Research Article

Performance of Local Sheep Fed Diets Containing Urea-Impregnated Zeolite

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Abstract | The main constraint in sheep rearing is the high price of protein source feed in tropical regions. Therefore, in this study, we substituted protein sources of the feed with urea which was processed with slow-release technology to avoid urea poisoning. Slow-release urea-impregnated zeolite (UZ) and Indonesia's natural zeolite (Z) were examined using 24 heads of seven-eight months old of local male lambs (20.12 ± 2.1 kg BW) allotted to four treatments in a randomized group design to determine how it affects lamb performances. The treatments were rations containing no urea (NU), urea (U), zeolite (Z), and urea-impregnated zeolite (UZ). Zeolite or urea-impregnated zeolite inclusion into field grass-based diets of lamb maintained feed intake level, improved dry matter (DM), organic matter (OM), neutral detergent fibre (NDF), acid detergent fibre (ADF) and hemicellulose digestibility ($P<0.05$), and increased feed efficiency and live weight gain of lambs ($P<0.05$). It is implicated that zeolite or urea-impregnated zeolite improves lamb performances probably as a result of the cation exchange capacity of zeolite or slow-release characteristics of urea-impregnated zeolite.

Keywords | Apparent digestibility, Daily gain, Lamb performances, Urea, Zeolite.

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INTRODUCTION

The utilisation of urea as a source of nonprotein nitrogen as an alternative partial substitute for sources of protein nitrogen for ruminants is still the choice of animal farmers today. However, both the amount and the method of use must be highly strict because rumen microbes can easily and quickly hydrolyze urea into ammonia so it can cause ammonia poisoning. Therefore, numerous efforts, i.e., N-(n-butyl) thiophosphoric triamide (Ludden et al., 2000) and zinc compounds (Kathirvelan and Balakrishnan 2006) as urease inhibitors, and polymer-coated urea (Taylor-Edwards, Hibbard et al., 2009; Calomeni et al., 2015; Gardinal et al., 2017) as slow-release urea agents had been focused on reducing its negative impact.

Most tropical forages are considered low-quality forages. Microbial fermentations of carbohydrates derived from low-quality forages by rumen microbes is a much slower process, so speeding it up requires synchronization between the use of carbohydrates and the use of nitrogen by rumen microbes. Kardaya et al. (2009) introduced urea-impregnated zeolite (UZ) as a newer form of slow-release urea agent (SRU) so that the rate of hydrolysis of urea to ammonia by rumen microbes runs slower in an in vitro study. In subsequent studies, the efficacy of UZ as an SLU has been tested in improving the fermentation characteristics of sheep rumens. It was found that UZ lowered ammonia levels, pH, and acetate to propionate ratios, and methane, and kept plasma urea levels low within the normal physiological range (Kardaya et al., 2012). The addition of 2% micronized zeolite to the grower feed had no effect on the performance of the weaned lamb (Toprak et al., 2016). The addition of 20 to 40 g/kg zeolite in the ration positively affected weight gain, ruminal fermentation patterns and rumen-fermentable energy estimates, while the addition of 60 g/kg zeolite increased nitrogen retention in ewe lamb (Roque-Jiménez et al., 2019). The addition of 20 g natural zeolite/kg of dry matter was the most efficient dose in reducing methane gas production, while the addition of 0.4 g of nano zeolite/kg of dry matter was the most effective dose in improving organic matter degradation and reducing ammonia nitrogen concentration (El-Nile et al., 2021). Nevertheless, the researchers only added zeolite of different types and shapes, none of which used urea-impregnated zeolite in their rations. This study evaluated performance indicators of local sheep fed urea-impregnated zeolite or natural zeolite inclusion in field grass-based diets.

MATERIALS AND METHODS

All applicable international, national, or institutional ethics, standards, or protocols for the care and use of animals were followed (SNI 8819:2019; SNI 39102017; 102/Permentan /OT.140/7/2014).

Feed intake and growth trial

This study used twenty-four thin-tailed local lambs aged 7 – 8 months with an initial body weight of 20.12 ± 2.1 kg. The experimental design used a randomized block design with four diet treatments.

Lambs were assorted ascending into six groups of different BW and then each of the four lambs with similar BW within each group was randomly allotted to one of four dietary treatments differently housed in 24 individual cages with one lamb per cage of 0.7 m^2 in size. The basic ration consists of forage (natural grass) with a forage ratio of 60% and concentrates of 40% (based on the dry matter). Ration treatment consists of basic rations: without the addition of urea (NU), with the addition of urea (U), zeolite (Z), or urea impregnated into zeolite (UZ). All diets have been arranged to contain a protein content of 16%. The percentage of urea in the diet was 0.8 %.

All livestock were given anthelmintics in the initial period of the study. The experiment was carried out for 76 days consisting of a 10-day adaptation period, a 56-day feeding and growth trial, and a 10-day digestibility experiment.

Lambs were weighed every two weeks before morning feeding whereas diet (field grass and concentrates) and orts (field grass and concentrates refusals) were weighed daily in the morning at 0700 h before feeding. The experimental diets were presented twice daily (0800 and 1600 h) at 3% of body weight (DM basis) and were adjusted biweekly for changes in body weight and DM ingredient whereas drinking water was available *ad libitum*.

Feed and feed residues from each lamb were collected by 100 g and dried at a temperature of 55 ^{0}C for 96 hours each week. The samples were composted for each livestock, then subsampled again by 100 g, ground and filtered with a 1-mm diameter sieve in a Willey grinder, and frozen in a freezer of -4 ^{0}C for further analysis. The samples were then analysed to define the dry matter, organic matter, crude protein (N x 6.25), and ether extract (AOAC, 2016). Neutral detergent fibres and lignin sulfuric acid were determined by the method of (van Soest et al. 1991), and acid detergent fibre by (AOAC, 2016) protocol.

Nutrient apparent digestibility and nitrogen retention

At the end of the feeding trial period (day 66), three of six groups of lambs were randomly selected for digestibility trial purposes. Then, each lamb was placed into a metabolic cage and allowed to have adaptation for five days within the metabolic cage environment. Thereafter, data collecting was begun for the next five days. Diets were weighed at 0600 h whereas the orts, faeces, and urine were collected daily at 0700 h before morning feeding for a 5-day collecting period. Total daily orts were weighed, sub-sampled, dried (55 ^{0}C, 96 h), and stored (-4 ^{0}C) for subsequent analysis. Total daily urine output was weighed, sub-sampled (5%), and acidified with sufficient H_2SO_4 to maintain a pH of 3 and stored (-4 ^{0}C) for subsequent analysis of urinary N. Daily faecal output was gathered several times, and stored in plastic bags. Total daily faecal output was weighed, sub-sampled (5%), dried (55 ^{0}C, 96 h), and stored (-4 ^{0}C) for subsequent analysis.

Diets, orts, and faecal samples gathered throughout the 5-d digestibility data collection period were used to estimate apparent nutrient digestibility. Feed, orts, and faecal samples were analysed in duplicate for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF), acid detergent fibre (ADF), and sulphuric acid lignin according to the method that was previously used in feeding trial samples. Apparent nutrient digestibility was calculated as Digestibility, % = {100 × (g of nutrient intake – g of faecal nutrient)/ (g of nutrient intake)}.

Statistical Analysis

All collected data were analysed as GLM univariate analysis of variance (UNIANOVA), and Duncan's Multiple Range Test was applied to reveal statistical differences among treatments (Steel & Torrie, 1986). All analyses were accomplished using IBM SPSS Statistics Version 26 for Windows (IBM 2019) at a significance level of 0.05.

Table 1: Feed ingredient and nutrients composition of experimental rations

Ingredients (%)	Ration (DM basis)			
	NU	U	Z	UZ
Field grass	60	60	60	60
Pollard	18	12.2	10	3.6
Yellow corn	2	11	6	16
Soybean meal	10	6	11.5	8.5
Coconut meal	10	9	11.5	8.79
Molasses	-	1	-	1
Zeolite	-	-	1	-
Urea	-	0.8	-	-
Urea-impregnated zeolite	-	-	-	2.11
Compositions				
DM	65.13	64.52	65.12	64.92
NDF	52.55	49.82	51.61	48.36
ADF	28.04	27.35	27.74	29.29
Hemicellulose	24.51	22.47	23.87	19.07
Cellulose	21.17	20.56	20.33	21.03
Lignin	5.38	5.39	5.03	6.18
Ash	7.70	7.31	8.33	8.24
OM	92.30	92.69	91.67	91.76
CP	16.41	16.53	16.49	16.12
CF	16.80	16.21	16.82	15.80
EE	3.07	3.12	3.48	2.66
NFE	56.90	56.82	55.18	58.63
TDN	68.76	68.34	67.99	68.56

NU: no urea, U: urea Z: zeolite, UZ: urea-impregnated zeolite. Urea N represented 16% of total natural feed protein (N x 6.25). Each sample was analyzed in duplicate.

RESULTS

Experimental rations

Experimental rations (Table 1) supplied nutrient content in relatively similar amounts for all lambs. However, the use of urea-impregnated zeolite (UZ) as a slow-release urea agent for replacing some nitrogen of soybean meal or coconut meal resulted in a slightly lower ether extract percentage. Nevertheless, adding molasses to the UZ ration increased slightly its NFE contents. Thus, all rations were expected to supply similar energy content to all the lamb as estimated with the total digestible nutrients (TDN) percentages.

Feed intake

Experimental rations did not affect DM, OM, CP, or cellulose intake of lambs but it influenced neutral detergent fibre (NDF) and hemicellulose intakes ($P<0.05$, Table 2). Neutral detergent fibre intake in lambs fed UZ ration was lower than those fed Z or NU ration ($P<0.05$) but the same as U ration ($P>0.05$). However, lambs fed NU, U, or Z ration showed similar NDF intake ($P>0.05$). In the case of hemicellulose intake, lambs fed UZ ration showed the lowest level among all the experimental rations ($P<0.05$). Dry matter intake responses of lambs when measured as a percentage of their body weight (% BW) and metabolic weight (g DM/kg $BW^{0.75}$) did not show significantly different across the experimental rations.

Nutrient apparent digestibility

Experimental rations influenced ($P<0.05$) all apparent nutrient digestibility of lambs with the exception of cellulose and crude protein digestibility (Table 3). Lambs fed Z or UZ ration showed higher dry matter digestibility (DMD) than lambs fed NU ration ($P<0.05$). Organic matter digestibility (OMD) of lambs fed UZ or Z ration was higher than OMD of lambs fed U or NU ration ($P<0.05$). In the case of fibre fraction digestibility, lambs fed UZ ration resulted in lower NDF digestibility than those fed Z rations ($P<0.05$) but similar to the lambs fed U or NU ration. Either ADF or hemicellulose digestibility of lambs fed UZ ration was the same as lambs fed Z, U, or NU ration

Table 2: Feed and nutrient intake of lambs fed experimental rations (g DM basis).

Nutrient intake	Ration			
	NU n=6	U n=6	Z n=6	UZ n=6
Field grass	404.85±56.24	412.02±63.60	423.43±38.71	392.65±50.84
Concentrates	288.01±26.32	283.06±25.87	287.92±26.31	286.27±26.16
Dry Matter	692.86±73.17	695.08±88.00	711.34±62.65	678.92±74.14
Organic Matter	639.53±67.54	644.24±81.57	652.09±57.43	622.99±68.03
Crude Protein	113.67±12.00	114.92±14.55	117.27±10.33	109.43±11.95
TDN	464.22±49.03	465.71±58.96	476.60±41.98	454.87±49.67
NDF	364.11±38.45[a]	346.29±43.84[ab]	367.14±32.34[a]	328.35±35.86[b]
ADF	194.29±20.52	190.10±24.07	197.34±17.38	198.85±21.72
Hemicellulose	169.82±17.94[a]	156.18±19.77[b]	169.80±14.96[a]	129.50±14.14[c]
Cellulose	146.67±15.49	142.94±18.10	144.63±12.74	142.79±15.59

Different superscripts in similar rows differ significantly (P<0.05). NU: no urea, U: urea, Z: zeolite, UZ: urea-impregnated zeolite, n: replicates. TDN: total digestible nutrient, NDF: neutral detergent fibre, ADF: acid detergent fibre.

Table 3: Apparent nutrient digestibility of lamb fed experimental rations.

Apparent digestibility (%, DM basis)	Rations			
	NU n=6	U n=6	Z n=6	UZ n=6
Dry Matter	72.43±1.53[a]	73.76±2.31[ab]	76.74±2.09[c]	75.58±1.28[bc]
Organic Matter	74.40±1.31[a]	75.35±2.19[a]	79.10±1.82[b]	77.94±1.18[b]
Neutral Detergent Fibre	64.26±6.24[a]	63.19±5.64[a]	70.39±5.98[b]	63.21±5.82[a]
Acid Detergent Fibre	53.02±13.75[a]	56.91±9.11[ab]	63.17±10.22[b]	59.11±8.70[ab]
Hemicellulose	74.80±2.76[ab]	69.90±3.44[a]	77.75±2.67[b]	69.68±1.51[ab]
Cellulose	66.65±10.97	68.14±5.07	73.11±8.60	69.48±5.53
Crude Protein	75.01±1.65	76.73±2.84	76.55±0.61	77.40±0.95

Different superscripts in similar rows differ significantly (P<0.05). NU: no urea, U: urea, Z: zeolite, UZ: urea-impregnated zeolite. n: replicates.

Table 4: Performance of lambs fed experimental rations.

Performance parameters	Rations			
	NU n=6	U n=6	Z n=6	UZ n=6
DMI (g/h/d)	692.86±73.17	695.08±88.00	711.34±62.65	678.92±74.14
DMI (% BW)	2.93±0.12	2.92±0.13	2.94±0.08	2.85±0.10
DMI (g/kg $BW^{0.75}$)	64.50±3.33	64.47±3.71	65.25±2.72	62.90±2.37
FER	0.10±0.02[ab]	0.08±0.01[a]	0.12±0.02[b]	0.10±0.03[ab]
Initial BW (kg/h)	20.50±2.82	20.50±2.06	19.52±1.72	20.03±2.08
Final BW (kg/h)	24.28±2.92	23.77±2.61	24.13±1.54	23.85±2.83
LWG (kg/h)	3.81±1.01[ab]	3.27±0.60[a]	4.62±0.55[b]	3.82±1.27[ab]
LWG (% IBW)	18.89±5.41[ab]	15.85±1.64[a]	23.91±4.44[b]	19.00±6.57[ab]
ADG (g/h/d)	68.09±17.97[ab]	58.33±10.69[a]	82.44±9.74[b]	68.15±22.63[ab]

Different superscripts in similar rows differ significantly (P<0.05). NU: no urea, U: urea, Z: zeolite, UZ: urea-impregnated zeolite, n: replicates, DMI: dry matter intake, BW: body weight, FER: feed efficiency ratio, LWG: live weight gain, ADG: average daily gain, IBW: initial body weight.

(P>0.05) meanwhile lambs fed Z ration produced higher ADF or hemicellulose digestibility than those fed NU or U ration, respectively (P<0.05).

Lamb performances

Experimental rations influenced live weight gain (LWG), average daily gain (ADG), and feed efficiency (P<0.05, (Table 4). Urea ration substitution for NU ration showed similar performance parameters of lambs. A similar result was also repealed by UZ substitution for U or NU ration. However, the feed efficiency ratio (FER), live weight gain (LWG), or average daily gain (ADG) of lambs fed Z ration was consistently higher compared to the lambs fed U ration (P<0.05).

DISCUSSION

Feed intake

Lower NDF intake of lambs fed UZ ration compared to Z or NU ration was in relation to lower NDF content of UZ ration (Table 1) rather than to its DMI (Table 2). Similar DMI level across all experimental rations repealed that each ration produced same palatability. This agreed with the study of (Galo et al., 2003) and (Taylor-Edwards, Hibbard, et al., 2009) who claimed that polymer-coated urea as a substitute for urea has no effect on feed consumption. Lower hemicellulose intake of lambs fed UZ ration could be explained in the same manner as in the NDF intake.

Another explanation is probably that the slow-release urea properties of UZ did not work well in refining NDF fermentability in the rumen which allowed the digesta retained any longer in the rumen. As a result, rumen volume became fulfilled with fibre fraction and promoted the lambs to eat fewer rations as reflected in slightly lower DMI under UZ ration even though its DMI failed to reach a significant level.

This explanation was in agreement with (Karsli and Russell 2001) who explained that dry matter intake increased due to the increased flow rate of rumen fluid and solid particles from the rumen to the small intestine. Changes in nutrient consumption due to the influence of experimental ration follow the consumption pattern of dry matter rations. This happens because its nutrient content fluctuates less between experimental rations.

Either NDF or hemicellulose intake was lower in the UZ ration because NDF or hemicellulose content was slightly lower in the UZ ration. Similarly, crude protein (CP) intake was similar across the experimental ration because its CP content was relatively uniform across the experimental rations.

Nutrient apparent digestibility

In the present research, higher apparent dry matter digestibility (DMD) in lambs fed Z or UZ ration compared to the lambs fed either NU or U ration was associated with its higher OM, NDF, ADF, and hemicellulose digestibility. Moreover, DMD was in positive correlation with OM digestibility (r = 0.99, P<0.01), NDF digestibility (r = 0.73, P<0.01), ADF digestibility (r = 0.78, P<0.01), and cellulose digestibility (r = 0.77, P<0.01). Apparently, dietary zeolite or urea-impregnated zeolite inclusion supported microbial fibre digestion occurred mostly in the rumen where microbial fibrolytic enzymes were produced.

These results revealed that either zeolite or urea-impregnated zeolite succeeded in improving the gastrointestinal tract environment and in turn, impacted on improving DM digestibility. Improvement in DMD and CP apparent digestibility was previously reported by (Galo et al., 2003) who used dietary polymer-coated urea as a substitution for urea inclusion despite the ADF apparent digestibility decreased. Contrarily, (Taylor-Edwards, Elam, et al., 2009) reported that polymer-coated urea substitution for urea did not influence DM, OM, NDF, and ADF apparent digestibility but decreased N digestibility.

Higher OM digestibility in lamb fed UZ or Z ration compared to U or NU ration was more likely because of the zeolite role in improving gastrointestinal tract environment. (Katsoulos et al., 2005) reported that the role of zeolite in ruminant nutrition was used as an adsorbent and its binding effect on any nutrient or other component influenced both metabolism and absorption processes. In addition, (Bechtel and Hutchenson 2003) reported zeolite inclusion in the ruminant ration was useful as a pellet binder, improved ammonia utilization, retained poison and heavy metal, and reduced metabolic disorder incidences.

Higher NDF, ADF, or hemicellulose digestibility in lambs fed Z ration, especially when compared to those fed NU or U ration, confirmed the previous presumption that zeolite ration was more prominent in supporting microbial fibre digestion occurred in the rumen. An increase in NDF and ADF digestibilities in male sheep fed urea-treated wheat straw was also reported by (Nurfeta et al., 2009). Contrarily, a decrease in ADF digestibility when slow-release urea agent such as polymer-coated urea substitution for urea as previously reported by Galo et al. (2003) did not happen in present research when urea-impregnated zeolite (as slow-release urea agent) substitution for urea. In ruminants, the main site for fibre degradation takes place in the rumen where rumen microbes degrade fibre fractions. Rumen microbes need readily available carbohydrates as energy sources and nitrogen sources in synchronous amounts to degrade the fibre.

In addition, DMD correlated positively with OMD (r = 0.989, P<0.01), NDF digestibility (r = 0.728, P<0.01), ADF digestibility (r = 0.778, P<0.01), and cellulose digestibility (r = 0.766, P<0.01). The correlations between DMD and OMD or between DMD and fibre fractions digestibilities (NDF, ADF, cellulose) occurred in the present research supported the presumption that both zeolite and urea-impregnated zeolite more prominent in supporting microbial fibre digestion occurred in the rumen. Seemingly, the ratio of energy to nitrogen available to rumen microbes was at an optimal level when zeolite was included in a ration containing protein nitrogen such as in Z ration rather than a ration containing non-protein nitrogen such as in UZ ration as indicated by the previous *in vitro* research (Kardaya et al., 2010) that UZ inclusion produced the highest microbial protein synthesis (MPS) (1,381.45 ± 77.1 mg/l) achieved in the 24-hour fermentation period.

Similarity in crude protein (CP) digestibility across the experimental rations in the present research is associated with its similarity in CP intake (Table 2). This result disagreed with (Galo et al., 2003) who reported an improvement in CP digestibility when polymer-coated urea substitution for urea ration. Despite showing no improvement in CP digestibility, this result (Taylor-Edwards, Elam, et al., 2009) showed no negative impact on nitrogen digestibility as reported that lower nitrogen digestibility occurred when slow-release urea substitution for urea ration.

Lamb performances

Lambs fed Z ration produced higher average live weight gain in account for average daily gain (ADG) or when it presented as a percentage of initial live weight gain compared to lambs fed U ration but showed similar ADG when it was compared to UZ or NU ration (Table 4). The higher ADG of lambs fed Z ration was in relation to its higher feed efficiency ratio. Increase in LWG, ADG, and feed efficiency because UZ ration substitution for U ration agreed to Ortiz et al. (2002) who revealed that feed intake, digestibility, and live weight gain of Zebu cattle were improved by slow intake of urea supplement (SIUS). Taylor-Edwards, Hibbard, et al. (2009) reported that polymer-coated urea (1.2% DM) did not show a significant increase (P=0.07) in the LWG of the steers. In this study, it seems that the ADG and the efficiency of feed utilization by lamb fed Z rations are because of the slow-release characteristic in improving utilization of nutrient as reflected in the apparent digestibility of the nutrients.

CONCLUSIONS

Zeolite or urea-impregnated zeolite inclusion into field grass-based diets of lamb maintaind feed intake level, improved DM, OM, NDF, ADF, and hemicellulose digestibility, and increased feed efficiency and live weight gain of lambs. It is implicated that zeolite improved lamb performance better than urea probably as a result of the cation exchange capacity of zeolite.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

NOVELTY STATEMENT

The inclusion of urea-impregnated zeolite or zeolite in sheep ration increases apparent digestibility of dry matter and organic matter. This study also revealed that the use of zeolite increases the feed efficiency and live weight gain of lamb

AUTHORS CONTRIBUTIONS

Dede kardaya worked on research proposal, research supervision, data validation, and edited manuscript. Deden Sudrajat helped in research, data analysis, initial manuscript draft, and research. Dewi Wahyuni assisted in data analysis, and research administration.

REFERENCES

AOAC. (2016). Official Methods of Analysis. 20th ed. Dr. George W. Latimer Jr, editor. Gaithersburg, MD, USA: Association of Official Analytical Chemists, AOAC International.

Bechtel R, Hutchenson D. (2003). Adding CZ to rations may reduce nitrogen losses. Feedstuffs. 7:75.

Calomeni GD, Gardinal R, Venturelli BC, Júnior JE de F, Vendramini THA, Takiya CS, de Souza HN, Rennó FP. (2015). Effects of polymer-coated slow-release urea on performance, ruminal fermentation, and blood metabolites in dairy cows. Revista Brasil. de Zoot. 44(9):327–334. https://doi.org/10.1590/S1806-92902015000900004

El-Nile A, Elazab M, El-Zaiat H, El-Azrak KED, Elkomy A, Sallam S, Soltan Y. (2021). *In vitro* and *in vivo* assessment of dietary supplementation of both natural or nano-zeolite in goat diets: Effects on ruminal fermentation and nutrients digestibility. Animals. 11(8). https://doi.org/10.3390/ani11082215

Galo E, Emanuele SM, Sniffen CJ, White JH, Knapp JR. (2003). Effects of a polymer-coated urea product on nitrogen metabolism in lactating Holstein dairy cattle. J. Dairy Sci. 86(6):2154–2162.

Gardinal R, Calomeni GD, Cônsolo NRB, Takiya CS, Freitas JE, Gandra JR, Vendramini THA, Souza HN, Rennó FP. (2017). Influence of polymer-coated slow-release urea on total tract apparent digestibility, ruminal fermentation and performance of Nellore steers. Asian-Australas J. Anim. Sci. 30(1):34–41. https://doi.org/10.5713/ajas.16.0058

IBM. (2019). IBM SPSS Statistics Version 26 for Windows. 1 New Orchard Road Armonk, New York 10504-1722 United States: International Business Machines Corporation.

Kardaya D, Sudrajat D, Dihansih E. (2012). Efficacy of dietary urea-impregnated zeolite in improving rumen fermentation characteristics of local lamb. Media Peternakan Fakultas Peternakan Institut Pertanian Bogor. 35(3):207.

Kardaya D, Wiryawan KG, Parakkasi A, Winugroho HM. (2009). In vitro slow-release urea characteristics under different molasses levels contained in rice straw based diets.

Kardaya D, Wiryawan KG, Parakkasi A, Winugroho HM. (2010). *In vitro* slow-release urea contained in rice straw-based diets to increase efficiency of rumen microbial protein synthesis.

Karsli M, Russell JR. (2001). Effects of some dietary factors on ruminal microbial protein synthesis. Turk J. Vet. Anim. Sci. 25(5):681–686.

Kathirvelan C, Balakrishnan V. (2006). Effect of zinc supplementation on urea hydrolysis in an in vitro fermentation using rumen liquor. Malays J. Nutr. 12(1):93–99.

Katsoulos P-D, Panousis N, Roubies N, Christaki E, Karatzias H. (2005). Effects on Blood Concentrations of Certain Serum Fat-soluble Vitamins of Long-term Feeding of Dairy Cows on a Diet Supplemented with Clinoptilolite. J. Vet. Me. Series A. 52(4):157–161.

Ludden PA, Harmon DL, Huntington GB, Larson BT, Axe DE. (2000). Influence of the novel urease inhibitor N-(n-butyl) thiophosphoric triamide on ruminant nitrogen metabolism: II. Ruminal nitrogen metabolism, diet digestibility, and nitrogen balance in lambs. J. Anim. Sci. 78(1):188–198.

Nurfeta A, Tolera A, Eik LO, Sundstøl F. (2009). Feeding value of enset (Ensete ventricosum), Desmodium intortum hay and untreated or urea and calcium oxide treated wheat straw for sheep. J. Anim. Physiol. Anim. Nutr. (Berl). 93(1):94–104.

Ortiz RMA, Galina MA, Carmona MMA. (2002). Effect of a slow non-protein nitrogen ruminal supplementation on improvement of Cynodon nlemfuensis or Brachiaria brizanta utilization by Zebu steers. Livest. Prod. Sci. 78(2):125–131.

Roque-Jiménez JA, Pinos-Rodríguez JM, Rojo-Rub R, Mendoza GD, Vazquez A, De Jesus JAC, Lee-Rangel HA. (2019). Effect of natural zeolite on live weight changes, ruminal fermentation and nitrogen metabolism of ewe lambs. S. Afr J. Anim. Sci. 48(6). https://doi.org/10.4314/sajas.v48i6.19

Steel R, Torrie J. (1986). Principles and procedures of statistics: a biometrical approach. [place unknown]: McGraw-Hill New York, NY, USA.

Taylor-Edwards CC, Elam NA, Kitts SE, McLeod KR, Axe DE, Vanzant ES, Kristensen NB, Harmon DL. (2009). Influence of slow-release urea on nitrogen balance and portal-drained visceral nutrient flux in beef steers. J. Anim. Sci. 87(1):209–221.

Taylor-Edwards CC, Hibbard G, Kitts SE, McLeod KR, Axe DE, Vanzant ES, Kristensen NB, Harmon DL. (2009). Effects of slow-release urea on ruminal digesta characteristics and growth performance in beef steers. J. Anim. Sci. 87(1):200–208.

Toprak NN, Yilmaz A, Öztürk E, Yigit O, Cedden F. (2016). Effect of micronized zeolite addition to lamb concentrate feeds on growth performance and some blood chemistry and metabolites. S. Afr J. Anim. Sci. 46:313–320.

Van Soest PJ, Robertson JB, Lewis BA. (1991). Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition. J. Dairy Sci. [Internet]. [accessed 2023 Jan 15] 74(10):3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2