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The Effect of Ammoniated Cymbopogon nardus Waste as Forage Substitution on Nutrient Digestibility and Performance of Ettawa Crossbreed Dairy Goat

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ABSTRACT

This study aimed to determine the effect of using ammoniated Cymbopogon nardus waste (ACNW) as a substitute for grass on growing male Ettawa Crossbreed dairy goats (ECDG). A total of eighteen male ECDGs aged between 24-30 months with a body weight of 26.4±1.01 kg were used in this study. The study used a Randomized Block Design (RBD) which consisted of three treatments and six replication. Treatments were A=40% native grass+60% concentrate, B=30% native grass+10% ammoniated C. nardus waste (ACNW)+60% concentrate, and C=20% native grass+20% ACNW+60% concentrate. Parameters observed were nutrient intake, digestibility of nutrients, and body weight gain of ECDG. The results showed that the treatment did not have a different effect on nutrient intake and digestibility of nutrients, body weight gain, and ration efficiency in male ECDGs that were given ammoniated C. nardus as a substitute for grass. Nutrient intake for each treatment were A=1.13kg/h/d, B=1.09kg/h/d, C=1.05kg/h/day. Digestibility of dry matter were A=77.85%, B=76.47%, C=76.46%. Daily weight gain were A=135g/d, B=122g/d, C=118g/d. The conclusion is the use of ammoniated C. nardus waste of up to 50 % as a grass substitute can be used for fattening Ettawa Crossbreed dairy goat.

Key words: Ammoniated Cymbopogon nardus waste, Daily weight gain, Digestibility, Ettawa crossbreed dairy goat, Nutrient intake.

INTRODUCTION

Feed is a crucial part of livestock management because approximately 70% of farm cost is allocated for feed supply. Nevertheless, Pazla et al. (2023a) stated that fluctuating feed availability and various feed quality still the main problem in Indonesia. It certainly causes low productivity of livestock. From these problems, the utilization of feeds using agriculture waste become the best strategy to enhance feed supply. *Cymbopogon nardus* waste can be utilized as feed for ruminant.

Cymbopogon nardus is essential oils plant that widely known since War World II, and it becomes the superior plantation commodities over the last decade, with an average plantation area 19,370ha and a biomass production of 2,340tons/year (Sulaswatty et al. 2019). The total agricultural yield of *C. nardus* is approximately 3.51kg/plant/year (Gusmaini and Syakir, 2020). These huge commodities are advantageous for feed source. The primary product from *C. nardus* is essential oil (Citronella oil) about 0.5-1.5%. The waste product from *C. nardus* refining process is *C. nardus* waste and distillation water (Usmiati et al. 2012).

C. nardus waste has better quality compared to rice straw. Protein content of *C. nardus* is 7%, higher than rice straw which is only 3.9%. Crude fiber of *C. nardus* is lower (25.73%) than *Pennisetum purpureum* and rice straw which are 25.73% and 34.15%, respectively (Balai Penelitian Tanaman Obat dan Aromatik, 2010). *C. nardus* waste has 11.97% of protein, 25.14% of crude fiber, 0.87% of extract ether, 71.07% NDF, and 35.02% of ADF (Elihasridas et al. 2020).

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The great potential of *C. nardus* waste and its nutritional content shows that it is very suitable for ruminant feed as an alternative source of fiber. Unfortunately, the obstacle in utilizing *C. narduas* waste as ruminant feed is the content of essential oils in the form of citronella and geraniol which may still remain. The essential oil components in *C. nardus* are not completely safe and may be carcinogenic. To minimize essential oil residues and increase the digestibility of *C. nardus* waste, drying and ammoniation processes were carried out. The drying process will evaporate the volatile components in *C. nardus* waste, while the ammoniation process can break down the fiber fraction and increase the protein content of feed. The *in vitro* study from Elihasridas et al. (2020) confirmed that the addition of 50% ammoniated *C. nardus* waste as a substitute for grass in forage-based ration resulted unsignificantly different.

We require to discover the effect of ammoniated *C. nardus* addition in forage-concentrate-based ration. Due to its potential availability and nutritional content, the study on the utilization of *C. nardus* waste as the component of ruminant feed is important. For these reasons, a research was carried out on the effect of ammoniated *Cymbopogon nardus* waste as forage substitution on nutrient digestibility and performance of Ettawa Crossbreed dairy goat.

MATERIALS AND METHODS

Ethical Approval

This experiment has referred to research ethics using livestock based on the Republic of Indonesia government law number 18 of 2009 (Section 66), which addressed animal keeping, raising, killing, and proper treatment and care. This experiment also followed the guide from Guide for the Care and Use of Agricultural Animals in Research and Teaching outlined by Federation of Animal Science Societies (American Dairy Science Association, 2020).

Sample Preparation and Experimental Diets

Experimental Site

This study was conducted at Elfitra Farm, Nanggalo District, Padang, West Sumatra from January to April 2022. The geographical position of this area is 0°58'S and 100°E. The average rainfall is 384.88mm/year.

Experimental Design

Eighteen Ettawa Crossbreed dairy goats (24-40 month of ages) with initial BW of 26.4±1.01kg were randomly allocated to metabolic cage 1.5x0.5m. This study was carried out using Randomized Block Design (RBD) consist of three treatments and six replication. Treatments were A=40% native grass+60% concentrate, B=30% native grass+10% ammoniated *C. nardus* waste (ACNW)+60% concentrate, and C=20% native grass+20% ACNW+60% concentrate. Data obtained in this study was analyzed according to analysis of variance procedure using Statistix8 software. Significant difference ($P<0.05$) is followed by posthoc Duncun Multiple Range Test.

This study was divided into four periods, namely the adaptation period, preliminary period, and collection period. The adaptation period aims to allow Ettawa Crossbreed dairy goat (ECDG) recognizing and adapting the treatment rations. This period was carried out until ECDG are used to the treatment ration. Then, the premilinary period was carried out for 10 days. In this period, the treatment was given according to the needs of 4% DM. The live weight of the cattles were measured in the beginning and the last day of each periods. During the fifth-day of collection period, ration intake and feces excreted per day were recorded. Dried ration and feces samples were subjected to proximate analysis (AOA 2016) and fiber fraction analysis (Goering and Van Soest 1970).

Treatment rations were consisted of native grass, concentrate (Zea mays, tofu waste, and rice bran), and ammoniated *C. nardus* waste. Nutrient composition of experimental treatments in this study was shown in Table 1 and the formula of 100% concentrate was shown in Table 2.

RESULTS

Nutrient Intake

Nutrient intake from this study was shown in Table 3. From Table 3. we can observe that the addition of 25-50% ammoniated *C. nardus* waste in ration as a substitute for forage did not have a significant effect on nutrient intake ($P>0.05$). Dry matter intake was range 1.05-1.13kg/h/d. Organic matter intake was range 0.96-1.04kg/h/d. Crude protein intake was range 0.152-0.161kg/h/d. Extract ether intake was range 0.038-0.039kg/h/d. Crude fiber intake was range 0.181-0.196 kg/h/d. NDF intake was range 0.263-0.287kg/h/d. ADF intake was range 0.169-0.183kg/h/d. Cellulose intake was range from 0.130-0.150kg/h/d and hemicellulose intake was range 0.095-0.104kg/h/d.

Nutrient Digestibility

Nutrient digestibility from this study was shown in Table 4. From this Table we can observe that the addition of 25-50% ammoniated *C. nardus* waste in ration as a substitute for forage did not have significant effect on nutrient digestibility ($P>0.05$). Dry matter digestibility was range 76.46-77.85%. Organic matter digestibility was range 77.79-79.80%. Crude protein digestibility was range 68.16-77.41%. Extract ether digestibility was range 82.56-84.18%. Crude fiber digestibility was range 65.01-69.29%. NDF digestibility was range 50.22-55.16%. ADF digestibility was range 35.07-44.19%. Cellulose digestibility was range from 57.98-64.21% and hemicellulose intake was range 71.12-79.11%.

Body Weight Gain and Feed Efficiency

Body weight gain and feed efficiency from this study are shown in Table 5. From Table 5. we can observed that the addition of 25-50% ammoniated *C. nardus* waste in ration as a substitute for forage did not have significant effect on Body weight gain and feed efficiency ($P>0.05$). Body weight gain in this study was range 118-135gr/h/d. Meanwhile, feed efficiency was range 31.18-31.83%.

DISCUSSION

Nutrient Intake

The recent study showed that the addition of ammoniated *C. nardus* waste in ration did not give significant effect on nutrient intake, although there was a decrease trend of nutrient digestibility with the increase of

Table 1: Nutrient composition of experimental treatments

Diet composition (%)	Experimental Treatments		
	A	B	C
Native grass	40	30	20
Cymbopogon nardus waste	0	10	20
Concentrate	60	60	60
Total	100	100	100
Nutrient composition (% dry matter)			
Crude Protein	12.19	12.93	13.67
Total Digestible Nutrient	72.99	71.46	69.93
Crude Fiber	15.61	17.70	19.79
Neutral Detergent Fiber	26.52	27.34	28.15
Acid Detergent Fiber	16.66	17.17	17.69
Lignin	2.34	2.77	3.20

Table 2: Formula of 100% concentrate

Feed	Formula (%)
Tofu waste	75
Zea mays	17
Rice bran	5
Mineral	3
Total	100

Table 3: Nutrient intake of Ettawa crossbreed dairy goat with experimental treatments

Nutrient Intake	Experimental Treatments			
	A	B	C	SE
Dry matter (kg/h/d)	1.13	1.09	1.05	0.03
Dry matter (%BW)	4.45	4.39	4.08	0.05
Dry matter (metabolic BW)	99.67	97.87	91.65	0.09
Organic matter (kg/h/d)	1.04	1.00	0.96	0.03
Crude protein (kg/h/d)	0.161	0.158	0.152	0.04
Extract ether (kg/h/d)	0.039	0.038	0.038	0.06
Crude fiber (kg/h/d)	0.196	0.188	0.181	0.05
NDF (kg/h/d)	0.287	0.269	0.263	0.05
ADF (kg/h/d)	0.183	0.170	0.169	0.06
Cellulose (kg/h/d)	0.150	0.135	0.130	0.04
Hemicellulose (kg/h/d)	0.104	0.097	0.095	0.05

Table 4: Nutrient digestibility of Ettawa crossbreed dairy goat with experimental treatments

Nutrient digestibility (%)	Experimental Treatments			
	A	B	C	SE
Dry matter	77.85	76.47	76.46	0.77
Organic matter	79.80	77.99	77.79	0.87
Crude protein	77.41	72.55	68.16	0.61
Extract ether	84.18	82.67	82.56	0.73
Crude fiber	69.29	66.41	65.01	0.42
NDF	55.16	53.06	50.22	0.56
ADF	44.19	37.16	35.07	0.93
Cellulose	64.21	61.43	57.98	0.64
Hemicellulose	79.11	77.83	71.12	0.67

Table 5: Body weight gain and feed efficiency of Ettawa crossbreed dairy goat with experimental treatments

Parameter	Experimental Treatments			
	A	B	C	SE
Initial body weight (kg)	25.50	26.60	27.10	0.09
Final body weight (kg)	34.20	34.00	33.80	0/05
Body weight gain (gr/h/d)	135	122	118	0.007
Feed efficiency (%)	31.83	31.18	31.20	0.009

ammoniated *C. nardus* waste level. In line with Nurhayu and Warda (2018) who reported that there was a decrease in dry matter intake in Bali cattle given 20-40% *C. nardus* waste as a substitute for *Pennisetum purpureum*. Otherwise, the present study had higher nutrient intake compared to Al-Kindi et al. (2020) who reported that nutrient intake of local male sheed fed fermented *C. nardus* as substitute for basal feed was 677.63-860.58g/h/d. The difference in the value of nutrient intake is caused by differences in the type, age, and health condition of the livestock. Factors influenced nutrient intake are feed factors which include digestibility and palatability of feed, livestock factors which include breed, sex, age, and health condition of livestock.

Ammoniated *C. mardus* waste is quite palatable to livestock causes the substitution of native grass with ammoniated C. nardus waste did not affect ration consumption. Feed palatability is generally associated with high digestibility of feed. Zimpel et al. (2018) and Pazla et al. (2023b) stated that palatability is the main factor explaining the difference in dry matter intake between feed and low-producing livestock. Positive nutrient intake in the present study reflected that the ammonia treatment is able to improve the physical quality of *C. nardus* waste and potentially reduce the limiting factor utilizing *C. nardus* waste as livestock feed. In agreement with Li et al. (2021) and Zeidali-Nejad et al. (2018) who stated that nutrient intake is influenced by the shape and physical quality of the feed, the chemical composition of the ration, the frequency of administration and anti-nutrients in the ration.

Nutrient intake is basically intended to meet the energy requirement of livestock. The compact and dust-free form of ration is highly preferred by livestock, while the high fiber content especially lignin will reduce nutrient intake. Likewise, bulky feed characteristics and low digestibility feed will reduce nutrient intake. Livestock will stop eating when their energy needs are met. Fiber-rich feed and rumen capacity are the main limiting factor for nutrient intake. Besides, nutrient intake is also influenced by nutrient digestibility and rumen fermentation process. Another factor that causes unsignificant nutrient intake is because the age of ECDG in the present study is almost the same so that the ability of ECDG in consuming rations is also almost the same.

Nutrient Digestibility

Digestibility is defined as that part of a feed nutrient which is able to be absorbed by the animal's body and is not excreted in the form of feces. Digestibility of dry matter is one of the determinants of ration quality. The higher the digestibility of dry matter, the higher the opportunity for nutrients that can be utilized by livestock. The digestibility of dry matter in this study was in line with dry matter intake. The increasing substitution of naive grass with ammoniated *C. nardus* waste, the lower the consumption and digestibility of dry matter. However, this was not statistically significant, so that ammoniated *C. nardus* waste was stated to have the same digestibility value as native grass in ECDG. The average dry matter digestibility in this study was higher than the study of Zain (2009) which gave local sheep ammoniated cocoa pod husks as a substitute for field grass, which was 61.88–65.86%.

Nutrient digestibility is influenced by the composition and nutrient content of the feed ingredients in feed formulation. Agricultural waste including *C. nardus* is characterized by high lignin content. Lignin is known to be a limiting factor for the digestibility of a feed ingredient in ruminants. Increasing the substitution of native grass with ammoniated *C. nardus* waste further increases the lignin

content of the ration so that the nutrient digestibility also decreases. Lignin is a digestibility limiting factor because it binds directly to the fiber fraction so that the lignin content will be negatively correlated with the nutrient digestibility of the ration. In line with Oluokun (2005) and Pazla et al. (2021a) who stated that high lignin and silica content in feed can cause low digestibility, because lignin cannot be digested by rumen microbes and can even interfere with digestion. Lignin content in ration A is 2.34%, ration B is 2.77%, and ration C is 3.20%. The percentage of lignin content in rations A to ration C increased which resulted in decreased nutrient digestibility.

The content of the fiber fraction in the composition of the ration greatly affects its digestibility. The fiber fraction is part of the plant cell wall which generally binds to lignin which is difficult for rumen microbes to digest, so that when the content of the fiber fraction in the ration is high, the contents of the cells are also easily digested. This is due to the fact that the higher fiber fraction can act as an inhibitor in rumen biodegradation. In this study, from rations A to rations C, there was an increase in the content of the fiber fraction which caused a decrease in the digestibility of dry matter, organic matter, crude protein, fat, crude fiber, NDF, ADF, cellulose and hemicellulose.

Concentrate in this research also helps improve nutrient digestibility. It has been reported by Rodrigues et al. (2021) and Zain et al. (2023) that giving concentrate in feed formulation can increase overall feed digestibility. The more concentrate that can be digested, it means that the flow of feed in the digestive tract becomes faster, causing increased rumen emptying and causing a sensation of hunger in livestock. consequently enabling livestock to increase feed consumption.

In the present study, digestibility of nutrients tended to decrease with increasing of ammoniated *C. nardus* waste level in ration. This is due to the increase in the lignin content of the rations. Increasing the digestibility of low quality fiber feed can be done by adding a good source of protein for livestock and also adding feed additives. One source of protein that is quite promising in increasing the digestibility and body weight gain of livestock is through the addition of legumes. The addition of Gliricidia sepium and Leucaena leucocephala can increase the digestibility and production of VFA in high-fiber feeds (Ningrat et al. 2019; Zain et al. 2019, 2020). The addition of additives in the form of Sacharomyces cerevisiae from several studies can also increase the digestibility of fiber feeds as reported by Pazla et al.(2018a) and Zain et al. (2011; 2016). For this reason, the use of ammoniated *C. nardus* waste as feed with the addition of legumes and feed additives needs to be studied further.

Nutrient digestibility is related to nutrient intake, so the results of this research on nutrient digestibility obtained the same results as nutrient intake, which was not significantly different (P>0.05). This showed that the ammonia treatment of *C. nardus* waste is able to loosen lignin bonds with cellulose and hemicellulose so that *C. nardus* waste can be digested almost the same as native grass. Ammonia treatment by adding urea also adds a large amount of nitrogen (crude protein) for microbial protein synthesis in the rumen where this substance is naturally limited to agricultural wastes (Pazla et al. 2018b; Putri et al. 2021; Sari et al. 2022).

Urea treatment is done by dissolving urea with water. Although ammonia is a weaker alkali compared to NaOH which is less efficient in degrading fiber, it provides nitrogen which can be converted into microbial protein and contributes to protein supply for ruminant productivity. The ammonia treatment of *C. nardus* waste was able to increase its digestibility, so that the substitution of native grass with 50% ammoniated *C. nardus* waste could match the digestibility of 100% of native grass.

Body Weight Gain and Feed Efficiency

Body weight gain is a reflection of the feed consumption, metabolism, fermentation and absorption of nutrients from feed. Besides, it also reflects the quality of feed consumed by livestock. Body weight gain is strongly influenced by the quality and quantity of feed. This means that the assessment of livestock body weight gain is proportional to the ration consumed. Statistically, the substitution of native grass with ammoniated *C. nardus* waste had no significant (P>0.05) effect on body weight gain. This unsignificant body weight gain due to consumption of different rations was also not significant. As seen in Table 5, body weight gain is in line with the consumption and digestibility of ration nutrients.

The present study confirmed that feeding ammoniated *C. nardus* waste up to 20% as a substitute for native grass had no significant effect (P>0.05) on body weight gain of ECDG, in fact it tended to decrease compared to the control treatment. The decrease in body weight gain from the control ration is in line with the results of Al-Kindi et al. (2020) which gave fermented *C. nardus* up to 30% to male local sheep as a substitute for basal feed. The average of body weight gain in this study was higher than Kholif et al. (2021) who observed the body weight gain on lactating Damascus × Baladi goats fed with coriander oil on diet. Body weight gain in this study was high, because the goats were reared intensively in individual cages.

One of the factors that affect body weight gain is nutrient intake. The higher the body weight gain, the dry matter intake by livestock will also increase. The quantity and quality of feed ingredients will affect body weight gain. Besides, genetics, age and environment will also affect body weight gain. Body weight gain in ration A was higher because the consumption and digestibility of dry matter and organic matter were highest in ration A so that there were more nutrients to produce, especially body weight gain. In accordance with the opinion of Pazla et al. (2022) and Salem and Smith (2008) that the digestibility of feed reflects the amount of nutrients available and can be utilized by livestock for basic life, growth, production and reproduction. However, ration A had an effect that was not significantly different from ration B and C.

Feed efficiency is the value obtained from the body weight gain produced per unit of ration dry matter intake. The greater this value, the better and more efficient the feed. The efficiency of the feed for this study also provided no significant differences between treatments as shown in Table 5. The amount of ration efficiency depends on the amount of dry matter intake that is able to provide body weight gain (Pazla et al. 2021b). Ration will be more efficiently used if the ration is consumed in small quantities and is able to provide a large body weight gain.

Conclusion

Cymbopogon nardus is an alternative fiber source for ruminant. The great chemical ingredients and availability of *C. nardus* are potential as substitution in livestock diet. From this study, it can be concluded that ammonia *C. nardus* waste can be used up to 20% as a substitute for 60% of concentrate and 20% of native grass in Ettawa Crossbreed dairy goat without deleterious effect.

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Authors' Contribution

MZ designed the concept of the study, RWSN, E, and E designed the methodology, WN, EMP, and RP analyzed the data and drafted the manuscript, POS and UA did the analysis in the laboratorium.

Conflict of Interests Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Al-Kindi M, Wajizah S and Rachmadi D, 2020. Performance of male local sheep feeding fermented lemongrass waste (*Cymbopogon nardus*) as partly basal feed subtitution. Jurnal Ilmiah Mahasiswa Pertanian 5(1): 213–224.

American Dairy Science Association, American Society of Animal Science and Poultry Science Association, 2020. Guide for the Care and Use of Agricultural Animals in Research and Teaching Fourth edition. www.adsa.org

AOA, 2016. Appendix F: Guidelines for Standard Method Performance Requirements. Association of Official Analysis Chemists International, pp: 1–18.

Balai Penelitian Tanaman Obat dan Aromatik, 2010. *Cymbopogon Nardus* culivation. Badan Penelitian dan Pengembangan Pertanian.

Rodrigues TCG, Santos SA, Cirne LGA, dos Santos Pina D, Alba HDR, de Araújo MLGML, Silva WP, de Oliveira Nascimento C, Rodrigues CS, Tosto MSL and de Carvalho GGP, 2021. Palm kernel cake in high-concentrate diets for feedlot goat kids: nutrient intake, digestibility, feeding behavior, nitrogen balance, blood metabolites, and performance. Tropical Animal Health and Production 53(5). https://doi.org/10.1007/s11250-021-02893-y

Elihasridas, Zain M, Ningrat RW, Erpomen, Makmur M and Putri EM, 2020. Ammonia and fermentation treatment of *Cymbopogon nardus L*. waste as a substitution of grass: effect on nutritional profile and ruminal in vitro digestibility. Journal of Animal Health and Production. 9(1): 27–32. https://doi.org/http://dx.doi.org/10.17582/journal.jahp/2021/9.1.27.32

Goering HK and Van Soest PJ, 1970. Forage Fiber Analyses. (Apparatus, Reagents, Procedures, and Some Applications). In Agriculture Handbook No 379. United States Department of Agriculture, Washington DC (Issue 379).

Gusmaini G and Syakir M, 2020. Effect of potassium on growth, yield and quality of *Citronella grass*. Jurnal Penelitian Tanaman Industri 26(1): 32-39. https://doi.org/10.21082/jlittri.v26n1.2020.32-39

Kholif AE, Elazab MA, Matloup OH, Olafadehan OA and Sallam SMA, 2021. Crude coriander oil in the diet of lactating goats enhanced lactational performance, ruminal fermentation, apparent nutrient digestibility, and blood chemistry. Small Ruminant Research 204: 1065222. https://doi.org/10.1016/j.smallrumres.2021.106522

Li Y, Guo YL, Zhang CX, Cai XF, Liu P and Li CL, 2021. Effects of physical forms of starter feed on growth, nutrient digestibility, gastrointestinal enzyme activity, and morphology of pre- and post-weaning lambs. Animal 15(1): 1–6. https://doi.org/10.1016/j.animal.2020.100044

Ningrat RWS, Zain M, Erpomen, Putri EM and Makmur M, 2019. Effects of *Leucaena leucocephala* supplementation to total mixed ration based on ammoniated rice straw onfiber digestibility and rumen fermentation characteristics in vitro. International Journal on Advance Science, Engineering and Information Technology 9(3): 916–921. https://doi.org/10.18517/ijaseit.9.3.8009

Nurhayu A and Warda, 2018. The effect of *Cymbopogon nardus* Waste supplementation on cattle feed on the appearance of Bali cattle. Biocelebes 12(03): 30–40.

Oluokun JA, 2005. Intake, digestion and nitrogen balance of diets blended with urea treated and untreated cowpea husk by growing rabbit. African Journal of Biotechnology 4(10): 1203–1208.

Putri EM, Zain M, Warly L and Hermon H, 2019. In vitro evaluation of ruminant feed from West Sumatera based on chemical composition and content of rumen degradable and rumen undegradable proteins. Veterinary World 12(9): 1478–1483. https://doi.org/10.14202/vetworld.2019.1478-1483

Pazla R, Jamarun N, Zain M and Arief A, 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). Pakistan Journal of Nutrition 17(10): 462-470. https://doi.org/10.3923/pjn.2018.462.470

Pazla R, Zain M, Ryanto HI and Dona A, 2018b. Supplementation of minerals (phosphorus and sulfur) and *Saccharomyces cerevisiae* in a sheep diet based on a cocoa by-product. Pakistan Journal of Nutrition 17(7): 329-335. https://doi.org/10.3923/pjn.2018.329.335

Pazla R, Jamarun N, Warly L, Yanti G and Nasution NA, 2021a. Lignin Content, Ligninase Enzyme Activity and in vitro Digestability of Sugarcane Shoots using *Pleurotus ostreatus* and *Aspergillus oryzae* at Different Fermentation Times. American Journal of Animal and Veterinary Sciences 16(3): 192-201. https://doi.org/10.3844/ajavsp.2021.192.201

Pazla R, Adrizal and Sriagtula R, 2021b. Intake, nutrient digestibility, and production performance of pesisir cattle fed *Tithonia diversifolia* and *Calliandra calothyrsus*-based rations with different protein and energy ratios. Advances in Animal and Veterinary Sciences 9(10): 1608-1615. http://dx.doi.org/10.17582/journal.aavs/2021/9.10.1608.1615

Pazla R, Jamarun N, Zain M, Arief, Yanti G, Putri EM and Candra RH, 2022. Impact of *Tithonia diversifolia* and *Pennisetum purpureum*-based ration on nutrient intake, nutrient digestibility, and milk yield of Etawa crossbreed dairy goat. International Journal of Veterinary Science 11(3): 327-335. https://doi.org/10.47278/journal.ijvs/2021.119

Pazla R, Jamarun N, Arief, Elihasridas, Yanti G and Putri EM, 2023a. In Vitro evaluation of feed quality of fermented *Tithonia diversifolia* with *Lactobacillus bulgaricus* and *Persea americana miller* Leaves as Forages for Goat.

Tropical Animal Science Journal. https://doi.org/10.5398/tasj.2023.46.1.43

Pazla R, Jamarun N, Elihasridas, Arief, Yanti G and Ikhlas Z, 2023b. 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 perform. Advances in Animal and Veterinary Sciences 11. https://doi.org.10.17582/journal.aavs/2023/11.3.394.403

Putri EM, Zain M, Warly L and Hermon H, 2021. Effects of rumen-degradable-to-undegradable protein ratio in ruminant diet on in vitro digestibility, rumen fermentation, and microbial protein synthesis. Veterinary World 14(3): 640-648. https://doi.org/10.14202/VETWORLD.2021.640-648

Salem H and Smith T, 2008. Feeding strategies to increase small ruminant production in dry environments. Small Ruminant Research 77(2–3): 174–194. https://doi.org/10.1016/j.smallrumres.2008.03.008

Sari RM, Zain M, Jamarun N, Ningrat RWS, Elihasridas and Putri EM, 2022. Improving rumen fermentation characteristics and nutrient digestibility by increasing rumen degradable protein in ruminant feed using *Thitonia diversifolia* and *Leucaena leucocephala*. International of Journal Veterinary Science 11(3): 353–360. https://doi.org/0. https://doi.org/10.47278/journal.ijvs/2021.121

Sulaswatty A, Rusli MS, Abimanyu H and Tursiloadi S, 2019. Quo Vadis Essential Oil of *Cymbopogon nardus* and its derivative product. In LIPI Press 9(2).

Usmiati S, Nurdjannah N and Sri Yuliani, 2012. Solid waste of cymbopogon nardus and patchouly oil distillation as the insect repellent for *Musca domestica*. Jurnal Teknologi Industri Pertanian 15(1): 10–16.

Zain M, 2009. Substitusi Rumput Lapangan dengan Kulit Buah Coklat Amoniasi dalam Ransum Domba Lokal. Media Peternakan 32(1): 47–52.

Zain M, Jamarun N, Arnim A, Ningrat RWS and Herawati R, 2011. Effect of yeast (*Saccharomyces cerevisiae*) on fermentability, microbial population and digestibility, microbial population and digestibility of low quality roughage in vitro. Archiva Zootechnica 14(4): 51–58.

Zain M, Ningrat RWS, Erpomen, Putri EM and Makmur M, 2019. The effects of leguminous supplementation on ammoniated rice straw based completed feed on nutrient digestibility on in vitro microbial protein synthesis. IOP Conference Series: Earth and Environmental Science 287(1): 012018. https://doi.org/10.1088/1755-1315/287/1/012018

Zain M, Putri EM, Ningrat RWS, Erpomen and Makmur M, 2020. Effects of supplementing *Gliricidia sepium* on ration based ammoniated rice straw in ruminant feed to decrease methane gas production and to improve nutrient digestibility (in-vitro). International Journal on Advanced Science, Engineering Information Technology 10(2): 724–729. https://doi.org/10.18517/ijaseit.10.2.11242

Zain M, Rahman J, Khasrad and Erpomen, 2016. Supplementation of *Saccharomyces cerevisiae* and *Sapindus Rarak* in diet based of oil palm frond (OPF) on nutrient digestibility and daily weight gain of goat. Asian Journal of Animal and Veterinary Advances 11(5): 314–318. https://doi.org/ 10.3923/ajava.2016.314.318

Zain M, Despal, Tanuwiria UH, Pazla R, Putri EM and Amanah U, 2023. Evaluation of legumes, roughages, and concentrates based on chemical composition, rumen degradable and undegradable proteins by in vitro method. International Journal of Veterinary Science 12(4): 528-538. https://doi.org/10.47278/journal.ijvs/2022.218

Zeidali-Nejad A, Ghorbani GR, Kargar S, Sadeghi-Sefidmazgi A, Pezeshki A and Ghaffari MH, 2018. Nutrient intake, rumen fermentation and growth performance of dairy calves fed extruded full-fat soybean as a replacement for soybean meal. Animal 12(4): 733–740. https://doi.org/10.1017/S1751_731117002154

Zimpel R, Poindexter MB, Vieira-Neto A, Block E, Nelson CD, Staples CR, Thatcher WW and Santos JEP, 2018. Effect of dietary cation-anion difference on acid-base status and dry matter intake in dry pregnant cows. Journal of Dairy Science 101(9): 8461–8475. https://doi.org/10.3168/jds.2018-14748