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VOLUNTARY INTAKE AND RUMINAL DIGESTION OF FIBROUS MATERIALS OF GRASS OR CORN SILAGE BY SHEEP

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1. Introduction

The voluntary intake (VI) of dry matter (DM) of silages has been recognized to be lower than that of the same crop fed fresh⁴⁾ or after drying^{3,7,21)}. The low intake of silages is unlikely to be explained only with such fermentation characteristics as pH value and organic acid content^{10,12)}. The importance of physical factors limiting the VI of silages by ruminants has been suggested^{5,6)}.

Slow rates of rumen fiber digestion and slow rates of evacuation of indigestible materials from the rumen are major constraints to the VI of poor-quality roughages by ruminants²⁰⁾. However, there is little information on the ruminal fiber digestion of silages. On the other hand, the ruminal fiber digestion is a function of the microbial breakdown of feeds ingested. The nutrients supply to the microbes will, therefore, produce a considerable effect on the digestion of fibrous fractions of feeds in the rumen. The nitrogen (N) and energy are the most critical nutrients to support microbial activity in the rumen¹⁾. There is a need to study how the supply of N and energy to the ruminal microbes affects the ruminal digestion of fiber and the VI of silages.

The experiment was purposed to study the correlation between the VI of silages, digestion of fibrous materials (cell wall constituents, CWC) and the supply of N and energy sources to the microbes in the rumen of sheep fed silage.

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Materials and Methods

Experimental Animals and Feeds

Animals used were three Suffolk cross sheep with rumen fistula and weighing about 80 kg. Experimental feeds were wilted grass silage (GS) and corn silage (CS). Details for animal management and preparation of silages were the same as described in the previous study¹²⁾.

Experimental Design and Procedures

Design

Experiment was carried out according to a change-over design. Each 26-d period consisted of 14 d adaptation and 12 d determination. The VI of GS and CS and the rate of ruminal passage of digesta (kp) were determined over 6 days (from d 15 to d 20). The ruminal degradation of crude protein (CP) and organic matter (OM) as estimate of N and energy supply to the ruminal microbes, and ruminal digestion of CWC were measured from d 21 to d 25. On d 26, the rumen fluid samples were taken for the determination of pH value and ammonia-N concentration.

The VI of silages

The VI of silage was determined with the same methods as described elsewhere¹²⁾.

The rate of passage through the rumen

The kp was measured using chromium-mordanted fiber (Cr-CWC)¹⁹⁾ as a marker. The preparation of Cr-CWC of each corresponding silage was dosed in the rumen via the cannulae with a rate of 1% (wt/wt) of the daily intake at the time of morning feeding. Fecal samples were collected every 4 h for 5 days postdosing and were analyzed for Cr concentration in a spectrophotometer (HITACHI, MODEL 101) by the method described by YOSHIDA *et al.*²⁰⁾. The value of kp was determined using the model of the first order kinetics presented by GROVUM and WILLIAMS⁹⁾, in which kp was defined by the slope of the descending portion of the excretion curve obtained by least square regression of $\ln [\text{Cr}]$ vs. incubation time.

Digestion kinetics of CWC in the rumen

Digestion kinetics of CWC were measured by in sacco technique described by MEHREZ and ØRSKOV¹⁴⁾. The nylon bag used was made with 300 mesh (pore size, 48 micron) nylon fabrics measured 5 × 10 cm with curved corners. Two-gram samples of each silage, ground by Wiley mill through 1 mm screen, and 2 steel balls (about 11 g) as a weight were enclosed in each bag, and

suspended in the rumen of sheep fed the corresponding silage. Bags with duplicates were removed from the rumen after 3, 6, 9, 15, 24, 48 and 72 h incubation. After incubation, the bags were washed under running tap water for about 1 h such that the rinsing water was colorless. The bags and contents were then dried at 60°C oven for 24 h. Air dried residues were used to determine CWC. The ruminal digestion of CWC was estimated with the model of MERTENS and LOFTEN¹⁶⁾. The nonlinear iterative least square procedure was used to fit the equation :

$$R = PED \times e^{-kd(t-LT)} + U$$

where: R = percentage of CWC recovered at time t ;

PED = potential extent of digestion at fractional rate kd ($kd > 0$) ;

LT = discrete lag time of digestion ;

U = indigestible fraction ;

t = incubation time (h).

Degradation of CP and OM in the rumen

The ruminal degradation of CP and OM was measured by the nylon bag technique as described above. Bags with duplicates were removed from the rumen of sheep fed the corresponding silage after 3, 6, 9, 15 and 24 h incubation. Residues were used to determine CP and OM and rate of disappearance of each component were calculated. Data of disappearance rate were fitted to the model of ØRSKOV and McDONALD¹⁷⁾ :

$$p = a + b(1 - e^{-ct})$$

where: p = disappearance rate at time t ;

a = rapidly digestible fraction in the rumen ;

b = fraction slowly digested at fractional rate c ($c > 0$)

t = incubation time (h).

The dg of CP and OM was calculated using the equation presented by ØRSKOV and McDONALD¹⁷⁾ :

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

Rumen parameters

Rumen fluid samples were withdrawn by using a tube under vacuum through the rumen cannulae at 0, 1, 3 and 6 h after the morning feeding. The samples were strained through four layers of cheesecloth. The pH was determined immediately with a glass pH meter (HS-205C, TOA Electronics Ltd.). Fifty milliliters of each rumen fluid sample were stored frozen and

later analyzed for ammonia-N. Rumen ammonia concentrations were determined by steam distillation into boric acid and titration with dilute sulfuric acid (1/50 N).

Results

Chemical composition and fermentation characteristics of silages are shown in Table 1. Contents of CP and fiber fractions were higher in GS than in CS. The CS was much superior to GS in fermentation quality, with no butyric acid and high Flieg's index.

Figure 1 presents the residue with incubation time of CWC in the rumen. The VI of silages and the results of kinetics analysis of CWC digestion are given in Table 2. The VI was 48.6 and 51.1 gDM/kg body

TABLE 1. Chemical composition and fermentation characteristics of grass or corn silage

Silage	Chemical composition				Fermentation Characteristics			
	DM	OM	CP	CWC	pH	Lactic acid	Butyric acid	Flieg's index
	%	———— %	———— %	———— %		———— %	———— %	————
Grass	32.0	88.2	11.9	58.0	4.1	2.0	1.1	36
Corn	31.9	93.9	8.7	42.4	3.8	2.9	0.0	100

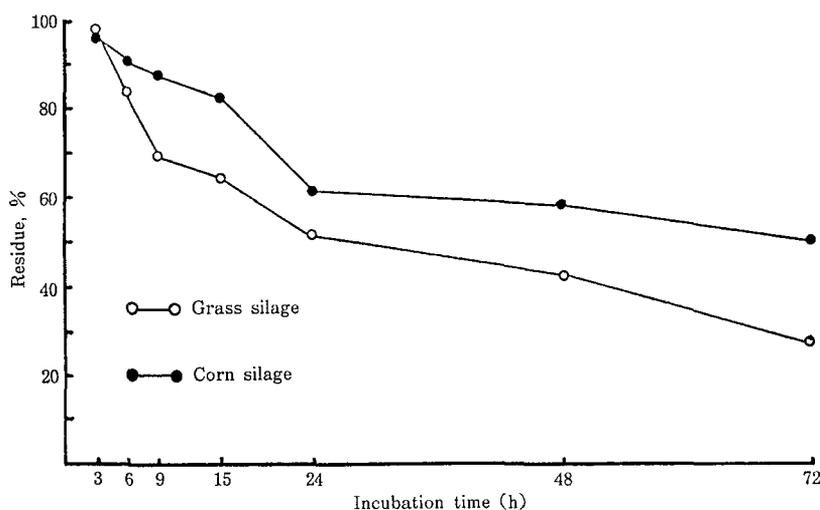


Fig. 1. Residue with incubation time of cell wall constituents from nylon bag suspended in the rumen of sheep given silage.

weight^{0.75} for GS and CS, respectively. The residues of CWC at 72 h incubation were 28.0 and 50.7 for GS and CS, respectively. The *PED* of CWC was higher in GS while the *kd* was higher in CS. The *LT* and *kp* were similar in sheep fed both silages.

Figure 2 and Table 3 show the result of CP and OM degradation in the rumen. The disappearance of CP and OM showed similar pattern for both silages. The rate of disappearance of CP at 3 h incubation was 65%

TABLE 2. Voluntary dry matter intake (VI) of silages and parameters of fiber digestion in the rumen of sheep given grass or corn silage alone

Silage	VI	Digestion parameters ¹⁾			
		<i>PED</i>	<i>kd</i>	<i>LT</i>	<i>kp</i>
	gDM/kg ^{0.75}	%	%/h	h	%/h
Grass	48.6	67.8	3.51	1.5	4.08
Corn	51.1	52.1	4.13	1.8	4.30

- 1) *PED*: Potential extent of digestion of fiber in the rumen
- kd*: Rate constant of digestion of *PED*
- LT*: Discrete lag time
- kp*: Rate constant of passage of digesta through the rumen

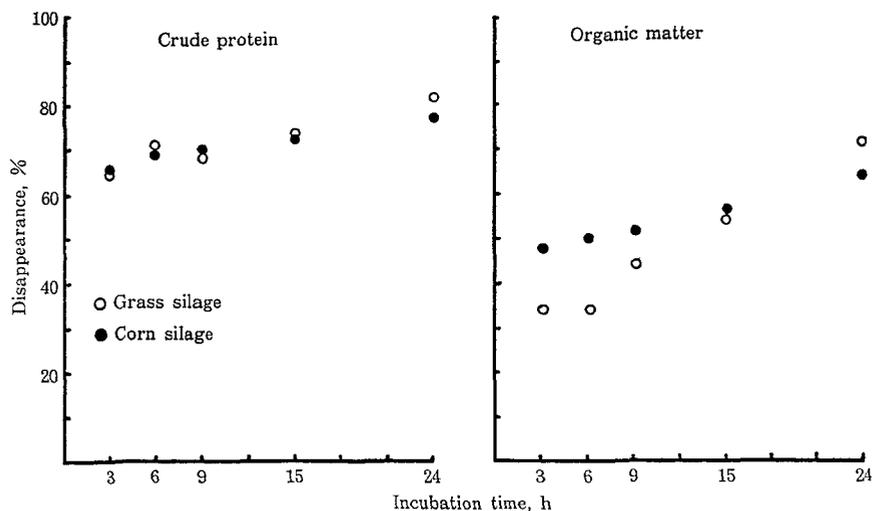


Fig. 2. Disappearance with incubation time of crude protein and organic matter from nylon bag suspended in the rumen of sheep given silage.

TABLE 3. Degradation of crude protein (CP) and organic matter (OM) in the rumen of sheep given grass or corn silage alone

Silage	Degradability		RDN ¹⁾	ADOM ²⁾	RDN/ ADOM
	CP	OM			
	%		%, DM		g/kg
Grass	74.4	57.8	1.42	51.0	27.8
Corn	73.1	56.3	1.02	52.8	19.2

1) RDN : Rumen degradable nitrogen

2) ADOM: Apparently digested OM in the rumen

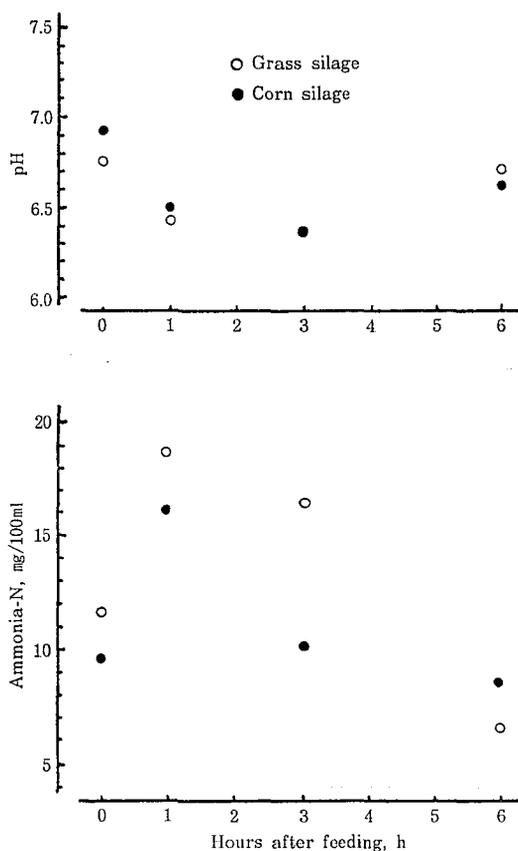


Fig. 3. Change with time after feeding in pH and ammonia-N concentration in the rumen of sheep given silage.

for both silages, which is above 80% of disappearance rate at 24 h. The GS and CS were similar in rumen degradability of CP and OM. Since GS had a higher CP content, the rumen degradable N (RDN) and the ratio of RDN to apparently digested OM in the rumen (ADOM) were higher in GS than in CS.

The changes in pH value and ammonia-N concentration in the rumen with time after feeding are shown in Fig. 3. There was no large difference in pH value in rumen fluid of sheep fed GS and CS. The ammonia-N concentration was higher in GS than in CS at all sampling times. In sheep fed either silage, rumen ammonia-N concentrations reached to a peak value at 1 h, then declined to the lowest value at 6 h after feeding. The peak concentrations of ammonia-N were 18.8 and 16.0 mg per 100 ml rumen fluid for GS and CS, respectively.

Discussion

The GS and CS used in the present study were consumed by sheep to approximately similar extent, although they were much different from each other in chemical composition and fermentation characteristics, indicating again that the low consumption of silages is unlikely to be explained by only fermentation characteristics^{10,12}.

The GS and CS were different in the PED of CWC and *kd* in the rumen from each other. However, when the PED was multiplied by the *kd*, the product $PED \times kd$, was similar for both silages (Table 2). Moreover, the *LT* and *kp* for GS approximated to that for CS (Table 2). There was little difference in ruminal digestion of CWC between both silages as well as the VI of silage. It suggests that physical factors play an important role in the regulation of silage intake. Many experiments can support this^{3,5,6}. The result that water-filled bags in the rumen depressed silage intake in dry cows⁶ confirms that physical fill of the rumen is important, moreover the fact that chopping silage length at ensiling or before feeding increased the VI⁶ support this.

The ruminal digestion of fibrous materials of roughages is affected by the cellulolytic activity and the synchronized supply of N and energy is considerably important for microbial activity in the rumen^{1,20}. It has been adopted that mean efficiency of microbial N synthesis in the rumen is 32 g/kg ADOM and that the efficiency of conversion of RDN into microbial N is 1.0²¹. Thus the ratio of RDN to ADOM can be a good estimate to the balance of supply of N and energy to the microbes in the rumen. Usually silage contains a large proportion of NPN and is low in the ease-to-use

carbohydrates^{13,18}. The N compounds of silages were highly and rapidly degraded in the rumen (Fig. 2 and Table 3). The estimated ratio of N to energy supply (RDN/ADOM) to ruminal microbes was high in either silage (Table 3) and approximated to the efficiency of microbial N synthesis in the rumen⁹. However, there was a pronounced peak of rumen ammonia-N soon after sheep consumed silage, as shown in Fig. 3. The peak values of ammonia-N were higher than the levels for maximal rate of fermentation to be 13.3 mg/100 ml rumen fluids⁹. The ruminal microbes will be unable to make full use of the temporarily high concentration of ammonia-N, and a large part of ammonia is absorbed, converted to urea and excreted in the urine, as shown previously^{10,11,21}. This may result in a shortage supply of N to the ruminal microbes in later period after a meal, suppress the cellulolytic activity in the rumen and decrease the silage intake. The observation that protein supplements increased the VI of silages^{12,16} supports this.

WALDO *et al.*²² noted the rumen contents were less in heifers or sheep fed silage than on hay. CAMPLING⁹ observed that silage particle stayed in the rumen for longer than those of hays and there was more pseudo-rumination in silage-fed sheep than in those offered hay. It appears that the regulation of VI of silage and hay involved different modes. Further research is needed to clarify the factors influencing the VI of silages from the viewpoint of physical regulation.

Summary

The experiment was purposed to study the correlation between the voluntary intake of silages, ruminal digestion of fibrous materials and the supply of nitrogen (N) and energy sources to the microbes in the rumen of sheep fed grass or corn silage. Fiber digestion and degradation of crude protein and organic matter in the rumen of sheep was determined by using in sacco technique. Both silages were much different from each other in chemical composition and fermentation characteristics. Sheep consumed similar dry matter from each silage. The potential extent of digestion (*PED*) of fiber in the rumen was higher for GS while digestion rate of *PED* (*kd*) was higher for CS. However, the product of *PED* and *kd* (*PED* × *kd*) for both silages was not different from each other. Rate of passage of digesta through the rumen was also similar for both silages. The degradation of CP and OM was high for both silages and there was no difference between GS and CS. The rumen degradable N and the supply of N and energy to ruminal microbes showed higher values, but this was associated with a pronounced peak of rumen ammonia-N concentration. It appears that the

physical factors play an important role in the regulation of silage intake through the digestion of fibrous materials in the rumen.

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