NUTRITIONAL QUALITY OF WHOLE CROP CORN FORAGE ENSILED WITH CAGE LAYER MANURE. Ⅱ. *IN SITU* DEGRADABILITY AND FERMENTATION CHARACTERISTICS IN THE RUMEN OF GOATS

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Summary

In situ degradability and fermentation characteristics in the rumen of goats fed whole crop corn forage ensiled with (MS silage) or without (CS silage) 30% of cage layer manure (CLM) were investigated. The two silages were well preserved. To adjust nitrogen intake of CS silage to that of MS silage, the 3rd group of goats was given urea with CS silage at feeding time (US silage). Each goat was given a diet of 2% of the body weight (dry matter basis) daily. *In situ* degradability of dry matter (DM) and crude protein (CP) of MS silage in the rumen were higher than those of CS and US silages. Total potentially degradable portions of DM and CP in MS silage were also higher than those in CS and US silages. Blood urea nitrogen and rumen ammonia nitrogen concentration of goats fed US and MS silages were significantly ($p < 0.05$) higher than those of goats fed CS silage. Acetic, propionic and butyric acids in ruminal fluids of goats fed MS silage were significantly ($p < 0.05$) higher than those of goats fed CS and US silages.

(**Key Words**: Corn Silage, Cage Layer Manure, Digestibility, Ruminal Acid Concentrations, Degradability)

Introduction

The capacity of a silage to promote feeding value depends on the composition of nutrients in the plant, the ability of ruminants to utilize these nutrients and the amount eaten by the animal. In general, whole crop corn silage is an important dietary material for ruminants. Although it contains high energy, crude protein (CP) content is low and the digestibility is also low due to zein. Some essential mineral contents, especially calcium and phosphorus contents are also low for ruminants.

Cage layer manure (CLM) is a waste product of the poultry industry from the environmental point of view and is a good source of dietary crude protein for ruminants, because CLM contains some nitrogenous compounds. Moreover, because of the high cost of feeds and the insufficiency of feed resources, CLM is considered to be a feed additive for ruminants in developing countries. Harmon et al. (1975a, b) reported that fermentation quality and feeding value of whole crop corn forage ensiled with broiler litter were improved in sheep. Whole crop corn ensiled with CLM showed a higher palatability and digestibility in ruminants, which was due to deodorization and aerobic stability by lactic acid fermentation (Spoelstra et al., 1985; Ko & An, 1987, 1988; Ko et al., 1990a,b; Ko et al., 1991). Similar results were obtained in our previous study (Kim et al., 1993) where whole crop corn ensiled with CLM was higher in digestibilities of CP and fiber fraction and in palatability than whole crop corn silage, but the fermentation quality was somewhat deteriorated by the CLM addition.

In the present experiment, *in situ* degradability of dry matter (DM) and CP in the rumen of goats fed whole crop corn forage ensiled with CLM were studied, and discussed the relation of it with ruminal fluid characteristics and blood plasma components.

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Materials and Methods

Whole crop corn silage (CS silage) and whole crop corn ensiled with CLM (MS silage) were prepared as the previous paper (Kim et al., 1993). The CS silage was directly ensiled and the MS silage was ensiled after mixing well with 30 % CLM (based on DM of corn forage). The two silages were well preserved; pH values were 3.78 and 4.85, and lactic acid contents were 9.8 and 3.9% of DM, for CS and MS silages, respectively. Chemical compositions of the two silages are summarized in table 1.

TABLE 1. CHEMICAL COMPOSITIONS OF THE WHOLE CROP CORN ENSILED WITH OR WITHOUT 30% CAGE LAYER MANURE (% OF DM BASIS)

	Cage layer manure[1]	
	−	+
Dry matter (%)	19.7	25.1
Organic matter (% DM)	91.4	86.1
Crude protein (% DM)	6.3	14.2
Neutral detergent fiber(% DM)	62.2	55.1
Acid detergent fiber (% DM)	37.9	33.0
Acid detergent lignin (% DM)	5.1	4.8

[1] −: Whole crop corn ensiled without any additions. +: Whole crop corn ensiled with 30% cage layer manure.

Animal Trials

In addition to MS and CS silages, CS silage supplemented with urea at feeding time was prepared to adjust the nitrogen content to MS silage (US silage). The three kinds of silages were given to 3 goats (Shiba strain Japanese pigmy goats, average body weight 20 kg) in a 3 × 3 Latin square design. The goats were individually reared in a metabolism cage and fed each diet at 2% of the body weight (DM basis) daily. Half of the diet was given at 8 A.M. and the other half at 4 P.M. Water and mineral blocks were accessed freely. The rumen fluid and blood samples were collected on day 13 from a stomach tube and jugular vein, respectively, at 0 hour (just before the feeding in the morning), 0.5, 1, 2, 4 and 8 hours after the morning feeding. After measuring the pH value, the ruminal fluid was filtered through a double cheese cloth and added with a few drops of mercuric chloride to stop further fermentation. Blood plasma was taken by centrifugation of the blood and stored at −15℃ until analysis. Degradabilities of silage samples were measured on day 14 and 15 *in situ* bag technique (Orskov & McDonald, 1979). Nylon bags (11 × 7 cm) with a pore size of 42 μm were placed in the rumen of goats. Each bag contained approximately 3 g of sample which was freeze dried and ground with a mill having 5 mm screen. Five bags were suspended in the rumen of each goats at 8 A.M. on day 14 and removed from the rumen at 3, 6, 12, 24 and 48 hours after incubation. The removed bags were rinsed thoroughly under running tap water and distilled water, and stored at −15℃ until analysis.

Analyses

The pH value of rumen fluid was determined with a glass rod electric pH meter. Ruminal lactic acid concentration was analysed photometrically by the methods of Barnett (1951). Urea nitrogen in blood plasma was determined with a commercial kits (Unikit, Chugai, Tokyo). Volatile fatty acids and ammonia nitrogen of rumen fluids were determined by steam distillation method and molar ratio of VFA was analysed by a gas chromatograph (GC-12A, Shimadzu, Kyoto). The degradabilities of DM and CP were determined from the proportion remaining in the bags after incubation in the rumen. Dry matter was estimated after drying samples at 60℃ for 24 hours. Crude protein was determined with dried samples by Kjeldahl method. The degradation characteristic was determined by fitting the data to the exponential equation of the form: $P = a + b(1 - e^{-ct})$, where P is proportion of DM or CP disappeared at the incubation time t, a is rapidly soluble or degradable fraction, b is slowly degradable fraction, and c is the rate of degradation of fraction b (Orskov & McDonald, 1979). In these calculations non-linear regression analysis procedure of SAS (1985) at Nagoya University Computer Center was used. The other data were subjected to analysis of variance, and statistical significance among treatment means were determined by Student's t test.

Results and Discussion

Time course of disappearance rates of DM and CP from the bags suspended in the rumen are shown in figure 1. Degradability of DM of CS and US silages were similar throughout the incubation time, but significantly lower than that of MS silage. At 0 time of the incubation, DM disappearance rate of MS silage (32.40%) was significantly ($p < 0.05$) higher than those of CS and US silages which were 24.06 and 23.82%, respectively. These differences in the value between CS and US silages and MS silage may be due to quantity of washing loss (water soluble and small particles) in the CI.M. The degradability for 6 hours of incubation was markedly still higher (43.85%) in MS silage. Fujita et al. (1990) indicated that the extent of ruminal DM degradability of orchardgrass silage after 3 and 48 hours of incubation were approximately 30 and 80% respectively. However, DM degradability of the low quality roughage after 72 hours of incubation was reported to be about 50% (Orskov, 1985). The pattern of CP degradability was similar to that observed in DM throughout the incubation time. However, CP degradability was markedly increased to 79.35% in MS silage for the first 3 hours of incubation, while the values were 63.93 and 65.18% in CS and US silages respectively. Crude protein degradability of MS silage was significantly ($p < 0.05$) higher than that of CS and US silages at all incubation times. Fujita et al. (1988) reported that CP degradability of a corn silage was approximately 65-70% for 48 hours of incubation and it was already high at early period of incubation (0 to 9 hour) for a high moisture corn silage. These differences in the disapparance pattern between CS and US silages and MS silage may be due to a consider ably higher content of nitrogenous compounds in the CI.M, because CP degradability of MS silage was markedly higher compared to those of CS and US silages. Urea supplementation to CS silage at feeding increased CP degradability compared to CS silage, but the difference was not significant.

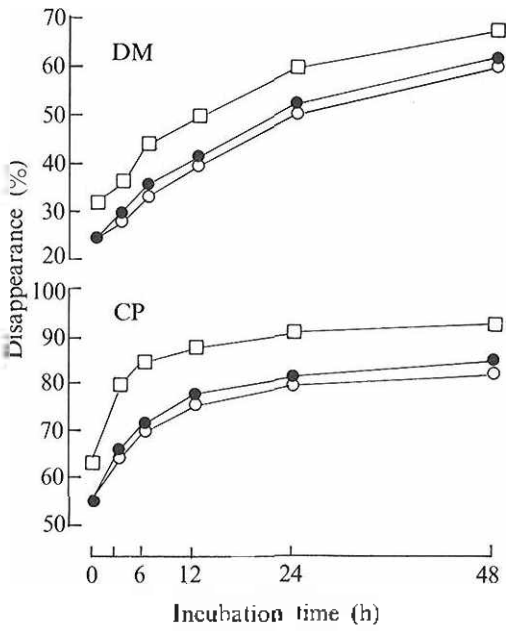

Figure 1. Disappearance of dry matter (DM) and crude protein (CP) of silages in the rumen of goats fed whole crop corn silage (○), urea supplemented whole crop corn silage (●) or whole crop corn ensiled with 30% of cage layer manure (□).

Constants from fitted exponential equation (Orskov & McDonald, 1979) of DM and CP degradability from the bags are shown in table 2. The 'a' is the rapidly degradable fraction or water soluble fraction. The 'b' is the slowly degradable fraction. The 'c' is the degradation rate of the 'b' fraction. It follows that 'a'+'b' value gives an index of the potential digestibility or the potential degradability (Orskov, 1985). The 'a' fraction of DM was significantly ($p < 0.05$) higher in MS silage than in CS and US silages. However, the 'b' fraction was lower in MS silage compared to CS and US silages, although there was no significant difference between these 3 silages. No significant difference was also observed in the 'c' among the three silage. However, 'a' + 'b' fraction in MS silage (70.33%) was significantly ($p < 0.05$) higher than those in CS and US silages which were 65.16 and 66.87% respectively. These differences in the 'a' fraction between CS and US silages and MS silage may be due to water soluble component (water soluble and small particles) in the CI.M. Orskov (1985) reported that higher values of the 'a' + 'b' fraction showed the potential digestibility for the fibrous feeds. In the previous study (Kim et al., 1993), the goats fed MS silage showed higher digestibility of the fibrous material and palatability

TABLE 2. ESTIMATED VALUE OF PARAMETERS OF *IN SITU* DRY MATTER AND CRUDE PROTEIN DEGRADATION OF WHOLE CROP CORN ENSILED WITH OR WITHOUT CAGE LAYER MANURE AND WHOLE CROP CORN SILAGE SUPPLEMENTED WITH UREA AT FEEDING TIME

Parameter[1]	CS[2]	US	MS
Dry matter			
a (%)	23.40[b3]	23.71[b]	31.67[a]
b (%)	41.76	43.16	38.66
c (h^{-1})	0.047	0.040	0.054
a + b (%)	65.16[b]	66.87[b]	70.33[a]
Crude protein			
a (%)	54.21[b]	54.62[b]	63.46[a]
b (%)	27.53	28.74	27.55
c (h^{-1})	0.133[b]	0.141[b]	0.250[a]
a + b (%)	81.74[b]	83.36[b]	91.01[a]

[1] $P = a + b\ (1 - e^{-ct})$, where P: degradability value (%) at the incubation time t and a, b and c are parameters describing the curve.

[2] CS; Whole crop corn silage. US; Urea was supplemented at feeding time to adjust nitrogen content to MS silage. MS; Whole crop corn ensiled with 30% cage layer manure.

[3] Means having different superscripts are significantly different ($p < 0.05$) in the same row.

than those fed the other silages. The higher 'a' +'b' fractions in the present experiment were comparative with the higher values in digestibility and palatability in the previous paper. The pattern of CP losses from the bag was similar to that of DM losses. However, all the parameters of 'a' fraction, 'a'+'b' fraction and 'c' for CP were higher than those of DM. These results may be related to the higher degradability at early incubation times (0 to 0.5 hours) of CP in MS silage as shown in figure 1.

Blood plasma urea nitrogen (BUN) and ruminal ammonia nitrogen (RAN) concentration are shown in figure 2. Concentration of BUN was significantly ($p < 0.05$) higher in goats fed US and MS silages than those fed CS silage for 8 hours after feeding. At 0.5 hours after feeding BUN in goats fed CS silage was increased a little and gradually decreased thereafter. However, BUN of goats fed US and MS silages gradually increased after feeding. These results suggest that the higher crude protein digestibility (Kim et al., 1993) and higher RAN in goats fed US and MS silages could attribute to the continuouly gradual nitrogen degradation after feeding. The concentration of RAN rapidly increased after feeding and the maximum was attained at 2 hours after feeding in the all groups. In the present experiment the higher RAN in goats fed MS silage might be explained from the higher ruminal degradability of the crude protein of feeds in bags during early stage of incubation (figure 1). However, the highest RAN in goats fed US silage may be related to the supplementation of urea at feeding time. In all the groups the concentration of RAN was higher than 5 mg/100 ml of ruminal fluid regardless of the silages. Satter and Slyter (1974) reported that optimum RAN concentration for maximum microbial protein synthesis was more than this level. Leng (1989) and Mehrez et al. (1977) however suggested that RAN concentration as high as 20 mg/100 ml was a requisite for the maximum intake of rations and their digestibility. Generally, ammonia toxicity symptoms appear when ruminal and blood plasma ammonia concentrations were more than 176 and 1.0 mg/100 ml, respectively. Caswell et al. (1978) reported that BUN and RAN concentrations were normal in sheep fed a silage ensiled with broiler litter. In the provious paper (Kim et al., 1993), digestibility and voluntary feed intake of US and MS silages were higher than those of CS silage. These results were accompanied with higher levels of RAN and BUN concentrations in this experiment. Although maximum RAN concentrations were 50.3 and 39.6 mg/100 ml in US and MS silages, respectively, symptoms of ammonia toxicity were not observed.

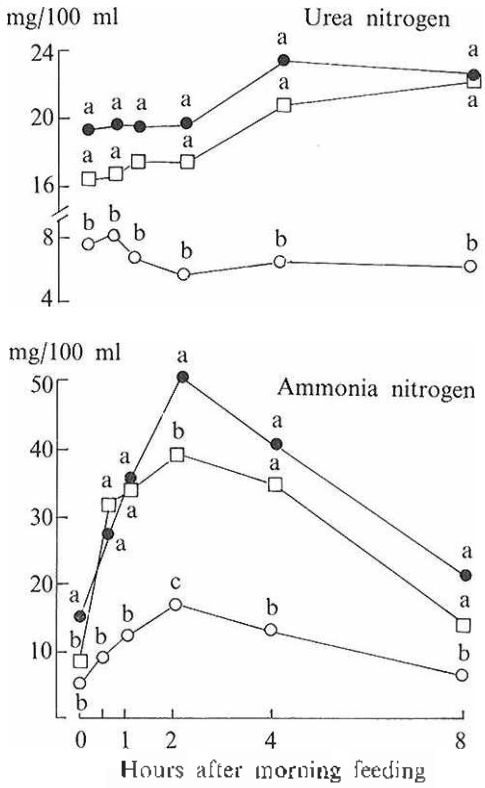

Figure 2. Time course of urea nitrogen in blood plasma and ammonia nitrogen concentration of goats fed whole crop corn silage (○), urea supplemented whole crop corn silage (●) or whole crop corn ensiled with 30% of cage layer manure (□). The data shows means of 3 goats. Different letters in the same hour are statistically different at 5% level of probability.

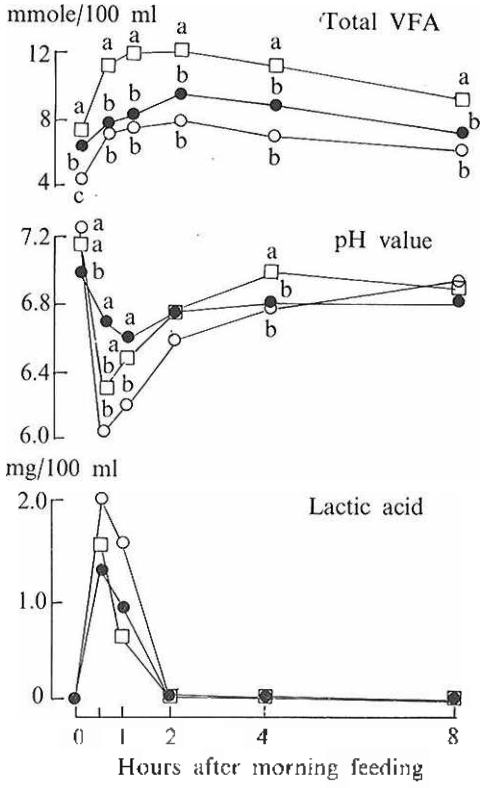

Figure 3. Time course of ruminal total VFA, pH and lactic acid concentration of goats fed whole crop corn silage (○), urea supplemented whole crop corn silage (●) or whole crop corn ensiled with 30% cage layer manure (□). The data shows means of 3 goats. Different letters in the same hour are statistically different at 5% level of probability.

Time course of ruminal total VFA, pH and lactic acid concentrations are shown in figure 3. Total VFA concentration in the rumen fluid of goats fed MS silage significantly ($p < 0.05$) increased after feeding. The maximum was obtained at 1 to 2 hours after feeding and the concentration was gradually decreased thereafter irrespective of the diets. However, changes in CS and US silages were small. The pH value of the ruminal fluid of goats fed CS and MS silages was drastically decreased at 0.5 hours after feeding. This result is comparable to Ohshima et al. (1991) that ruminal pH was drastically reduced just after feeding a silage containing higher content of lactic acid, and was synchronized with a high lactic acid concentration in the rumen fluid at 0.5 hours after feeding in this experiment. Ruminal lactic acid concentration reached a maximum of 2.09, 1.35 and 1.57 mg/100 ml at 0.5 hours after feeding in CS, US and MS silages respectively, and was drastically reduced to almost zero at 2 hours after feeding. Similar results were reported in the case of hays and silages prepared from Italian ryegrass and its pressed cake (Ohshima et al., 1991). Although lactic acid content of MS silage was low, ruminal lactic acid concentration was almost the same as the other silages. These results suggest that CLM in the silage has a productive effect on the ruminal lactic acid in goats. The little change in the ruminal

pH of goats fed US silage suggests that rumen contents was neutralized with ammonia derived from urea.

Time course of ruminal acetic, propionic and butyric acid concentrations are shown in figure 4. The ruminal acetic acid concentration of goats fed MS silage was significantly ($p < 0.05$) increased by feeding and the maximum was shown at 2 hours after feeding. However, the maximum value was obtained at 0.5 hours after feeding of CS silage. Ruminal propionic acid concentration was also higher in MS silage than in CS and US silages for 8 hours after feeding. Irrespective of the diets the maximum concentration was obtained at 2 hours after feeding and gradually decreased. Ruminal propionic acid was produced from lactic acid in the rumen (Russell and Hespell, 1981 and Gill et al., 1986), and could be also derived from the remaining WSC in silages after feeding. In the present experiment, however, ruminal lactic acid concentrations were similar in the three groups and WSC content of CS silage (2.06% of DM) was higher than that of US and MS silages (1.29% of DM). These results suggest that CLM had an effect on the production of propionic acid in the rumen. The ruminal butyric acid concentration was also significantly ($p < 0.05$) higher in MS silage than in CS and US silages. The concentration in goats fed MS silage increased rapidly and the maximum value (1.57 mmol/100 ml) was shown at 0.5 hours after feeding, while it was obtained at 2 hours after feeding in the case of CS and US silages. The higher ruminal butyric acid concentration of goats fed MS silage could be explained by high butyric acid content of the silage (2.47% of DM, Kim et al., 1993).

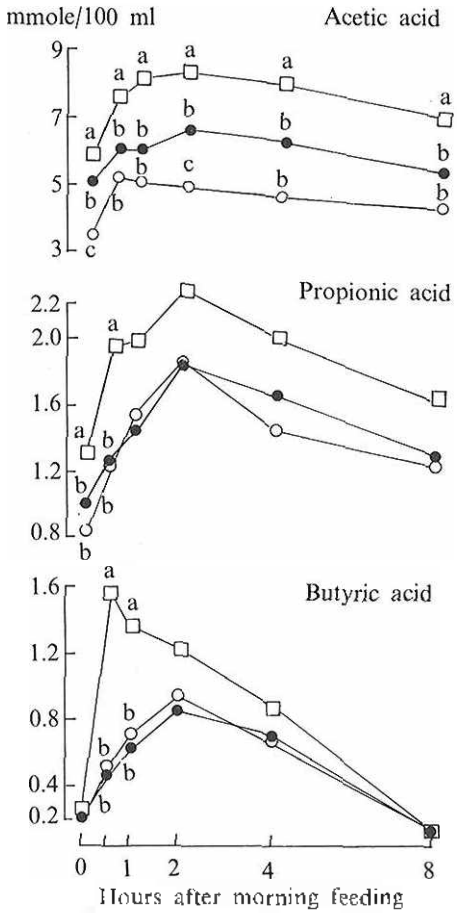

Figure 4. Time course of ruminal acetic, propionic and butyric acids concentration of goats fed whole crop corn silage (○), urea supplemented whole crop corn silage (●) or whole crop corn ensiled with 30% of cage layer manure (□). The data shows means of 3 goats. Different letters in the same hour are statistically different at 5% level of probability.

Whole crop corn forage ensiled with CLM had a definite effect on the fermentation characteristics and DM and CP degradabilities in the rumen. In the future, further investigation should be made on the relationship between the ruminal degradation characteristics and rumen microbial populations in goats fed CLM containing silage.

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