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THE NUTRITIVE VALUES OF GRASS, CORN AND RICE SILAGES FED TO SHEEP AT DIFFERENT LEVELS

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Introduction

Silage is a conserved forage product of major importance, comparable to hay. Grass and corn silages are commonly utilized throughout the world[20,33]. Attention has been recently paid to rice whole crop as a new resource for feed[13,15,19]. Very little is known about the nutritive value and the efficiencies of utilization of nitrogen and energy of rice whole crop silage by ruminants.

An increase in feed intake generally causes a reduction in nutrient digestibility. McDONALD *et al.*[22] have mentioned a decrease of 1-5% unit in digestibility by increasing the feeding level by one unit above maintenance. BLAXTER[5] reported that the apparent digestibility of the energy in long roughage fell on average from 60% to 55% when feed intake was doubled. The extent, however, to which the nutritive value of silages is affected by feeding level keeps less clear when they were fed alone.

This study is purposed: (1) to determine the nutritive value for grass silage (GS), corn silage (CS) and rice whole crop silage (RS), and (2) to assess the effect of the feeding level on the utilization efficiencies of the nutrients.

Materials and Methods

Animals and their management

Animals used were 4 ram lambs and 4 wethers weighing about 40 and 60 kg, respectively. They were individually kept in a metabolism crates. Feeds were offered in two equal meals every day at 09:00 and 17:00 hours. The sheep had ad libitum access to water and mineralized salt block.

Experimental feeds

The GS was prepared from orchardgrass cut at early blooming stage. The grass was allowed to wilt before ensilage, and then ensiled with a precision chop forage harvester in an air-tight silo. The CS was made of whole corn crop cut at a yellow ripe stage in an air-tight silo, and the RS was made of whole rice crop (*cv. Ishikari*) harvested at a yellow ripe stage in a silo made with galvanized iron sheets.

Treatment, and digestion and metabolism trials

The GS was given to the lambs and the CS and RS to the wethers. Each silage was alternatively offered at levels of maintenance (M) and twice maintenance (2M)[2] for a period of 12 days. The fresh amounts offered were 3.0 or 6.0, 3.0 or 6.0 and 2.5 or 5.0 kg for GS, CS and RS at M or 2M feeding level, respectively.

Initial and final weights for 12 days were taken to calculate weight gain.

Feces and urine were collected to determine the digestibility of nutrients, and nitrogen and energy balance for each silage over 5 days (from days 8 to 12). During the collection period of 5 days, daily sample of silage offered were taken and daily residues were removed, weighed and sampled before morning feeding. Feeds, weighback and feces were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber and nitrogen-free extract (NFE) with the methods described by AOAC[3], and neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) by the methods of GEORING and VAN SOEST[16]. Energy value were measured using an adiabatic bomb calorimeter (CA3, Shimadzu Seisakusho Co., Ltd.). Content of nitrogen in urine was analyzed by Kjeldahl method. Urine was added to cellulose powder (CM-Cellulose, Brown Co., Ltd.) and then lyophilized in a $-60°C$ vacuum freezer (MODULYO, Edwards Co., Ltd.) for measuring energy value. The loss of energy as methane (CH_4) was calculated with the equation present by BLAXTER and CLAPPERTON[6]. The metabolizable energy (ME) content of each silage was estimated by substracting the energy losses in urine and methane from digestible energy (DE) content.

Fermentation quality of silage was assessed on both Flieg's index, based on the relative amounts of lactic, acetic and butyric acids in silage[23], and the pH value. The pH value was measured with a pH meter (HM-5A, TOA Electronics Ltd.).

Results

Chemical Composition and Fermentation Characteristics

Table 1 shows chemical composition together with gross energy of silages.

TABLE 1. Chemical composition and gross energy (GE) of the silages

Silage	DM	OM	CP	EE	NFE	Crude fiber	NDF	ADF	ADL	GE
	%				% of DM					MJ/kgDM
Grass	29.4	87.9	11.0	2.9	36.3	37.7	67.7	44.9	6.8	18.2
Corn	30.4	94.5	9.5	4.0	59.7	21.3	43.7	23.9	2.6	18.9
Rice	30.7	86.7	8.3	3.1	44.1	31.2	55.1	40.7	5.6	18.0

All abbreviated notations were shown in the text.

All silages had a similar DM content. Of three silages, the GS had the highest content of CP and of fibrous fraction, and the CS was the highest in OM and NFE, indicative of a great amount of easily available carbohydrate in the rumen. The RS was medium in the fibrous fraction but the lowest in the OM due to high content of silica in the straw. All silage had a similar content of gross energy (GE).

Table 2 presents fermentation characteristics of silages. The GS had the highest pH value in three silages and CS the lowest. Total acid content was very similar among the silages, but the composition of acids significantly differed. The CS showed a dominant concentration of lactic acid with no butyric acid while GS and RS had higher proportion of butyric acid than lactic acid, resulting in a lower Flieg's index.

TABLE 2. Means of pH and organic acid contents of the silages

Silage	pH	Acids (as is basis, %)				Flieg's index
		Total	Lactic	Acetic	Butyric	
Grass	5.2	3.0 (100)[1]	1.2 (40)	0.3 (10)	1.5 (50)	17
Corn	3.8	3.4 (100)	2.8 (82)	0.6 (18)	0.0 (0)	100
Rice	4.6	3.5 (100)	1.0 (29)	1.1 (31)	1.4 (40)	2

1) The figures in the parentheses indicate proportion of each organic acid to the total.

Intake and body weight change

The DM intake of silages and daily gain of sheep are shown in table 3. No sheep was able to completely consume silages offered at 2 M feeding level. The residue of GS was found even at M feeding level. The average DM intake was 761 or 836, 913 or 1207 and 768 or 1301 g/day of a sheep for GS, CS and RS at M or 2 M feeding level, respectively.

TABLE 3. Dry matter intake and daily gain of a sheep given a silage at maintenance (M) or twice maintenance (2M) level

Silage		Grass		Corn		Rice	
Feeding level		M	2M	M	2M	M	2M
DM intake	g/d	761	836	913	1207	768	1301
	$g/kg^{0.75}$	47.0	54.3	42.3	56.9	36.3	59.3
Daily gain	g/d	−218	−129	−49	86	−11	161

No sheep was able to maintain their body weight when fed at M level. At 2 M feeding level, the sheep offered CS or RS had a few body weight gains while those given GS lost their weight.

Digestibility

Table 4 shows the results of digestion trial. There were no significant differences in nutrient digestibilities between the feeding levels. Of three

TABLE 4. Digestibility of nutrients of the silage, given at maintenance (M) or twice maitenance (2M) level

Silage	Grass		Corn		Rice	
Feeding level	M	2M	M	2M	M	2M
Digestibility, %						
DM	50.4±4.2[1)]	48.3±2.6	64.0±1.9	63.0±4.3	49.0±2.0	48.6±3.6
OM	53.6±4.0	51.2±2.7	67.4±2.4	66.1±4.4	55.1±1.4	54.5±3.2
CP	36.4±9.8	35.7±6.6	48.0±6.7	53.4±2.4	44.7±1.8	44.5±3.1
EE	18.4±8.6	19.2±7.2	83.6±3.7	82.5±6.1	67.4±4.9	68.1±1.7
NFE	51.2±1.9	47.9±2.8	75.0±1.5	74.2±4.1	61.4±1.3	58.7±2.8
C. fiber	62.6±5.3	61.4±2.3	51.3±4.3	45.1±8.1	48.9±3.5	49.4±4.4
NDF	52.1±5.3	49.7±3.2	42.7±2.1	40.0±7.3	33.4±1.6	30.3±4.3
ADF	48.1±4.5	44.2±4.2	35.5±1.8	33.2±6.7	28.8±3.1	27.0±5.4

1) Mean±SD

silages, the CS had the highest digestibility of nutrients except for such fibrous fraction as crude fiber, NDF and ADF, which were most digested by sheep on GS. Compared to GS and CS, digestibilities of OM, CP, and NFE for RS were medium and its fibrous fractions were least digested.

Nitrogen Balance

The results of nitrogen balance are shown in table 5. Nitrogen loss in feces was the highest in sheep fed on GS and the lowest on CS irrespective of the feeding level. Urinary nitrogen loss was somewhat higher when silages were fed at M level than at 2 M level, and the highest in sheep fed GS. In terms of the proportion to the intake, nitrogen retained was −19.5 or −12.5%, 16.7 or 28.6% and −4.8 or 10.7% for GS, CS and RS at M or 2 M feeding level, respectively.

TABLE 5. Nitrogen balance of a sheep given a silage at maintenance (M) or twice maintenance (2M) level

Silage	Grass		Corn		Rice	
Feeding level	M	2M	M	2M	M	2M
	g/d					
N. intake	12.8±2.2[1]	14.3±3.8	13.8±0.0	19.9±2.1	10.0±0.2	16.9±1.9
Fecal n.	8.0±0.7	9.1±2.0	7.2±0.9	9.2±0.8	5.6±0.2	9.4±1.1
Urinary n.	7.3±3.3	7.2±3.2	4.3±1.0	4.9±1.1	4.7±1.2	5.8±1.8
N. retention	−2.5±1.5	−1.8±1.4	2.3±1.5	5.7±1.0	−0.3±1.5	1.8±0.9

1) Mean±SD

Energy Balance

Table 6 and table 7 show the results of energy balance.

The intake of energy was reflective of the DM intake (table 6). There was no significant difference in energy balance between the feeding levels (table 7). Of three silages, digestibility and metabolizability of energy were the highest for sheep fed CS and the lowest for those fed GS. The RS had medium energy loss in feces but the lowest in urine. The pooled metabolizability of energy were 35.8, 53.8 and 43.5% for GS, CS and RS, respectively.

Nutritive Value

There were no differences in nutrient digestibility, and nitrogen and energy balance in all of three silages between the feeding levels. The pooled nutritive values of silage are, therefore, summarized in table 8 regardless of the feeding level. The contents of ME and total digestible nutrients (TDN) were the highest for CS and the lowest for GS. The ME content for GS, CS and RS were 6.5, 10.2 and 7.8 MJ/kgDM, respectively. Of three silages, the CS had highest digestible crude protein (DCP) with RS the lowest.

TABLE 6. Energy intake of a silage given at maintenance (M) or twice maintenance (2M) level

Silage	Grass		Corn		Rice	
Feeding level	M	2M	M	2M	M	2M
Energy intake, kJ/kgW$^{0.75}$						
GE[1)]	887±77[2)]	973±259	793±45	1113± 77	649±44	1093±118
DE	426± 8	437±117	518±38	718±103	347±22	579± 32
ME	328±10	334± 86	430±36	600± 96	281±22	473± 20

1) All abbreviated notations were shown in the text.
2) Mean±SD

TABLE 7. Partition of energy ingested by a sheep given a silage at maintenance (M) or twice maintenance (2M) level

Silage	Grass			Corn			Rice		
Feeding level	M	2M	pooled	M	2M	pooled	M	2M	pooled
	%								
DE/GE	48.3	45.0	46.7	64.7	64.3	64.5	53.5	53.6	53.5
ME/GE	37.2	34.3	35.8	53.8	53.8	53.8	43.4	43.5	43.5
ME/DE	76.9	76.5	76.7	83.0	83.6	83.3	81.1	81.2	81.1
CH_4/GE	6.9	6.8	6.9	7.7	7.7	7.7	7.2	7.2	7.2
Ue[1)]/GE	4.2	3.9	4.0	3.3	2.8	3.0	2.9	2.5	2.7

1) Ue indicates the energy lost in urine.

TABLE 8. Nutritive value of the silages

Silage	GE	DE	ME	TDN	DCP
	MJ/kg DM			% of DM	
Grass	18.2	8.4	6.5	46.5	4.0
Corn	18.9	12.4	10.2	67.1	4.8
Rice	18.0	9.6	7.8	49.7	3.5

Discussion

Each silage was offered at M and 2 M feeding levels but no sheep could completely consume the silages given at 2 M feeding level. The DM intakes at 2 M feeding level were 1.1, 1.3 and 1.7 times that of M level for GS, CS and RS, respectively. As a result, there were no differences in the coefficients of digestibility of the nutrients, nitrogen and energy balance, and nutritive value in all of three silages when offered at M and 2 M level. The results for them were, therefore, discussed below regardless of the feeding level.

In the present study, GS was offered to lambs, and CS and RS to wethers. CHURCH[9] has shown that the reticulorumen of lambs has reached its mature size by 8 weeks of age. The lambs used in our study was 11 months old. We considered that the lambs had similar digestive ability to the wethers offered CS and RS.

The results of the present study for digestibilities of nutrients were comparable to those observed in other experiments for CS[1,25] and RS[19,26] but not for GS[11,18,25]. The our result for GS was, however, the same as the grass silage reported by GILL and ENGLAND[17]. Compared with other literature, the GS in our study, as well as that used by GILL and ENGLAND[17], was higher in fibrous fractions and lower in nitrogen content. This could result in a depressed cellulolytic activity of the microbes in the rumen, hence decreased digestion.

Our results show no consistent with the suggestions by VAN SOEST[28]. He suggested that the digestibility of NDF in forages could be calculated from ADL/ADF expressed as logarithm. Using his equation, NDF digestibility could approximately be estimated for GS while overestimated for CS or RS. Two reasons may be considered for CS. On one hand, the CS was low in nitrogen and still more the conversion of nitrogenous compounds to ammonia in the rumen is relatively low, as described by BERGEN *et al.*[4]. This may suppress the cellulose digestion by the ruminal microbes. On the other hand, the content of NFE was 60%, indicative of a great amount of easily available carbohydrate in the rumen. This may decrease fiber digestion in the rumen because many workers have reported that supplementation of fibrous roughages with an easy-to-use substrate depressed the breakdown of fiber[1,24,30]. As far as the RS concerned, it may be owing to a higher content of silica, which has a reverse effect on the digestion of NDF[29]. Those relations suggested by VAN SOEST[28] are unlikely to exist in CS and RS.

The results of nitrogen balance show that the nitrogen lost in urine of sheep fed GS was above 50% of the intake and sheep had a negative nitrogen balance (table 4), indicating much less efficient utilization of nitrogen in GS. This may be related with the high concentration of non-protein nitrogen in grass silage, which result in a relatively high ammonia concentration in the rumen[11,14,21,27], along with the high content of fibrous fraction slowly-degraded by the microbes in the rumen. The CS was low in the nitrogen but had a relatively high content of NFE, indicative of relatively sufficient amount of easy-to-utilize carbohydrates. This was associated with the lowest loss in urine and the highest retention of the nitrogen. As far as RS concerned, nitrogen utilization were inferior to CS but superior to GS. Of three silages, the CS had highest DCP content, although the content of CP was the highest in GS.

There were little difference among the content of GE in three silages but the digestible and metabolizable energy were highest in CS, reflective of the highest digestibility and metabolizability in CS. From the point of view of caloric value, RS is appromaxitely equivalent to 75% of CS or 120% of GS. On the other hand, TDN value of GS was expressed as 100, that was 144 and 107 for CS and RS, respectively.

The feeding value of a feed depends partly on the nutritive value but largely on the voluntary intake by animals. In the present study, all sheep was unable to completely consume any silage given at 2 M feeding level. The residue of GS was found even at M feeding level. All sheep lost their body weight or gained, if any, a little. The results suggest that no one would expect to derive profits from animals given a silage alone.

The voluntary intake of silage have been shown to be lower than that of the same crop fed fresh[10] or after drying[7,12,31]. Low levels of consumption have been variously associated with the fermentation characteristics of silages. WILKINS *et al.*[32] have reported that the voluntary intake of silages was positively correlated with the contents of DM and nitrogen, lactic acid as a percentage of total acids and with the Flieg's index, and negatively the contents of acetic acid. Our results are not consistent with those equations presented by WILKINS *et al.*[32]. All silages had a similar DM content. The GS was the highest in nitrogen and the RS had the highest acetic acid but the lowest lactic acid and Fleig's index. Considering the 2 M feeding level as ad libitum intake level, the voluntary intake of RS was the highest in three silages and GS was the lowest. This suggests that low consumption of silages can not be explained with only fermentation characteristics. CAMPLING[8] has showed the importance of physical factors in limiting the voluntary intake of certain roughage diets by ruminants. Further experiments are required to study the factors affecting the voluntary intake of silage and other roughages.

Summary

This study was carried out to determine the nutritive value for three kinds of silage. Orchardgrass silage (GS) was offered to four lambs, and corn silage (CS) and rice whole crop silage (RS) were to four wethers, respectively.

Each silage was alternatively fed at levels of maintenance (M) and twice maintenance (2 M) to determine consumption of silage, digestibility of nutrients, and nitrogen and energy balance. All sheep did not completely consume any silage given at 2 M feeding level. The residue of GS was found even at M feeding level. The DM intakes at 2 M feeding level were only 1.1, 1.3 and 1.7 times that of M level for GS, CS and RS, respectively. There was no significant difference in digestibility of nutrients and energy balance between the feeding levels. All sheep lost more nitrogen in urine at M feeding level than at 2 M. Of three silages, CS had the highest digestibility of nutrients except such fibrous fractions as crude fiber, NDF and ADF, which were most digested by sheep on GS. Nitrogen retention and caloric value for CS were higher than those for GS or RS. The RS was somewhat superior to GS in digestibility of nutrients, nitrogen retention and caloric value.

Contents of metabolizable energy of GS, CS and RS were 6.5, 10.2 and 7.8 MJ/kgDM, respectively. All sheep were unable to maintain their body weight or gain, if any.

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