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Effects of supplementary urea-minerals lick block on the kinetics of fibre digestion, nutrient digestibility and nitrogen utilization of low quality roughages*

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Abstract: Three yearling lambs with a rumen cannula were used to investigate the effects of supplementation with an urea-minerals lick block (ULB) on the kinetics of ruminal fibre digestion, nutrient digestibility and nitrogen (N) utilization of rice straw (RS), ammonia bicarbonate (AB)-treated RS (ABRS) and hay prepared from natural pasture. The digestibility of dry matter and organic matter of RS increased by 13.1% and 12.7% (P<0.05) when the diet was supplemented with ULB, and approached to that of ABRS, indicating that the effect of ULB on digestibility of RS is similar to that of AB treatment. The digestibility of ABRS was slightly improved by the ULB feeding. Nitrogen retention was highest in lambs fed on ABRS alone, followed by hay with ULB, and was lowest in animals fed on RS with ULB. However, both the amount and proportion of N retention to N intake were enhanced by ULB supplementation to lambs fed on hay. The proportion of N retained to N digested decreased due to ULB supplementation to lambs fed on RS or ABRS. Supplementing ULB did not greatly influence the rumen degradation of either dry matter or crude protein in each of the three diets. RS and hay had similar values in the potential extent of digestion (PED) and digestion rate of PED (kd) of fibrous materials, but the discrete lag time for RS was lower than that for hay. The AB treatment significantly increased the PED (P<0.05) and kd (P<0.05) of RS. Neither the PED nor kd for RS and ABRS was influenced by ULB supplementation, but the kd for hay significantly increased due to ULB. The lag time for hay was also shortened by the ULB feeding. The ULB improved the digestion of fibre in the rumen of lambs fed on low quality roughage. It is inferred that while ULB is effective in increasing nutrient digestibility of low quality roughages by improving ruminal fibre digestion. A synchronized supply of N and energy to rumen microbes should be considered to improve the efficiency of N utilization when the basal diet is ammoniated straw.

Key words: Urea-minerals lick block, Digestibility, Nitrogen utilization, Fibre digestion, Kinetics, Roughage, Sheep
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INTRODUCTION

It was recognized that when animals are offered a low-nitrogen, high fibre roughage such as rice straw (RS), one of the critical nutrients is fermentable nitrogen (N) available to rumen microbes (ARC, 1984). The use of urea/molasses blocks is a convenient way for avoiding excessive intake of urea, and will ensure an almost continuous supply of ammonia-N (Preston, 1986).

Urea/molasses block feeding yielded positive results in many parts of the world (Kunju, 1986; Hadjipanayiotou *et al*., 1993b; Chen *et al*., 1993). The blocks containing molasses are highly palatable, but are unlikely to be widely applied in many countries because of the unavailability of molasses. Therefore

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some workers tried to manufacture blocks with reduced quantities of molasses (Hadjipanayiotou *et al*., 1993a; Liu *et al*., 1996).

The objective of this study was to evaluate the effect of an urea-minerals lick block (ULB) without molasses on rumen fibre digestion kinetics and on the nutrient digestion and nitrogen utilization of rice straw (RS), ammonia bicarbonate treated RS (ABRS) and hay prepared from natural pasture.

MATERIALS AND METHODS

Animals and their managements

Three yearling lambs each equipped with a rumen cannula and weighing about 30 kg were dosed with anthelminthic and housed individually in metabolism crates. Feeds were offered in two equal meals per day at 9:00 and 18:00 o'clock, and the daily amounts were calculated to exceed that eaten on the previous day by about 10% to avoid selective feed intake. All the animals had free access to drinking water.

Experimental feeds

The RS was obtained from the Experimental Farm of Zhejiang University. The ABRS was prepared by the stack method: one ton of RS was treated with 100 kg ammonia bicarbonate and 250 kg water for 30 d at ambient temperature of 15~20 °C (Liu *et al*., 1991). Hay was prepared from natural pasture which is the main roughage source for ruminants in our region. The composition of the experimental diets is presented in Table 1.

Table 1 Chemical composition of the experimental feeds

Feed	DM (%)	OM (%DM)	CP (%DM)	NDF (%DM)
RS	81.8	86.0	8.8	69.9
ABRS	80.7	85.2	12.5	61.8
Hay	83.1	78.0	10.6	60.0

DM: Dry matter; OM: Organic matter; CP: Crude protein; NDF: Neutral detergent fibre

The ULB was prepared without molasses, and contained 4% N in all minerals. The composition of the ULB used was the same as described by Liu *et al*.(1996).

Experimental design and procedures

The experiment was carried out according to two 3×3 Latin square designs, one for roughage with ULB and the other without ULB. Each period consisted of 21 d, the first 10 d were for adaptation followed by 11 d of measurements. A digestibility and N balance trial was conducted over 5 d (from day 11 to 15), while the rate of passage of digesta through the rumen (*kp*) was determined. The degradation of crude protein (CP) and dry matter (DM), and digestion of neutral detergent fibre (NDF) in the rumen were measured from day 16 to 21.

The digestibility of nutrients and N balance were determined by collection of total faeces and urine. Feed and faeces were sampled and analyzed for DM, organic matter (OM), CP (AOAC, 1990) and NDF (Goering and van Soest, 1970). The N content in urine was also analyzed by the Kjeldahl method.

The procedure for determining the *kp* was the same as described in Liu *et al*.(1995), where the model of Grevum and Williams (1973) was used. Rumen digestion of NDF and ruminal degradation of CP and DM were determined in sacco (Ørskov, 1985), and details of the procedure were as described in Liu *et al*.(1995). The digestion kinetics parameters of NDF in the rumen were estimated by using the model of Mertens and Loften (1980). Nonlinear iterative least square procedure was used to fit the equation:

$$R=PED\times\exp[-kd(t-LT)]+U$$

Here R is the percentage of NDF recovered at time t (h), PED is the potential extent of digestion at fractional rate kd (kd>0), LT is the discrete lag time of digestion, and U is the indigestible fraction (U=100−PED).

$$p=a+b\times[1-\exp(-ct)]$$

Here p is disappearance rate at time t (h), a is the rapidly digestible fraction in the rumen, and b is the fraction slowly digested at rate c (c>0).

The effective degradability (dg) of CP and DM was calculated by using the equation of Ørskov (1985):

$$dg=a+bc/(c+kp)$$

Statistical analyses

The experimental results were analyzed as a two-way factorial design (Steel and Torrie, 1980), in which the square was considered as a factor.

RESULTS AND DISCUSSION

The results of the digestion trial are presented in Table 2. The DM intake of all three roughages slightly decreased with ULB supplementation but the differences were not significant. Intake of ULB was estimated to be about 10 g per day, which was similar to that obtained for goats (Liu *et al*., 1996).

The digestibility of DM and OM of RS increased by 13.1% and 12.7% (P<0.05) as a result of the ULB feeding and approached to that of ABRS, indicating that the effect of supplementing ULB on the digestibility of RS was similar to that of treatment with AB. The hay used in this study was of low quality as shown by its digestibility, which was the same as that of RS. The digestibility of hay was significantly enhanced by supplementing ULB (P<0.05). When ABRS was supplemented with ULB, the digestibility of all nutrients was also improved.

The N balance results are shown in Table 3. Nitrogen intake was significantly lower in lambs given the RS (P<0.05) even with ULB. When RS or hay was fed to lambs alone the loss of faecal N was more than 60%. Both ammonia treatment and ULB supplementation could decrease the faecal N loss in RS diets. The lambs fed on ABRS with or without ULB had the highest urinary N loss, while the lowest urinary N loss occurred in lambs fed on hay. The ULB supplementation increased the N losses via urine of lambs fed on all three roughages, regardless of the amount and the proportion to N intake. Without the ULB, N retention (NR) was the highest in lambs fed on ABRS, followed by NR in lambs fed on hay, and was the lowest in lambs fed on RS. While the feeding of ULB increased the NR in lambs fed on hay, the NR in lambs fed on ABRS decreased due to the ULB supplementation. Little difference was found in the NR in lambs fed on RS with or without ULB.

Table 2 The effects of supplementing ULB on the intake and digestibility of experimental diets offered to lambs

Roughage	RS		ABRS		Hay		Significance		
ULB supplementing	No	Yes	No	Yes	No	Yes	R	B	R×B
DM intake (g/d)	576±33.7	534±33.1	683±35.3	591±34.2	735±36.4	705±35.8	*	NS	NS
dg (%)									
DM	48.9±1.10	55.3±1.16	54.4±1.15	57.1±1.20	49.1±1.11	55.0±1.13	*	**	NS
OM	51.8±1.13	58.4±1.19	57.6±1.25	60.2±1.29	53.0±1.17	58.5±1.24	*	**	NS
CP	39.5±1.86	45.7±1.95	60.1±2.36	61.0±2.45	35.2±1.93	48.8±2.11	**	*	NS
NDF	62.6±0.91	66.8±0.96	65.6±1.01	68.5±1.04	66.2±1.03	69.4±1.06	*	*	NS

R: Roughage effect; B: ULB effect; R×B: Interaction effect between roughage and ULB; *Different significantly P<0.05; **P<0.01; NS: Not significant; The data in the table are mean±*SEM*

Table 3 The nitrogen utilization of lambs fed on experimental diets with or without ULB

Roughage	RS		ABRS		Hay		Significance		
ULB supplementing	No	Yes	No	Yes	No	Yes	R	B	R×B
N intake (g/d)	8.1±0.41	8.1±0.33	13.2±0.51	12.3±0.47	12.5±0.44	12.5±0.52	**	NS	NS
Faecal N loss (g/d)	4.9±0.33	4.4±0.29	5.4±0.37	4.8±0.34	8.1±0.48	6.4±0.42	**	*	NS
Urine N loss (g/d)	1.6±0.21	2.2±0.23	2.3±0.26	3.1±0.30	1.2±0.16	1.6±0.18	*	*	NS
N retention (g/d)	1.6±0.23	1.5±0.20	5.5±0.56	4.4±0.42	3.2±0.38	4.5±0.48	**	NS	NS
Percent of N intake (%)									
Faecal N loss	60.5±3.55	54.3±3.23	40.9±2.51	39.0±2.41	64.8±3.82	51.2±3.07	**	*	NS
Urine N loss	19.8±2.83	27.2±3.32	17.4±2.45	25.2±3.13	9.6±1.87	12.8±1.95	*	*	NS
N retention	19.7±1.87	18.5±1.76	41.7±3.21	35.8±2.91	25.6±2.16	36.0±3.03	**	NS	NS
N retained/N digested (%)	50.0±2.52	40.5±2.06	70.5±3.21	58.7±2.75	72.7±3.41	73.8±3.43	**	*	NS

R: Roughage effect; B: ULB effect; R×B: Interaction effect between roughage and ULB; *Different significantly P<0.05; **P<0.01; NS: Not significant; The data in the table are mean±*SEM*

The proportion of N retained to N digested decreased by supplementing ULB to lambs fed on RS or ABRS, but there was little change in the proportion in lambs fed on hay. This may be associated with an unbalanced supply of N and energy to the rumen microbes when straw-basal diet was supplemented only with ULB, resulting in the inefficient use of N.

The results obtained for DM and CP degradation in the rumen are shown in Table 4. Without supplementing ULB, the degradability of DM and CP was significantly higher for ABRS than that for RS and hay, with little difference between RS and hay. The feeding of ULB had little effect on the rumen degradation of DM and CP in any of the three feeds.

The parameters of NDF digestion in the rumen are presented in Table 5. When given alone, RS was similar to hay in the potential extent of digestion (PED) and its digestion rate (kd), but the discrete lag time (LT) of RS was lower than that of hay. The AB treatment significantly increased the PED ($P<0.05$) and kd ($P<0.05$) for RS. Neither the PED nor kd for RS and ABRS were markedly influenced by the feeding of ULB, whereas the kd for hay was significantly enhanced. The product of PED×kd (NDF digested per hour) was, however, increased by 9.2% and 30.3% for RS and hay due to the ULB feeding respectively, though little effect was observed for ABRS. The LT for hay was shortened by the ULB feeding.

The effective extent of ruminal fibre digestion (EED) was estimated according to Huang and Xiong (1990) and is shown in Table 5. RS had an EED value similar to that of hay, and treatment with AB significantly improved the rumen fibre digestion and increased the EED of RS by 26.3% ($P<0.05$). The ULB feeding also improved the EED for all roughages, suggesting that the ULB can improve the integrated digestion of low quality roughage fibre in the rumen.

Table 4 Constants of the equation $p=a+b[1-\exp(-ct)]$ for the degradation of DM and CP of experimental feeds in the rumen of lambs with or without ULB

Roughage	RS		ABRS		Hay		Significance		
ULB supplementing	No	Yes	No	Yes	No	Yes	R	B	R×B
DM degradation									
a (%)	16.0±0.60	12.4±0.56	15.9±0.64	16.1±0.65	19.5±0.72	20.0±0.74	**	NS	*
b (%)	52.8±1.30	58.0±1.43	55.1±1.40	53.8±1.32	49.2±1.23	56.1±1.37	NS	*	*
c (%/h)	3.07±0.21	3.45±0.26	4.08±0.31	5.53±0.39	3.25±0.24	2.66±0.19	**	NS	*
kp (%/h)	2.96	2.88	3.14	2.71	3.54	3.00			
dg (%)	42.9±1.56	44.0±1.65	52.0±2.02	52.2±2.11	43.7±1.83	46.3±1.93	*	NS	NS
a+*b* (%)	68.8	70.4	71.0	69.9	68.7	76.1			
CP degradation									
a (%)	36.1±2.11	32.1±2.04	35.2±2.19	30.0±1.96	29.3±1.87	28.0±1.73	NS	NS	NS
b (%)	50.7±2.28	50.4±2.21	53.1±2.15	45.0±1.92	46.0±1.97	44.6±2.01	NS	NS	NS
c (%/h)	0.98±0.19	1.72±0.23	3.95±0.44	5.68±0.51	2.06±0.28	1.85±0.31	**	NS	NS
dg (%)	48.7±3.14	50.9±3.23	64.4±3.92	60.5±3.71	46.2±3.09	45.0±3.01	*	NS	NS

R: Roughage effect; B: ULB effect; R×B: Interaction effect between roughage and ULB; *Different significantly $P<0.05$; **$P<0.01$; NS: Not significant; The data in the table are mean±*SEM*

Table 5 Parameters of the ruminal digestion kinetics of dietary fibre in lambs with or without ULB

Roughage	RS		ABRS		Hay		Significance		
ULB supplementing	No	Yes	No	Yes	No	Yes	R	B	R×B
PED (%)	59.2±1.34	59.6±1.39	62.3±1.47	63.1±1.51	59.6±1.41	55.2±1.27	*	NS	NS
kd (%/h)	3.29±0.25	3.58±0.28	5.68±0.41	5.19±0.37	3.32±0.31	4.67±0.33	*	NS	*
PED×*kd* (%)	1.95	2.13	3.54	3.27	1.98	2.58			
LT (h)	5.4±0.30	5.4±0.38	5.6±0.36	5.1±0.34	6.3±0.41	5.0±0.29	NS	NS	NS
kp (%/h)	2.96	2.88	3.14	2.71	3.54	3.00			
EED (%)	26.6±1.26	28.2±1.29	33.6±1.47	36.1±1.53	23.1±1.17	28.9±1.36	**	*	NS

R: Roughage effect; B: ULB effect; R×B: Interaction effect between roughage and ULB; *Different significantly $P<0.05$; **$P<0.01$; NS: Not significant; The data in the table are mean±*SEM*. *EED* is calculated as: $PED\times kd/(kd+kp)\times\exp(-kp\times LT)$

CONCLUSION

The ULB significantly increased the nutrient digestibility of RS and hay, and slightly improved the digestibility of ABRS, possibly as a result of an improved digestion of fibre in the rumen. Both the amount and the proportion of N retention to intake were increased by ULB supplementation to lambs fed on hay. The proportion of N retained to N digested decreased with the feeding of ULB to lambs fed on RS or ABRS, indicating that the effect of ULB on the efficiency of N utilization varied between different roughages. It was concluded that when low quality roughages high in fibre and low in N are supplemented with ULB containing urea and minerals, a synchronized supply of N and energy to rumen microbes should be considered to improve the efficiency of N utilization.

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References

AOAC (Association of Official Agricultural Chemists), 1990. Official Methods of Analysis. 15th Ed., Vol. 1, AOAC, Washington, DC, p.69-90.

ARC (Agricultural Research Council), 1984. The Nutrient Requirements of Ruminant Livestock, Suppl.1. Commonwealth Agricultural Bureau, London, UK, p.351-360.

Chen, Y.Z., Wen, H., Ma, X., Li, Y., Gao, Z., Peterson, M.A., 1993. Multinutrient lick blocks for dairy cattle in Gansu Province, China. *Livestock Research for Rural Development*, **5**(3):60-63.

Goering, H.K., van Soest, P.J., 1970. Forage Fibre Analyses. *In*: Agricultural Handbook, No. 37. USDA, Washington, DC.

Grevum, W.J., Williams, V.J., 1973. Rate of passage of digesta in sheep. 4. Passage of marker through the alimentary tract and the biological relevance of rate constants derived from the changes in concentration of marker in faeces. *British Journal of Nutrition*, **30**:313-319.

Hadjipanayiotou, M., Verhaeghe, L., Allen, M., Kronfoleh, A.R., Al-Wadi, M., Amin, M., Naigm, T., El-Said, H., Al-Haress, A.K., 1993a. Urea blocks. I. Methodology of block making and different formulae tested in Syria. *Livestock Research for Rural Development*, **5**(3):6-15.

Hadjipanayiotou, M., Verhaeghe, L., Kronfoleh, A.R., Labban, L.M., Amin, M., Al-Wadi, M., Badran, A., Dawa, K., Shurbaji, A., Houssein, M., *et al*., 1993b. Urea blocks. II. Performance of cattle and sheep offered urea blocks in Syria. *Livestock Research for Rural Development*, **5**(3):16-23.

Huang, B.Y., Xiong, Y.Q., 1990. Effect of dietary concentrate level on ruminal fibre digestion kinetics. *Acta Zoonutrimenta Sinica*, **2**(2):30-35.

Kunju, P.J.G., 1986. Urea Molasses Block Lick-a Feed Supplement for Ruminants. *In*: Ibrahim, M.N.N., Schiere, J.B. (Eds.), Rice Straw and Related Feeds in Ruminant Rations. SUP Publication No. 2, Kandy Offset Printers Ltd., Sri Lanka, p.261-274.

Liu, J.X., Xu, N.Y., Wu, Y.M., Dai, X.M., Han, Y.G., 1991. Ammonia bicarbonate as a source of ammonia for improving the nutritive value of rice straw. *China Feed*, **Suppl.**:87-92 (in Chinese).

Liu, J.X., Wu, Y.M., Xu, N.Y., 1995. Effects of ammonia bicarbonate treatment on liveweight gain, kinetics of fibre digestion, nutrient digestibility and nitrogen utilization of rice straw by sheep. *Animal Feed Science and Technology*, **52**:131-139.

Liu, J.X., Dai, X.M., Yao, J., Zhou, Y.Y., Chen, Y.J., 1996. Effect of urea-mineral lick block feeding on liveweight gain of local yellow cattle and goats in grazing conditions. *Livestock Research for Rural Development*, **7(2)**:9-13.

Mertens, D.R., Loften, J.R., 1980. The effect of starch on forage fibre digestion kinetics in vitro. *Journal of Dairy Science*, **63**:1437-1446.

Ørskov, E.R., 1985. Evaluation of crop residues and agro-industrial by-products using the nylon bag method. *Research and Development in Agriculture*, **4(2)**:65-69.

Preston, T.R., 1986. Better Utilization of Crop Residues and By-products in Animal Feeding: Research Guidelines. 2. A Practical Manual for Research Workers. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, p.20-25, 32-35.

Steel, R.D.G., Torrie, J.H., 1980. Principles and Procedures of Statistics. 2nd Ed., McGraw-Hill, New York, p.132-194, 363-372.