block design, with four treatment formulations being compared and four body weight groups serving as replicates. The ration was provided at 3.5% rate of body weight in terms of the conversion of dry matter (Kearl, 1982). This study consisted of 3 periods: the first was a 21-day adaptation period, the second was a 14-day prelimination period, and the last was a five-day collection period. During the fecal collection, 10% was taken as an analytical sample. In the laboratory, the nutritional composition of the feed ingredients comprising the ration and feces is analyzed. Proximate analysis following the procedure of AOAC (2016). Fiber fraction analysis according to Van Soest et al. (1991). Chemical composition of the feed ingredients making up the treatment ration is shown in Table 1. Treatment Ration Composition is shown in Table 2 and the nutritional content of treatment ration is shown in Table 3.

Table 1: Chemical composition of the feed ingredients making up the treatment ration (% DM).

Chemical composition (%)	Feed ingredients					
	ML	FTD	TD	RB	PKC	Corn
Dry matter	84.27	91.22	90.47	88.29	90.32	87.55
Organic matter	90.26	85.49	94.18	88.99	96.13	95.87
Ash	9.74	14.51	5.82	11.01	3.87	4.13
Crude protein	10.13	25.85	24.62	8.94	22.29	13.87
Crude fiber	14.87	12.43	21.94	25.74	29.96	9.61
Crude fat	2.45	2.61	8.12	7.52	6.15	3.09
NFE	62.81	44.60	39.5	46.79	37.73	69.30
TDN	75.58	64.61	69.65	70.10	66.19	82.81
NDF	34.01	54.17	42.66	48.11	72.59	49.96
ADF	22.67	36.82	22.92	25.69	50.33	36.76
Cellulose	14.87	23.12	20.44	19.63	26.85	29.52
Hemicellulose	11.34	17.35	19.74	22.42	22.26	13.20
Lignin	7.54	4.57	1.84	3.78	9.25	7.50
Silica	0.26	4.07	0.64	2.28	14.23	0.70

ML= mangrove leaves; FTD= fermented *Tithonia diversifolia*; TD= tofu dregs; RB= rice bran; PKC= palm kernel cake; NFE= nitrogen free extract, TDN= total digestible nutrient; NDF= neutral detergent fiber; ADF = acid detergent fiber.

Table 2: The composition of the treatment ration.

Feed ingredients	Treatment ration (% DM)			
	T1	T2	T3	T4
Mangrove leaves	35	30	25	20
Fermented *Tithonia diversifolia*	5	10	15	20
Tofu dregs	5	2	1	1
Rice bran	25	28	29	29
Palm kernel cake	14	5	2	1
Corn	15	24	27	28
Mineral	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5
Total	100	100	100	100

Table 3: Nutritional content of the treatment ration.

Nutritional content (% DM)	Treatments			
	T1	T2	T3	T4
Dry matter	86.43	86.46	85.80	87.02
Organic matter	90.66	90.24	88.98	89.70
Ash	8.34	8.76	9.02	9.30
Crude protein	13.51	13.06	13.22	14.14
Crude fiber	18.99	17.15	16.16	16.13
Crute fat	4.60	4.31	4.16	4.20
NFE	53.56	55.71	55.44	55.23
TDN	72.38	73.34	72.63	72.91
NDF	46.57	45.79	45.48	47.00
ADF	30.05	29.70	29.56	30.64
Cellulose	20.48	21.11	21.42	22.03
Hemicellulose	16.52	16.09	15.92	16.36
Lignin	6.58	6.58	6.56	6.74
Silica	2.00	1.66	1.73	2.02

Research stage

T. diversifolia fermentation: *T. diversifolia* fermentation is carried out to reduce phytic acid levels. The steps in fermenting the feed are as follows:

Rejuvenation of *A. ficuum*

Rejuvenation of *A. ficuum* on Potato Dextrose Agar (PDA) oblique media and incubated at room temperature for seven days. Cracked corn was weighed 100 grams, soaked for 24 hours, then sterilized by autoclaving at 121°C for 30 minutes. Then cooled, the *A. ficuum* was inoculated into corn from slanted media and incubated for 14 days. *A. ficuum* inoculum is ready to use.

Feed ingredients preparation

The feed ingredients used in this study were *T. diversifolia* plants and mangrove leaves. Mangrove leaves were collected from the coastal areas and *T. diversifolia* from the Puncak Lawang, Agam regency, and West Sumatera. Mangrove leaves are given in the form of hay. Mangrove leaf hay is made by drying fresh mangrove leaves in the sun until they reach a moisture content of 12-20%. While, *T. diversifolia* was air dried and then in a chopper, then given *A. ficuum* inoculum.

T. diversifolia fermentation process

According to Pazla et al. (2023a), the *T. diversifolia* fermentation process involved several steps for the *T. diversifolia* substrate. Firstly, it underwent cutting, drying, and crushing. Subsequently, the *tithonia* was evenly distributed on a tarp and treated with a 10% concentration of *Aspergillus ficuum*. Afterwards, it was placed in a plastic container, compacted under facultative aerobic conditions, and securely fastened. Following a seven-day incubation period, the *tithonia* was harvested. It is important to note that the harvested *tithonia* needs to be air-dried prior to being utilized as livestock feed.

Statistical analysis

Data analysis was conducted using Analysis of Variance (ANOVA) in IBM SPSS Statistics version 26.0 (IBM Corp., NY, USA). For further test, Duncan Multiple Range Test (DMRT) was employed.

Parameter measured

The study measured several parameters including feed intake (organic matter, dry matter, crude protein), nutrient digestibility (organic matter, dry matter, crude protein), body weight gain, the correlation between dry matter intake and body weight gain, and the correlation between crude protein intake and body weight gain.

Formula calculation

Rations intake (fresh) (g/day) = total rations provided – remaining rations

Dry matter intake (g/day) = consumption of fresh rations * Dry matter ration

Organic matter intake (g/day) = DM ration consumption * Organic matter ration

Crude protein intake (g/day) = DM ration consumption * Crude protein ration

Dry matter digestibility (%) = (DMI- Feces)/ DMC * 100%)

Organic matter digestibility (%) = (OMI- Feces)/ OMC * 100%)

Crude Protein Digestibility (%) = (CPI- Feces)/ CPC * 100%)

Body weight gain (g/day) = (Final weight -Initial weight)/ Research Time

Where:

DM = Dry matter; DMI = Dry matter intake; OMI = Organic matter intake; CPI = Crude protein intake

RESULT AND DISCUSSION

Nutrients intake

It can be seen in Table 4 that the intake of crude protein, dry matter, and organic matter are significantly different between treatments (P<0.05). The DMRT follow-up test showed that in the T4 treatment, the dry matter intake significantly differed from the T1, T2, and T3 treatments. The dry matter intake values ranged from 409.90 – 478.95 g/d (Figure 1). The intake of organic matter in the T4 treatment was significantly different (P<0.05) from the T1, T2, and T3 treatments. Crude protein intake in the T4 treatment was significantly different (P<0.05) with T1, T2, and T3. The lowest value was in treatment T1 recorded a value of 382.27 g/d, whereas the highest value of 451.74 g/d was observed in treatment T4 (Figure 2).

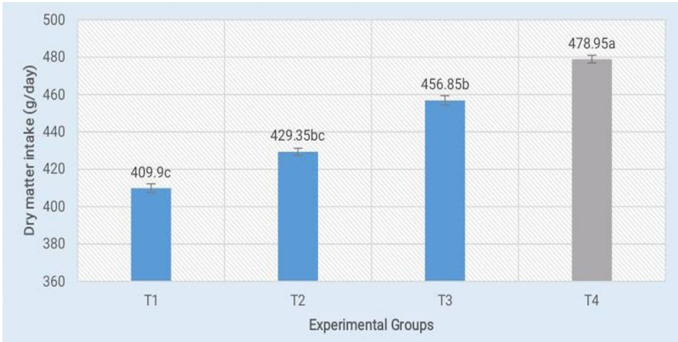

Figure 1: Dry matter intake of the treatments.

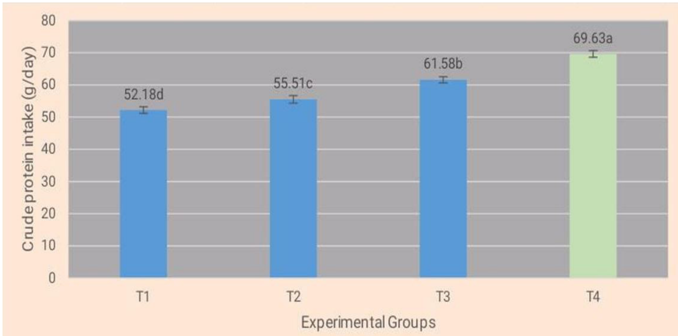

Figure 2: Crude protein intake of the treatments.

Digestibility of dry matter (DM), organic matter (OM), and crude protein (CP),

Figures 3, 4 and 5 clearly demonstrates that each treatment had a distinct and significant impact (P < 0.05) on the digestibility of crude protein, organic matter, and dry matter. Regarding dry matter digestibility, T1 significantly differed from T2, T3, and T4. In terms of the treatment comparison, there was no significant difference between T2 and T3, but there was a significant difference between T2 and T4. Treatment of T3 was significantly different from T4. Organic Matter digestibility in the T1 treatment differed significantly from T2, T3, and T4.

Table 4: Nutrient intake of the treatment ration.

Nutrient intake (g/day)	Treatments			
	T1	T2	T3	T4
Dry matter intake	409.90±2.34[c]	429.35±1.89[bc]	456.85±2.54[b]	478.95±2.05[a]
Organic matter intake	382.27±1.89[d]	401.74±2.87[c]	425.09±2.45[b]	451.74±2.03[a]
Crude protein intake	52.18±1.02[d]	55.51±1.17[c]	61.58±0.96[b]	69.63±1.04[a]

T2 treatment did not exhibit a significant difference compared to T3, but it showed a significant difference compared to T4. Crude protein digestibility gives significantly different results for each treatment.

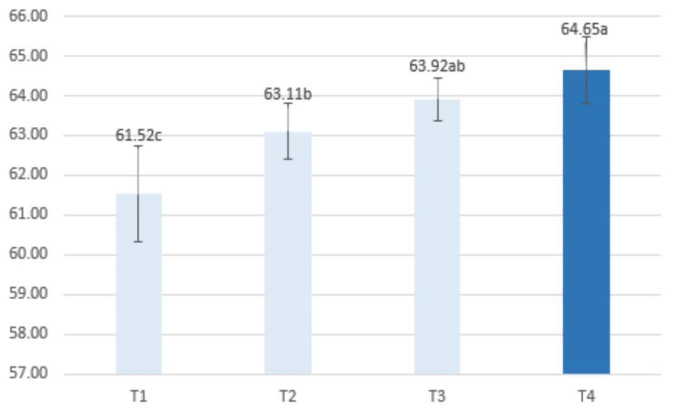

Figure 3: Dry matter digestibility of the treatments.

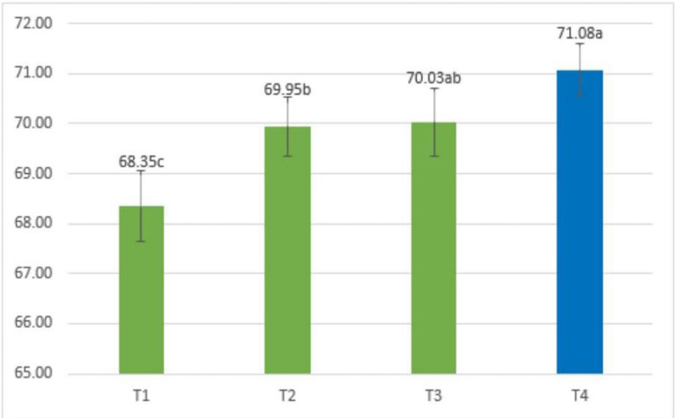

Figure 4: Organic matter digestibility of the treatments.

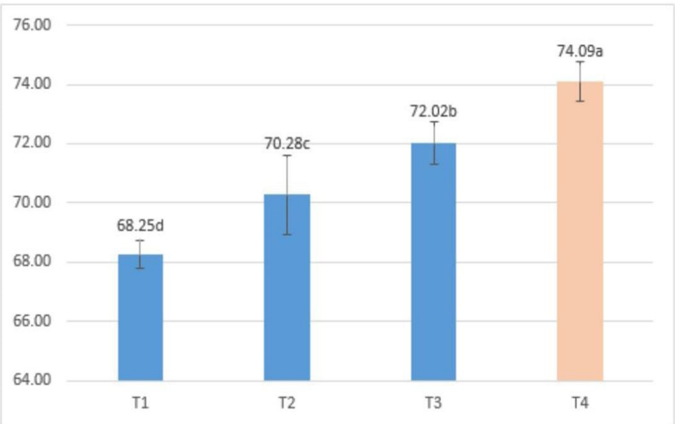

Figure 5: Crude protein digestibility of the treatments.

The T4 treatment showed the best value for the digestibility of dry matter with a value of 65.50% (Figure 3), the digestibility of organic matter of 71.36% (Figure 4), the digestibility of crude protein of 75.30% (Figure 5), The mangrove leaves combination, *T. diversifolia* and concentrates, affected the digestibility of crude protein, dry matter, and organic matter.

Body weight gain

In Figure 6, the results of statistical analysis using analysis of variance (ANOVA) show a significant difference (P <0.05) between treatments. The average daily weight gain of goats in treatments T1, T2, T3, and T4, which was 54.00; 57.50; 60.06; and 62.25 g/head/day. The DMRT follow-up test on daily weight gain showed that T1 Treatment was not significantly different from T2 but significantly different (P<0.05) with T3 and T4 treatment. The T2 treatment showed no significant difference (P>0.05) compared to the T3 treatment, but it exhibited a significant difference from the T4 treatment. Similarly, the T3 treatment was significantly different (P<0.05) from the T4 treatment.

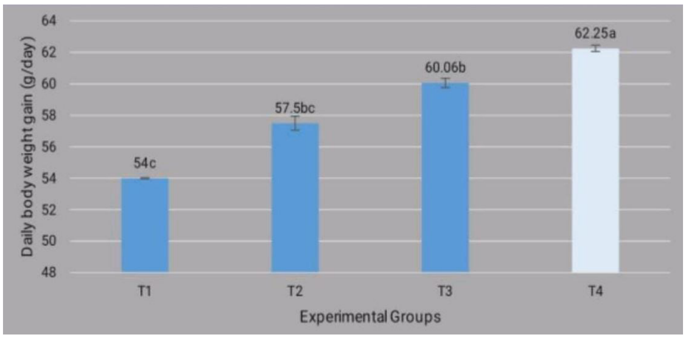

Figure 6: Daily body weight gain of the treatments.

Nutrients intake

The amount of food substances contained in the food that can be devoured minus the sum of food substances contained within the excreted feces (feces) is called the digestibility of food ingredients (Jamarun et al., 2021a). The apparent digestibility coefficient of a food ingredient is also called the digestibility value of a food substance. From Table 4, it can be observed that the T4 treatment resulted in an increased digestibility coefficient for all nutrients across the proportion. This happened because in the T4 treatment, the use of fermented *T. diversifolia* was higher compared to the other treatments, specifically at 20%. Fermented *T. diversifolia* is one of the feeds that has excellent quality when given to livestock due to its high protein content. Livestock tends to prefer fermented *T. diversifolia*, which leads to increased consumption in the T4 treatment where *T. diversifolia* is used more than in the other treatments. Fermented *T. diversifolia* has a fragrant aroma that increases palatability. while mangrove leaves have a bitter taste because there is a high tannin content (Jamarun et al., 2021b). Wojtunik et al., (2020) state that the relationship between digestibility and consumption is that increasing digestibility causes increased consumption. Besides being influenced by nutrient content, consumption is also influenced by feed flow rates. The feed flow rate is affected by good feed digestibility. if the feed is digested properly, the rumen will empty faster so that the livestock will automatically consume more to keep the rumen filled with food. The inclusion of titonia at the highest level of

20% is believed to optimize the performance of rumen microbes in efficiently degrading feed. Pazla et al. (2023b) reported that titonia contains a high phosphorus mineral which plays a very important role in the growth and activity of rumen microbes. In addition, the proportion of mangrove leaves that was low at T4 (20%) compared to other treatments facilitated the rumen microbes' performance in degrading feed because decreasing the proportion of mangroves would reduce the tannin content contained in the ration. Jamarun et al. (2021b) reported that mangrove leaves contain a fairly high tannin content of 11.10%. High levels of tannins can adversely affect the performance of rumen microbes (Rira et al., 2022).

Organic matter consumption increases with increasing dry matter consumption. Pazla (2018) expressed that organic matter is closely related to dry matter since organic matter is contained in dry matter. Statistically, there were significant differences ($P < 0.05$) in the consumption of crude protein among the different treatments. Crude protein consumption ranged from 47.69%-54.52% (Figure 2). This is due to the use of different mangrove and *T. diversifolia* leaves. So, the possibility of nutrient content is different. As a result, the forage consumption in each treatment is significantly different. Increasing the use of *T. diversifolia* and decreasing the use of mangrove leaves in rations can lead to increased ration consumption. This is because mangrove leaves contain high levels of tannins (8-11%), making them difficult for rumen microbes to digest and low palatability (Ikhlas et al., 2023). On the other hand, increasing the use of fermenred *T. diversifolia* is beneficial due to its good palatability and nutritional content, particularly its high protein content, which helps increase consumption. Feed protein was positively correlated with organic matter and dry matter (Mastoraki et al., 2022). Arief et al. (2023) reported that goats given titonia were able to increase the consumption of organic matter and consumption of crude protein. Utari (2018) and Jusman et al. (2020) state that feed consumption is mainly influenced by feed quality and related livestock energy demand factors. With better quality of feed, it will increase feed consumption. However, the consumption of good quality animal feed is determined by the physiological status of an animal. Consumption of feed dry matter by ruminants can range from 1.5–3.5%, but generally 2–3% of body weight (Wanapat, 2009). The consumption of crude protein was found to be lower compared to the findings reported by Laksana et al. (2016). In their study, the reported consumption ranged from 48 to 111g/head/day, using rations with a protein content of 18.33% and TDN (Total Digestible Nutrients) of 65.23%. The higher consumption of high protein rations can be attributed to the elevated protein content in the ration (Marwah et al., 2010; Krisna, 2015).

Digestibility of dry matter (DM), organic matter (OM), and crude protein (CP)

The highest level of dry matter digestibility and the digestibility of organic matter were 65.50% and 71.36% for the P4 treatment (mangrove leaf 20% + *tithonia* 20% + concentrate 60%). This may occur because using more *T. diversifolia* than other treatments causes the digestibility of the dry matter to increase. *T. diversifolia* is one of the bushes with excellent nutritional content for livestock. Rianita et al. (2019) stated that *T. diversifolia* plants are excellent feed given to livestock with excellent nutritional content to increase the productivity of goat livestock.

Crude protein is a food substance that is needed by ruminants. Figure 5 shows the highest crude protein digestibility in T4 (20% mangrove leaves + 20% *T. diversifolia* + 60% concentrate). In the T4 treatment, utilization of *T. diversifolia* was higher than in the other treatments and increased the crude protein digestibility in the T4 treatment. Jamarun et al. (2017c) and Rostini et al. (2022) the crude protein digestibility is affected by a few factors, including the dietary protein content, protein composition, and microbial activity. The high organic matter of T4 is in line with the digestibility of crude protein, including organic matter components.

T. diversifolia used in this study is *T. diversifolia*, which has been fermented to break the fiber bonds and phytic acids contained in *T. diversifolia*, making *T. diversifolia* easier to digest and more palatable for goat. Also, at T4, the use of mangrove leaves is less so that fiber is easier to digest, and the less fiber there is in plants, the easier it is for the rumen microbes to digest the rations in the T4 treatment (Cone et al., 2012). The high digestibility of dry matter, organic matter, and crude protein is due to the increased rumen microbial activity, so rumen metabolic processes run smoothly. Pazla et al. (2018a) and Katoch (2022) explained that high microbial activity requires sufficient nutrients, especially energy and protein. In this study, the crude protein digestibility was found to be similar to that reported by Laksana et al. (2016). The research findings revealed that forage-based rations containing elephant grass, with a crude protein content of 18.33% and TDN of 65.23%, exhibited a crude protein digestibility of 72.45%, according to both studies.

Body weight gain

Figure 6 shows that combining mangrove leaves and fermented *T. diversifolia* can increase Kacang goats daily body weight gain. The high daily body weight gain in the T4 treatment was due to the feed ingredients used for the study (20% mangrove leaves + 20% *T. diversifolia*), which had a higher digestibility than the other treatments, so more nutrients were absorbed by livestock for production.

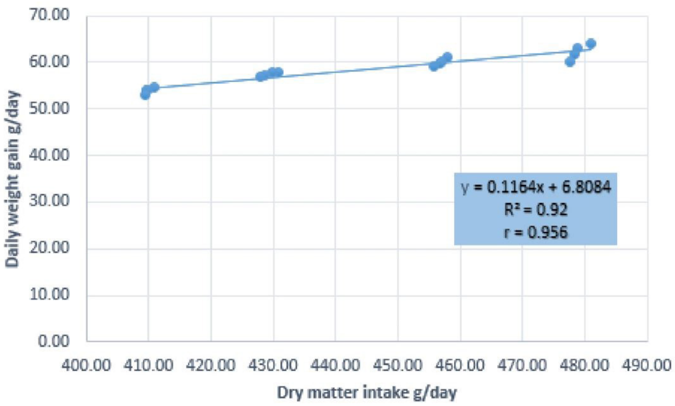

Figure 7: Correlation daily weight gain with dry matter intake.

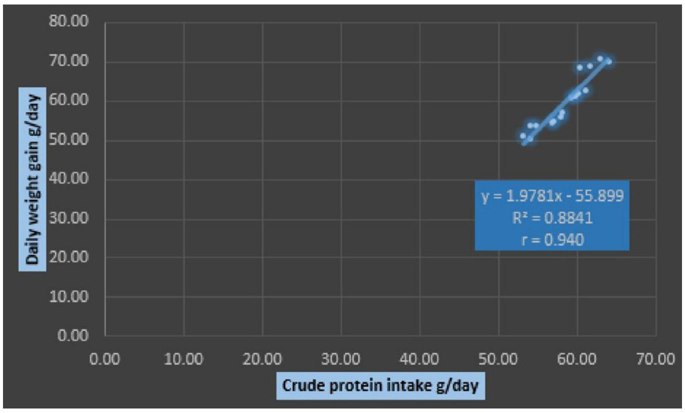

Figure 8: Correlation daily weight gain with crude protein intake.

The high daily weight gain in the T4 treatment was due to the high intake of nutritional content of the ration owned by T4. The high intake of nutrients observed in the T4 treatment was due to the T4 treatment using a significant amount of fermented *T. diversifolia* compared to other treatments, which caused high nutrient intake. Fermented *T. diversifolia* would be consumed more by livestock than mangrove leaves. The effort that affects the increase in weight gain is feed consumption. According to Van Soest (2018), consumption is calculated as the amount of feed eaten by livestock. The nutrients it contains meet basic life needs and livestock production needs. This is under the income of Mdletshe et al. (2017). Consumption can increase with increasing body weight because, in general, the capacity of the digestive tract increases with increasing body weight so that it can accommodate more feed. Figures 7 and 8 show a strong relationship between consumption of dry matter and crude protein on daily body weight gain of treated kacang goats.

These results indicate that combining mangrove leaves and *T. diversifolia* provides good ration consumption. Barragan et al. (2017) explained that the better the nutritional content of a feed ingredient, the higher the consumption of the ration that will be given to livestock. The excellent content of *T. diversifolia*, which is used as animal feed, makes ration consumption the best T4 treatment. The body weight increase of Kacang goats observed in this research was almost similar to that reported by Fardana et al. (2019), which was 62 grams per head per day with a composition of corn and concentrate rations supplemented with multi-nutrient blocks and lower from Pazla et al. (2023a), which was 67.25 g/day with feed formulation 35% fermented sugarcane shoots + 14% fermented *tithonia* + 1% avocado waste + 50% concentrate.

CONCLUSIONS AND RECOMMENDATIONS

The combination of 20% mangrove leaves + 20% *T. diversifolia* + 60% concentrate gave the best results on the consumption of nutrients, nutrient digestibility, and increased body weight gain of 62.25 gr/head/day. This study examines the utilization of mangrove leaves and *T. diversifolia* as green fodder sources for goat livestock. The future direction of this research involves the application of this feed formulation to coastal farmers.

ACKNOWLEDGMENTS

We would like to express our gratitude to the Andalas University Research and Community Service Institute for their generous funding of this research project. This support was made possible through the "Professor Publication Research" research scheme, with contract number T/12/UN.16.17/PT.01.03/KI/KPR1GB/2022.

NOVELTY STATEMENT

This study found goat ration formulation to optimize body weight gain by using fermented tithonia *(Tithonia diversifolia)* and mangrove *(Rhizophora apiculata)* leaves hay.

AUTHOR'S CONTRIBUTION

The research project involved a team of individuals who contributed to different aspects of the study. Novirman Jamarun and Roni Pazla were responsible for the conceptualization of the project. Roni Pazla and Gusri Yanti handled the data curation, while the formal analysis was conducted by Roni Pazla, Gusri Yanti, Zaitul Ikhlas, Rani Winardi Wulan Sari, and Elihasridas. The in vivo treatment was administered by Zaitul Ikhlas, Gusri Yanti, Rani Winardi Wulan Sari, and Roni Pazla. The funding for the project was acquired by Novirman Jamarun. Methodology development was carried out by Roni Pazla and Novirman Jamarun, and project administration was overseen by Gusri Yanti. The supervision was provided by Arief and Novirman Jamarun, while Roni Pazla and Elihasridas conducted the validation of the research. The initial draft of the manuscript was written by Roni Pazla, and both Roni Pazla and Novirman Jamarun contributed to the review and editing process.

Ethics approval

This experiment followed research ethics guidelines pertaining to livestock, in accordance with the Animal Science and Health regulations outlined in government law number 41/2014 issued by the Republic of Indonesia.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

AOAC (2016). Official methods of analysis of the Association of Analytical Chemists. Virginia USA: Association of Official Analytical Chemists, Inc.

Arief, Pazla R (2023). Milk production and quality of etawa crossbred goats with non-conventional forages and palm concentrates. Am. J. Anim. Vet. Sci., 18(1): 9-18. https://doi.org/10.3844/ajavsp.2023.9.18

Arief, Pazla R, Jamarun N, Rizqan (2023). Production performance, feed intake and nutrient digestibility of Etawa crossbreed dairy goats fed *tithonia (Tithonia diversifolia),* cassava leaves and palm kernel cake concentrate. Int. J. Vet. Sci., 12(3): 428-435. https://doi.org/10.47278/journal.ijvs/2022.211

Aye PA (2016). Comparative nutritive value of *Moringa oleifera*, *Tithonia diversifolia*, and *Gmelina arborea* leaf meals. Am. J. Food Nutr., 5: 23-32.

Baba, Shigeyuki, Chan, Hung, Oshiro, Nozomi, Maxwell, Gordon, Inoue, Tomomi, Chan, Eric (2016). Botany, uses, chemistry and bioactivities of mangrove plants IV: Avicennia marina. ISME/GLOMIS Electron. J., 14.

Barragan FKB, Dicke M, Van LJJ (2017). Nutritional value of the black soldier fly (*Hermetia illucens* L.) and its suitability as animal feed. A review. J. Insects Food Feed, 3(2). https://doi.org/10.3920/JIFF2016.0055

Cone JW, Baars JJP, Sonnenberg ASM, Hendriks WH (2012). Fungal strain and incubation period affect wheat straw's chemical composition and nutrient availability for rumen fermentation. Bioresour. Technol., 111: 336-342. https://doi.org/10.1016/j.biortech.2012.02.001

Fardana DH, Tampoebolon BIM, Pangestu E, Widiyanto, Pujaningsih RI (2019). Evaluasi pemberian pakan dengan jumlah multinutrient block yang berbeda sebagai suplemen terhadap performans kambing kacang. J. Litbang Provinsi Jawa Tengah, 17: 87-99. https://doi.org/10.36762/jurnaljateng.v17i1.789

García MI, Yebra MJ, Haros M, Monedero V (2016). Expression of bifidobacterial phytases in Lactobacillus casei and their application in a food model of whole-grain sourdough bread. Int. J. Food Microbiol., 216: 18-24. https://doi.org/10.1016/j.ijfoodmicro.2015.09.003

Hafis A (2019). Produksi *T. diversifolia* (*Tithonia* diversifolia) sebagai pakan hijauan dengan jenis pupuk berbeda pada tanah ultisol. Thesis. Fakultas Peternakan Universitas Andalas, Padang. Indonesian.

Ikhlas Z, Jamarun N, Zain M, Pazla R, Yanti G (2023). Impact of mangrove leaves (*Rhizophora apiculata*) in limewater on nutrients digestibility, rumen ecosystem and *in vitro* methane production. Am. J. Anim. Vet. Sci., 18(1): 40-46. https://doi.org/10.3844/ajavsp.2023.40.46

Jamarun N, Zain M, Arief, Pazla R (2017c). Populations of rumen microbes and the in vitro digestibility of fermented oil palm fronds in combination with *Tithonia* (*Tithonia diversifolia*) and elephant grass (*Pennisetum purpureum*). Pak. J. Nutr., 17: 39-45.https://doi.org/10.3923/pjn.2018.39.45

Jamarun N, Pazla R, Zain M, Arief (2019). Comparison of *in vitro* digestibility and rumen fluid characteristics between the *tithonia* (*Tithonia diversifolia)* with elephant grass (*Pennisetum purpureum*). Earth Environ. Sci., 287: 1-5. https://doi.org/10.1088/1755-1315/287/1/012019

Jamarun N, Pazla R, Arief, Jayanegara A, Yanti G (2020). Chemical composition and rumen fermentation profile of mangrove leaves (*Avicennia marina*) from west Sumatera. Indonesia Biodivers., 21(11): 5230-5236. https://doi.org/10.13057/biodiv/d211126

Jamarun N, Zain M, Pazla R (2021a). Dasar nutrisi ruminansia Jilid II. Andalas University Press. Padang.

Jamarun N, Pazla R, Yanti G (2021b). Effect of boiling on *in-vitro* nutrients digestibility, rumen fluid characteristics, and tannin content of mangrove (*Avicennia marina*) leaves as animal feed. IOP Conf. Ser. Earth Environ. Sci., 733: 012106. https://doi.org/10.1088/1755-1315/733/1/012106

Jusman V, Arnim, Marlida Y, Pazla R (2020). Production performance and blood profile of Ongole crossbred cattle receiving *Saccharomyces cerevisiae* supplementation. J. Res. Agric. Anim. Sci., 7: 53-58. https://www.questjournals.org/jraas/papers/v7-i7/H07075358.pdf

Katoch R (2022). Quality and digestibility of crop residues. In: Nutritional quality management of forages in the Himalayan Region. Singapore: Springer Singapore. pp. 399-463. https://doi.org/10.1007/978-981-16-5437-4_14

Kearl L (1982). Nutrient requirements of ruminants in developing countries. All Graduate Theses and Dissertations. Department and University missing.

Krisnan R, Praharani L, Supriyadi PA (2015). Kecukupan nutrien kambing peranakan etawah periode laktasi (Nutrient Adequacy of Ettawa Crossbreed Goats in Lactation Period). In: Prosiding Seminar Nasional Teknologi Peternakan dan Veteriner.

Laksana AA, Rianto E, Arifin M (2016). Pengaruh kualitas ransum terhadap kecernaan dan retensi protein ransum pada kambing Kacang jantan. Anim. Agric. J., 2(4): 63-72.

Marwah PM, Suranindyah YY, Tridjoko, Murti W (2010). Milk production and milk composition of Ettawa crossbred goat, fed katuk leaves *Sauropus androgynus (L.) merr*) as supplementation during early lactation. Bull. Peternak., 34(2): 94–102.https://doi.org/10.21059/buletinpeternak.v34i2.95

Mastoraki M, Panteli N, Kotzamanis YP, Gasco L, Antonopoulou E, Chatzifotis S (2022). Nutrient digestibility of diets containing five different insect meals in gilthead sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*). Anim. Feed Sci. Technol., 292: 115425. https://doi.org/10.1016/j.anifeedsci.2022.115425

Mdletshe ZM, Chimonyo M, Marufu MC, Nsahlai IV (2017). Effects of saline water consumption on physiological responses in Nguni goats. Small Ruminant Res., 153: 209-

211. https://doi.org/10.1016/j.smallrumres.2017.06.019

Oluwasola TA, Dairo FAS (2016). Proximate composition, amino acid profile, and some anti-nutrients of *Tithonia diversifolia* cut at two different times. Afr. J. Agric., 11(38): 3659-3663. https://doi.org/10.5897/AJAR2016.10910

Onyeonagu CC, Obute PN, Eze SM (2013). Seasonal variation in the anti-nutrient and mineral components of some forage legumes and grasses. Afr. J. Biotechnol., 12(2). https://doi.org/10.5897/AJB11.1359

Pazla R (2018). Pemanfaaatan pelepah sawit dan titonia (*Tithonia* diversifolia) dalam ransum kambing Peranakan Etawa untuk menunjang program swasembada susu 2020. Disertation. Universitas Andalas, Padang.

Pazla R, Jamarun N, Zain M, Arief (2018a). Microbial protein synthesis and in vitro fermentability of fermented oil palm fronds by phanerochaete chrysosporium in combination with tithonia (*Tithonia diversifolia*) and elephant grass (*Pennisetum purpureum*). Pak. J. Nutr., 17: 462-470. https://doi.org/10.3923/pjn.2018.462.470

Pazla R, Zain M, Ryanto HI, Dona A (2018b). Supplementation of minerals (phosphorus and sulfur) and *Saccharomyces cerevisiae* in a sheep diet based on a cocoa by-product. Pak. J. Nutr., 17(7): 329-335. https://doi.org/10.47278/journal.ijvs/2021.119

Pazla R, Adrizal, Sriagtula R (2021a). Intake, nutrient digestibility, and production performance of pesisir cattle fed *Tithonia* diversifolia and Calliandra calothyrsus-based rations with different protein and energy ratios. Adv. Anim. Vet. Sci., 9(10): 1608-1615. https://doi.org/10.17582/journal.aavs/2021/9.10.1608.1615

Pazla R, Jamarun N, Zain M, Yanti G, Candra RH (2021b). Quality evaluation of tithonia (*Tithonia diversifolia*) with fermentation using *Lactobacillus plantarum* and *Aspergillus ficuum* at different incubation times. Biodiversitas J. Biol. Divers., 22(9): 3936-3942. https://doi.org/10.13057/biodiv/d220940

Pazla R, Yanti G, Jamarun N, Elihasridas, Arief, Sucitra LS (2021c). Degradation of phytic acid from tithonia (*Tithonia diversifolia*) leaves using *Lactobacillus bulgaricus* at different fermentation times. Biodiversitas, 22: 4794–4798. https://doi.org/10.13057/biodiv/d221111

Pazla R, Jamarun N, Sucitra LS, Maihelfi, Wulandari Y (2022a). Potensi *Tithonia* diversifolia sebagai Pakan Ternak Ruminansia. Penerbit ADAB. Jawa Barat. ISBN: 9786234970395. [Indonesian].

Pazla R, Jamarun N, Yanti G, Sari DNI, Saputra I, Susanti S (2022b). Potensi Kombinasi Tithonia diversifolia dengan daun alpukat (*Persea americana miller*) sebagai pakan alternatif ternak kambing. Penerbit ADAB. Jawa Barat. ISBN: 9786234970579. [Indonesian].

Pazla R, Jamarun N, Zain M, Arief, Yanti G, Masdia EM, Chandra RH (2022c). Impact of Tithonia diversifolia and Pennisetum purpureum-based ration on nutrient intake, nutrient digestibility, and milk yield of Etawa crossbreed dairy goat. Int. J. Vet. Sci., 11(3): 327-335. https://doi.org/10.3923/pjn.2018.329.335

Pazla R, Jamarun N, Elihasridas, Arief, Yanti G, Ikhlas Z (2023a). The impact of replacement of concentrates with fermented *tithonia* (*Tithonia* diversifolia) and avocado waste (*Persea americana miller*) in fermented sugarcane shoots (*Saccharum officinarum*) based rations on consumption, digestibility, and production performance of Kacang goat. Adv. Anim. Vet. Sci., 11(3): 394-403. https://doi.org/10.17582/journal.aavs/2023/11.3.394.403

Pazla R, Jamarun N, Yanti G, Putri EM (2023b). *In vitro* evaluation of feed quality of fermented *Tithonia diversifolia* with *Lactobacillus bulgaricus* and *Persea Americana Miller* leaves as forages for goat. Trop. Anim. Sci. J., 46(1): 43–54. https://doi.org/10.5398/tasj.2023.46.1.43

Rahardian A, Lilik BP, Yudi S, Ketut W (2019). Tinjauan historis data fan informasi luas mangrove. Indonesia Media Konservasi, 24(2): 163-78.

Rianita R, Metri Y, Evitayani E, Warly L (2019). Substitusi *T. diversifolia* (*Tithonia diversifolia*) dengan baglog pelepah sawit yang difermentasi dengan Pleurotus ostreatus terhadap ketersediaan mineral makro pada kambing peranakan etawa (PE). J. Peternakan Indonesia (Indones. J. Anim. Sci.,) 21(3): 311-318. https://doi.org/10.25077/jpi.21.3.311-318.2019

Rira M, Morgavi D, Popova, Maxin G, Doreau M (2022). Microbial colonisation of tannin-rich tropical plants: Interplay between degradability, methane production and tannin disappearance in the rumen. Animal, 16: 8-10. https://doi.org/10.1016/j.animal.2022.100589

Rostini T, Zakir I, Biyatmoko D (2022). Effect of yeast and curcuma supplementation in palm kernel cake local feed on Jawarandu goats' performance. J. Adv. Anim. Vet. Sci., 10(2): 442-450. https://doi.org/10.17582/journal.aavs/2022/10.2.442.450

Samtiya M, Aluko RE, Dhewa T (2020). Plant food anti-nutritional factors and their reduction strategies: An overview. Food Prod. Process. Nutr., 2: 1-14. https://doi.org/10.1186/s43014-020-0020-5

Sari RWW, Jamarun N, Suyitman, Khasrad, Yanti G (2021). Mangrove (*Avicennia marina*) leaves as an alternative feed resource for ruminants. IOP Conf. Ser. Earth Environ. Sci., 888: 012079. https://doi.org/10.1088/1755-1315/888/1/012079

Sari RWW, Jamarun N, Arief, Pazla R, Yanti G, Ikhlas Z (2022a). Nutritional analysis of mangrove leaves (*Rhizophora apiculata*) soaking with lime water for ruminants feed. IOP Conf. Ser. Earth Environ. Sci., https://iopscience.iop.org/article/10.1088/1755-1315/1020/1/012010/pdf, https://doi.org/10.1088/1755-1315/1020/1/012010

Sari RWW, Jamarun N, Suyitman, Khasrad, Elihasridas, Hellyward J, Yanti G (2022b). *In vitro* evaluation of mangrove leaves (*Rhizophora apiculata*) and native grass based on phytochemical, nutritional and fiber degradability, rumen liquid characteristics and gas production. J. Adv. Anim. Vet. Sci.,

Sari RWW, Jamarun N, Suyitman, Khasrad, Yanti G (2022c). *In vitro* digestibility of hay mangrove with native grass. Am. J. Anim. Vet. Sci., 17(4): 288-293. https://doi.org/10.3844/ajavsp.2022.288.293

Steel PGD, Torrie JH (2002). Prinsip dan Prosedur Statistika suatu Pendekatan Geometrik. Terjemahan B. Sumantri. PT Gramedia. Jakarta.

Utari A (2018). Pemanfaatan limbah kulit buah aren sebagai pupuk kompos terhadap evaluasi nutrisi silase rumput gajah pada ternak ruminansia. Eksakta J. Penelitian Pembelajaran MIPA 3: 9-24.

Van Soest PV, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74(10): 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Van Soest PJ (2018). Nutritional ecology of the ruminant.

Cornell university press.

Wanapat M (2009). Potential uses of local feed resources for ruminants. Trop. Anim. Health Prod., 41(7): 1035-1049. https://doi.org/10.1007/s11250-008-9270-y

Wojtunik KK, Oniszczuk A, Oniszczuk T, Combrzyński M, Nowakowska D, Matwijczuk A (2020). Influence of in vitro digestion on composition, bioaccessibility and antioxidant activity of food polyphenols. A non-systematic review. Nutrients, 12(5): 1401. https://doi.org/10.3390/nu12051401

Yanti G, Jamarun N, Suyitman S, Satria B, Sari RWW (2021). Mineral status of soil, sea water, and mangrove (*Avicennia marina*) forages in several coastal areas of West Sumatra. Vet. World, 14(6): 1594-1601. www.doi.org/10.14202/vetworld.2021.1594-1601