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ENERGY METABOLISM IN LAMBS FED GRASS OR CORN SILAGE WITH PROTEIN SUPPLEMENTS OF DIFFERENT DEGRADABILITY

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Introduction

Silage is of ever-increasing importance in the ruminant feeding throughout the world. Silage has superseded hay as the principal type of conserved forage in many countries[20]. Some calorimetric determinations has been carried out with silage[4,8,11,16,19] but many of silages used have been preserved with additives and of high-fermentation quality. Information is insufficient about energy metabolism in ruminants fed silages in Japan, though ASAHIDA *et al.*[2] and HIROSE *et al.*[5,6] have studied energy utilization in sheep fed self-supplied feeds including grass and corn silage.

Silage is often offered with supplementation of concentrate such as protein source in practical feeding. There is little knowledge about the effect of degradability of protein supplements on energy metabolism in animals fed silages.

The experiment presented herein was, therefore, conducted to study the energy metabolism in lambs receiving grass or corn silage with protein supplements of different degradability.

Materials and Methods

Animals and Management

Four yearling lambs, weighing about 40–50 kg, were used. Their managements were the same as described in the previous study[9].

Experimental Design

The experiment involved three dietary treatments for grass or corn silage: (1) silage alone (GS, CS), (2) supplemented with soybean meal (GS–

SBM, CS-SBM) or (3) corn gluten meal (GS-CGM, CS-CGM). Two diets with silage alone were offered to meet the metabolizable energy requirement for maintenance and protein-supplemented diets to achieve 100 g of dairy gain according to ARC allowance[1].

Experiment was divided into six periods (Table 1). On the final day of each period, respiratory exchange was measured. Following the completion of three treatments of each silage, the fasting metabolism was measured (Table 1).

TABLE 1. Experimental designs[1]

Sheep code	Experimental period							
	I	II	III	Fasting-1	IV	V	VI	Fasting-2
A, B	GS	GS-SBM	GS-CGM	—	CS	CS-SBM	CS-CGM	—
C, D	GS	GS-CGM	GS-SBM	—	CS	CS-CGM	CS-SBM	—

1) All abbreviated notations were shown in the text.

Details of diets, digestion and metabolism trials have been described elsewhere[10].

Calorimetric Procedures

Energy values for feed, feces and urine and content of urinary nitrogen were measured by the method as described by LIU *et al.*[9].

Oxygen consumption and carbon dioxide and methane production were continuously determined for 24 hours by the procedure as described by SEKINE *et al.*[15]. Heat production was calculated from the gaseous exchange and urinary nitrogen loss using the factors of BROUWER[3]. Energy retention was calculated as the difference between metabolizable energy intake and heat production.

Statistical Analysis

Results were analyzed as a two-way factorial design by the methods of STEEL and TORRIE[17].

Results and Discussion

Digestibility and metabolizability

Table 2 shows the intakes of gross (GE), digestible (DE) and metabolizable energy (ME), losses of energy in urine and methane and digestibility and metabolizability of energy.

TABLE 2. The intakes of gross (GE), digestible (DE) and metabolizable enegy (ME), losses of energy in urine (Ue) and methane (CH_4), and digestibility and metabolizability of energy in lambs fed experimental diets

Silage	Grass			Corn			Significance[1)] of effect		
Treatment	GS	GS-SBM	GS-CGM	CS	CS-SBM	CS-CGM	Sil.	Sup.	S×S
	kJ/kg$^{0.75}$								
GE intake	919	1159	1183	834	1036	1038	NS	**	NS
DE intake	484	782	788	494	728	728	NS	**	NS
ME intake	410	665	679	419	629	637	NS	**	NS
Ue	31	52	47	22	33	31			
CH_4	43	65	62	53	66	60			
	%								
DE/GE	52.7	67.5	66.6	59.2	70.3	70.1	**	**	NS
ME/GE	44.6	57.4	57.4	50.2	60.7	61.3	**	**	NS
ME/DE	84.7	85.0	86.2	84.8	86.4	87.5	NS	NS	NS
Ue/GE	3.3	4.5	4.0	2.6	3.2	3.0	**	**	NS
CH_4/GE	4.6	5.6	5.2	6.3	6.4	5.8	*	NS	NS

1) Sil.: Silage effect.
Sup.: Supplementation effect.
S×S: Interactions between silage and supplementation.
*: Significant at $P<0.05$.
**: Significant at $P<0.01$.
NS: Not significant.

Either supplementation significantly increased the intake of GE, DE and ME ($P<0.01$), but there was little difference between supplements ($P>0.05$).

Grass silage used in the present experiment was of poor quality in terms of digestibility. This may be due to a later harvest stage (blooming stage) of parent material. SUNDSTØL and EKERN[18] observed that energy digestibilities were 68.2, 63.2 and 59.8% for silage from timothy sward cut at the stage of heading, pre-blooming and blooming, respectively. Digestibility of CS given alone was comparable to results reported by HOLTER *et al.*[7].

Energy digestibilities significantly increased in supplemented diets for both silages ($P<0.01$), compared with each silage given alone, but there was no significant difference between supplements ($P>0.05$). These results are in agreement with those for digestibility of dry matter[10]. MORITA[13] also observed no significant effect of degradability of dietary protein on energy digestibility in growing calves.

Supplementation resulted in more energy loss in urine ($P<0.01$), also with no significant difference between supplements ($P>0.05$). The increase of urinary energy may result from an increased urinary nitrogen with supplementation[10].

There was little difference in methane production between diets for both silages. Methane loss of 4.6-5.6% of GE intake for GS-based diets was lower than those reported by SMITH *et al.*[16] and EKERN and SUNDSTØL[4], but similar to results reported by McLELLAN and McGINN[11]. Methane loss for CS-based diets was 5.8-6.5% of GE intake and comparable with those values given by HOLTER *et al.*[7].

Metabolizability of energy for GS and CS given alone were 44.7 and 50.2%, respectively, which are consistent with those suggested by MAFF[12]. Supplementation significantly increased energy metabolizability ($P<0.01$) for each silage-based diet. There was little difference between diets in the proportion of ME to DE which approximated to 0.85-0.87 for each diets, indicating that improvement of metabolizability with supplementation results from that of digestibility. These values (ME/DE) determined in the present study are higher than that (0.81) indicated by MAFF[12].

Energy Balance and Net Efficiency of Utilization of ME

Table 3 presents the energy lost as heat production and retained, heat increment, intake of net energy (NE) in lambs fed experimental diets and net efficiency of utilization of ME.

The heat energy loss slightly exceeded ME intake for both silage given silage alone. Expressed as % of GE intake, heat production accounted for 50.2 or 54.1% for grass or corn silage, respectively. In animals receiving supplemented diets heat energy losses of GE intake tended to be lower than in each silage given alone. These losses were similar to values obtained from silages preserved with formic acid and formic acid-formaldehyde and given alone or supplemented with barley[8,11].

Each silage given alone resulted in an energy retention close to zero. Feed residual was found in grass silage given alone, suggesting that it is difficult to derive profits from animals given a grass silage alone. The similar results have been observed by SUNDSTØL and EKERN[18]. Supplementation gave a positive energy balance of 108, 93, 137 and 138 kJ/kg live weight$^{0.75}$ per day in GS-SBM, GS-CGM, CS-SBM and CS-CGM.

The mean values for fasting metabolism in two periods were similar (Table 4). The values were close to the value of 280 kJ/kg live weight$^{0.75}$ indicated by the ARC[1].

TABLE 3. The energy lost as heat production (HP) and retained (Er), heat increment (HI), intake of net energy (NE) and net efficiency of utilization of metabolizable energy (*k*) in lambs fed experimental diets

Silage	Grass			Corn			Significance[1)] of effect		
Treatment	GS	GS-SBM	GS-CGM	CS	CS-SBM	CS-CGM	Sil.	Sup.	S×S
	kJ/kg$^{0.75}$								
ME intake	410	665	679	419	629	637	NS	**	NS
NE intake	241	373	356	269	445	433	NS	**	NS
HP	461	557	586	451	492	499	*	NS	NS
Er	−51	108	93	−30	137	138	*	**	NS
HI	167	285	323	156	183	203			
	%								
HP/ME	112.4	83.8	86.3	107.6	78.2	78.3	*	**	NS
Er/ME	−12.4	16.2	13.7	−7.6	21.8	21.8	*	**	NS
NE/ME	60.0	56.1	52.9	64.1	67.8	66.3			
HP/GE	50.2	48.1	49 5	54.1	47.5	48.0	NS	NS	NS
NE/GE	26.4	32.1	32.0	32.2	41.4	41.2	*	**	NS
k	60.1	58.9	55.8	64.5	69.8	69.0	**	NS	NS

1) Sil.: Silage effect.
Sup.: Supplementation effect.
S×S: Interactions between silage and supplementation.
*: Significant at $P<0.05$.
**: Significant at $P<0.01$.
NS: Not significant.

The net efficiencies of utilization of ME (*k*) were 60.1 and 64.5% for GS and CS given alone, respectively (Table 3). Because each silage was offered at maintenance level, the value of *k* for silage given alone was considered to be the efficiency of utilization of ME for maintenance (*km*). The *km* value for grass silage agrees with that indicated by SUNDSTØL *et al.*[19)], but is lower than those reported elsewhere[4,8,11)]. The *k* value slightly decreased in supplemented GS diets, compared with GS given alone, while the *k* value was 4–5% unit higher in both supplemented CS diets than that in CS given alone. These were resultant from the difference in heat increment between GS-based and CS-based diets (Table 3). Expressed as % of ME intake, heat increment were 40, 43.9, 47.1, 36.9, 32.2 and 33.7 for GS, GS-SBM, GS-CGM, CS, CS-SBM and CS-CGM diets, respectively. With sup-

TABLE 4. The fasting metabolism of four lambs following the completion of three treatment of grass silage-based (Fasting-1) and corn silage-based (Fasting-2) diets

Sheep code	Fasting-1		Fasting-2	
	Urinary energy	Fasting metabolism	Urinary energy	Fasting metabolism
	kJ/kg$^{0.75}$			
A	21	261	20	300
B	19	269	21	298
C	21	260	18	290
D	16	296	20	282
Mean	19	272	20	295

plementation, heat increment increased in GS-based diets but decreased in CS-based diets. These values are higher than those reported by ASAHIDA *et al.*[2] and HIROSE *et al.*[5,6].

The proportion of NE to GE (NE/GE) were 26.4 and 32.2% for grass and corn silage, respectively. Supplementation increased the value of NE/GE by 6% unit for GS-based diets and by 9% unit for CS-based diets.

The Energy Value

The contents of DE, MEn (N-corrected ME) and NE were 9.5, 7.9 and 4.8 MJ/kgDM for grass silage, 11.2, 9.4 and 6.1 MJ/kgDM for corn silage (Table 5), respectively. Because each silage was offered at maintenance level, the value of the NE content for each silage given alone was considered to be NE for maintenance. These values are slightly lower than those indicated by MAFF[12] and NRC[14].

TABLE 5. Energy contents of the experimental diets

Silage	Grass			Corn		
Treatment	GS	GS-SBM	GS-CGM	CS	CS-SBM	CS-CGM
	MJ/kgDM					
GE	18.3	18.4	18.7	18.8	19.1	19.4
DE	9.5	12.5	12.5	11.2	13.4	13.6
MEn[1)]	7.9	10.4	10.6	9.4	11.4	11.6
NE	4.8	5.9	5.7	6.1	7.9	8.0

1) MEn: Nitrogen-corrected metablizable energy.

The contents of MEn and NE significantly increased in the supplemented diets ($P<0.01$), compared with each silage given alone, resulting from the increased energy digestibility with supplementation. There was, however, little difference in energy value between supplements.

Summary

Calorimetric experiments were conducted to study energy metabolism in four lambs fed grass or corn silage with protein supplements of different ruminal degradability. Soybean meal and corn gluten meal were used as protein supplements highly and lowly degraded in the rumen, respectively. Compared with silage given alone, either supplementation significantly increased digestibility and metabolizability of energy ($P<0.01$), but there was little difference between supplements ($P>0.05$). Efficiency of utilization of ME for maintenance was 60.1 and 64.5% for GS and CS, respectively. With supplementation, efficiency of utilization of ME slightly decreased for GS-based diets but increased for CS-based diets. The results suggested that protein supplementation improved the utilization of energy of silage, mainly through the increase of digestibility, while there was little effect of degradability of protein supplements on energy metabolism of lambs fed grass or corn silage.

Literature Cited

1) AGRICULTURAL RESEARCH COUNCIL: The Nutrient Requirements of Ruminant Livestock. 73–119. Commonwealth Agricultural Bureaux, Slough. 1980

2) ASAHIDA, Y., SEKINE, J., TOBINO, T. and YAMASITA, Y.: A study on energy values of whole crop silages. Report on Research by Grantees, MAFF, Japan. 1975 (in Japanese)

3) BROUWER, E.: Report of sub-committee on constants and factors. *in* Energy Metabolism. (BLAXTER, K. L., ed.) 441–443. Academic Press. New York & London. 1965

4) EKERN, A. and SUNDSTØL, F.: Energy utilization of hay and silage by sheep. *in* Energy Metabolism of Farm Animals. (MENKE, K. H., LANTZSCH, K. H. and REICHL, J. R., eds.) 221-224. E. A. A. P. Pub. No. 14. Universität Hohenheim Dokumentationsstell. Stuttgart. 1974

5) HIROSE, Y., ASAHIDA, Y., SEKINE, J., TOBINO, T. and YAMASITA, Y.: A study on energy values of whole crop silages. Report on Research by Grantees, MAFF, Japan. 1976 (in Japanese)

6) HIROSE, Y., ASAHIDA, Y., SEKINE, J., TOBINO, T. and YAMASITA, Y.: A study on energy values of whole crop silages. Report on Research by Grantees, MAFF, Japan. 1977 (in Japanese)

7) HOLTER, J. B., COLOVES, N. F. and URBAN, W. E.: Enegry utilization in the ruminant fed maize silages as the sole forage. *in* Energy Metabolism of Farm Animals. (SCHURCH, A. and WENK, C., eds.) 33-36. E.A.A.P. Pub. No. 13. Juris Verlag Zürich Zürish. 1970

8) KELLY, N. C. and THOMAS, P. C.: The nutritive value of silages. Energy metabolism in sheep receiving diets of grass silage or grass silage and barley. *Br. J. Nutr.*, **40**: 205-215. 1978

9) LIU, J. X., KONDO, S., SEKINE, J., OKUBO, M. and ASAHIDA, Y.: The Nutritive values of grass, corn and rice silages fed to sheep at different level. *J. Fac. Agr. Hokkaido Univ.*, **63** (1): 225-235. 1986

10) LIU, J. X., OKUBO, M., KONDO, S., SEKINE, J. and ASAHIDA, Y.: Effects of degradability of protein supplements on nutrient digestion and nitrogen utilization in lambs fed grass or corn silage. *J. Fac. Agr. Hokkaido Univ.*, **63** (3): 293-299. 1987

11) MCLELLAN, A. R. and MCGINN, R.: Energy and nitrogen balance, intake and growth rate of lamb fed on unwilted grass silages treated with a formaldehyde-acid mixture or untreated. *Anim. Feed Sci. Technol.*, **9**: 107-119. 1983

12) MINISTRY of AGRICULTURE, FISHERIES and FOOD: Energy Allowances and Feeding Systems for Ruminants. Tech. Bull. No. 33. Her Majesty's Stationery Office. London. 1975

13) MORITA, S.: Some Investigations on Energy Utilization in Early-Weaned Calves. Especially on the relationship between ruminal degradability of dietary protein and metabolizable energy intake. M. Agr. Thesis, Hokkaido Univ. Sapporo. 1985 (in Japanese)

14) NATIONAL RESEARCH COUNCIL: Nutrient Requirements of Sheep. 6th ed. National Academy of Press. Washington D. C. 1978

15) SEKINE, J., MORITA, S., MOROOKA, T., KONDO, S., OKUBO, M. and ASAHIDA, Y.: Fasting heat production of calves at 4 to 6 months of age. *Jpn. J. Zootech. Sci.*, **56** (10): 787-791. 1985 (in Japanese with English summary)

16) SMITH, J. S., WAINMAN, F. W. and DAVEY, P. J. S.: The energy value to sheep of a mixed grass silage. *Proc. Nutr. Soc.*, **34**: 101 A. 1975

17) STEEL, R. G. D. and TORRIE, J. H.: Principles and Procedures of Statistics. 194-231. 305-331. McGraw-Hill Book Co., New York. 1960

18) SUNDSTØL, F. and EKERN, A.: The nutritive value of frozen, dried and ensiled grass cut at three different stages of growth. *in* Energy Metabolism of Farm Animals (VERMOREL, M., ed.) 241-244. E.A.A.P. Pub. No. 19, G. de Bussac. Clermont-Ferrand. 1976

19) SUNDSTØL, F., EKERN, A., LINGVALL, P., LINDGREN, E. and BERTILSSON, J.: Energy utilization in sheep fed grass silage and hay. *in* Energy Metabolism. (MOUNT, L. E., ed.) 17-21. E.A.A.P. Pub. No. 26. Butterworths. London. 1979

20) WOOLFORD, M. K.: The Silage Fermentation. Marcel Dekker, Inc. New York and Basel. 1984