NUTRITIONAL QUALITY OF WHOLE CROP CORN FORAGE ENSILED WITH CAGE LAYER MANURE. I. QUALITY, VOLUNTARY FEED INTAKE AND DIGESTIBILITY OF THE SILAGES IN GOATS

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Summary

With the purpose to utilize cage layer manure (CLM), whole crop corn forage was ensiled with 30% CLM (MS silage) and without CLM (CS silage). MS silage was significantly ($p < 0.05$) higher in pH value, total VFA, propionic and butyric acids, and the ratio of ammonia nitrogen to total nitrogen, but lower ($p < 0.05$) in lactic acid and water soluble carbohydrate (WSC) contents than CS silage. Digestibility was evaluated using Shiba strain Japanese goats. Urea was supplemented to CS silage at feeding to adjust nitrogen intake to MS silage (US silage). There were no differences in digestibilities of dry matter (DM) and energy among the three silages. However, US silage showed higher ($p < 0.05$) digestibility of crude protein, but digestibilities of NDF, ADF, hemicellulose and cellulose were higher ($p < 0.05$) in MS silage. Nitrogen retention was positive in US and MS silages, but it was negative in CS silage. Voluntary feed intake of goats was 11.02, 12.03 and 13.34 g of DM per metabolic body weight ($kg^{0.75}$) for 10 minutes, for CS, US and MS silages, respectively.
(**Key Words**: Corn Silage, Cage Layer Manure, Digestibility, Nitrogen Retention, Voluntary Feed Intake)

Introduction

The use of whole crop corn forage as a feed for livestock is gradually becoming popular in many countries. At present, it is mostly used as silage. However, crude protein content of corn forage is low and the digestibility is also low due to zein. Some essential mineral contents, especially calcium and phosphorus are also low. On the other hand, cage layer manure (CLM) has been known to be a good source of dietary crude protein to ruminants. Therefore, some authors have shown that whole crop corn forage ensiled with CLM can be utilized as a useful feed to ruminants. In practice, supplementation of CLM enhanced the crude protein and mineral contents of the whole crop corn silage (D'Uros et al., 1979; Gouet & Girardeau, 1980; Buchanan-Smith et al., 1982; Martin et al., 1983; Spoelstra et al., 1985a,b; Ko & An, 1987, 1988; Ko et al., 1990a, b; Ko et al., 1991). Also digestibility and palatability of CLM containing silage were improved (Spoelstra et al., 1985b; Ko & An, 1988; Ko et al., 1990a). Besides, utilization of CLM for a feed additive to ruminants might offer other advantages, such as decrease of environmental pollution by CLM. Furthermore, in the case of the utilization of the excessive manure for cultivated land, negative effects were shown on soil fertility (Spoelstra et al., 1985a).

Generally the microbial activity increases temperature, pH, protein degradation in silages and loss of their feeding value (Spoelstra et al., 1985a). Whole crop corn ensiled with CLM, however, inhibits aerobic deterioration after opening a silo due to lower heat production. Ensiling of CLM may be an economical means of eliminating potential hazards from the possible presence of pathogenic organisms in it (Harmon et al., 1975a; Ko & An, 1987; Ko et al., 1990 a,b; Ko et al., 1991). Despite these advantages there is only a few literatures on feeding of whole crop corn ensiled with CLM for ruminants.

From these points of view, the present experiment was conducted to study the fermentation

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characteristics, digestibility and palatability of whole crop corn forage ensiled with CLM.

Materials and Methods

Preparation of silages

Whole crop corn forage was cultivated at the farm of Nagoya University, harvested at dough-stage on August 7th, 1991, cut into 0.9 cm in length with a forage cutter. The cage layer manure used in this study was collected from a local poultry house and dried by the sunlight to attain more than 80% of dry matter content, and feather and foreign substances in the CLM were removed. Before supplementation to corn forage, the CLM was ground to less than 1 mm through a wiley mill. One group of the corn forage was directly packed (CS silage) in plastic bags (625 mm in width, 800 mm in height and 0.06 mm in thickness). The other group of the corn forage was well mixed with 30% CLM (based on dry matter of corn forage) and packed (MS silage). The weight of the silages in a bag was 15 kg each. After removing air with a vacuum pump the upside of the bag was tied with a string and stored in a dark room at an ambient temperature. The silages were opened at 3 months after preparation and fed to goats for animal trials.

Animal trials

To adjust a nitrogen content to MS silage, urea was supplemented to CS silage at feeding time (US silage). Three kinds of silages were given to 3 goats (Shiba strain Japanese pigmy goats, average body weight 20 kg) by a 3 × 3 Latin square design. The goats were individually reared in metabolism cages and fed a diet daily at 2% of the body weight in dry matter basis. Half of the ration was given at 8 A.M. and the other half at 4 P.M. Water and mineral blocks were freely accessed. Each metabolism trial consisted of a 10 days preliminary period and following 5 days collection period for total feces and urine. Feces and urine were collected just before the morning ration and the collected feces was dried with a draft oven for 2 days at 60℃. After all the metabolism trials, palatability was estimated. Voluntary food intake was measured in 10 minutes each at 8 A.M., 1 P.M. and 6 P.M. for 3 days; 3 determinations were made by a 3 × 3 Latin square design. More than 90% of daily requirement of dry matter was consumed in 30 minutes (10 minutes × 3) each day. After measurements at 6 P.M., total amounts of intake were calculated for the day and the deficient dry matter were individually given to the goat.

Analyses

Dry matter content of silages was analysed by the toluene distillation method (Dewar & McDonald, 1961). Silage quality was estimated with the cold water extract. The pH values were determined with a glass rod electric pH meter. Lactic acid was analysed photometrically by the method of Barnett (1951). Volatile fatty acids and ammonia nitrogen were determined by steam distillation method and molar ratio of VFA was analysed by a gas chromatograph (GC-12A, Shimadzu, Kyoto) equipped with flame ionization detector and fitted with a 1.5 × 3 mm glass column packed with 25% FAL-M on 80 to 100 mesh Chromosorb W. The oven, injector and detector temperatures were 145, 200 and 200℃, respectively. Chemical compositions of silages were analysed on freeze dried samples. Nitrogen was determined by Kjeldahl method on fresh silages. Analyses of NDF and ADF were done by the methods of Van Soest and Wine (1967), and Van Soest (1963), respectively. Hemicellulose and cellulose were calculated by (NDF-ADF) and (ADF-Acid detergent lignin), respectively. Water soluble cabohydrate (WSC) in silages were analysed by the anthrone method of Yemn and Willis (1954). Gross energy contents in the silage and feces were analysed with a bomb calorimeter (CA-3, Shimadzu, Kyoto).

Statistical analysis

The data were subjected to analysis of variance, and statistical significance among treatment means was determined by Student's t test.

Results and Discussion

The chemical composition of the whole crop corn forage and CLM are shown in table 1. Crude protein content of CLM was 32.8% which was somewhat higher than that of CLM reported previously (Spoelstra et al., 1985a; Ko & An, 1987; Ko et al., 1990b). Although whole crop corn forage had a high gross energy value

TABLE 1. CHEMICAL COMPOSITION OF THE WHOLE CROP CORN AND CAGE LAYER MANURE

	Whole crop corn forage	Cage layer manure
Dry matter (%)	21.86	84.30
Organic matter (% DM)	92.28	76.15
Crude protein (% DM)	5.84	32.77
Neutral detergent fiber (% DM)	58.01	39.27
Acid detergent fiber (% DM)	33.43	20.92
Acid detergent lignin (% DM)	4.12	3.75
Silica (% DM)	1.89	0.01
Hemicellulose (% DM)	24.58	18.35
Cellulose (% DM)	29.32	17.17
Water soluble carbohydrate (% DM)	23.45	
Gross energy (Mcal/kg DM)	4.26	3.29

(4.26 Mcal/kg), its drawback was low crude protein content (5.84%). Neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose and cellulose contents of CLM were lower than those of whole crop corn forage. Whole crop corn forage contained 23.5% of WSC.

The chemical quality of silages is shown in table 2. Dry matter content of silages was significantly ($p < 0.05$) increased by CLM addition, which increased ($p < 0.05$) pH value of the silage from 3.78 to 4.85. Spoelstra et al. (1985a, b) and Ko et al. (1990b) reported that 20% CLM or 30% broiler manure addition increased pH value of the silages from 3.9 to 4.2, and from 3.82 to 4.49, respectively. In the present experiment pH value of MS silage was higher (4.85) than their results. Lactic acid content was decreased to 3.90% with CLM addition compared to 9.78% of CS silage. Ohshima and Oouchi (1979) reported that the low pH value in silages was derived from

TABLE 2. CHEMICAL QUALITY OF THE WHOLE CROP CORN ENSILED WITH OR WITHOUT 30% CAGE LAYER MANURE (DM BASIS)

	CS[2]	MS
Dry matter (%)	$19.71^{b} \pm 0.18$[1]	25.05^{a}[3] ± 0.21
pH	$3.78^{b} + 0.03$	$4.85^{a} \pm 0.02$
Lactic acid (% DM)	$9.78^{a} \pm 1.16$	$3.90^{b} \pm 0.79$
Total VFA (% DM)	$3.20^{b} \pm 0.14$	$5.94^{a} \pm 0.24$
Acetic acid (% DM)	3.14 ± 0.13	3.23 ± 0.18
Propionic acid (% DM)	$0.04^{b} \pm 0.01$	$0.15^{a} \pm 0.02$
i-Butyric acid (% DM)	Trace	0.03 ± 0.01
n-Butyric acid (% DM)	$0.02^{b} \pm 0.00$	$2.44^{a} \pm 0.32$
i-Valeric acid (% DM)	–	0.06 ± 0.02
n Valeric acid (% DM)	–	0.03 ± 0.01
Total acids (% DM)	12.98 ± 1.13	9.84 ± 0.85
Lactic acid/Total acid (%)	$74.89^{a} \pm 2.41$	$38.90^{b} \pm 4.87$
Water soluble carbohydrate (% DM)	$2.06^{a} + 0.01$	$1.29^{b} + 0.03$
NH_3-N/Total N (%)	$8.23^{b} \pm 0.46$	$18.78^{a} \pm 0.69$

[1] Mean $\pm$ S.E. (n = 3).

[2] CS: Whole crop corn 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.

removal of buffering activity by pressing out the juice in original materials before ensiling, even if lactic acid formation in the silage was little. On the other hand high pH value of MS silage in the present experiment may be related to the buffering activity of the CLM, which contains much calcium and phosphorus. Total VFA content was increased from 3.20 to 5.94% by CLM addition. In particular, CLM addition increased propionic and butyric acid from 0.04 to 0.15% and 0.02 to 2.44%, respectively. And valeric acid appeared in MS silage but not in CS silage. Johnson and McClure (1968) reported that lactic acid content was higher when moisture content of corn silage was higher. Ko et al. (1987) reported that lactic acid content of corn silage was decreased with increasing levels of broiler manure addition. In the present experiment, CLM addition increased acetic, propionic and butyric acid contents, but decreased lactic acid content. High crude protein and low WSC in CLM resulted in the delay of the increase of lactic acid bacteria against butyric acid bacteria and probably increased acetic, propionic and butyric acid contents in MS silage. The ratio of lactic acid content to total acid content and the WSC content of MS silage decreased from 74.9 to 38.9% and from 2.1 to 1.3%, respectively. However, the ratio of ammonia nitrogen to total nitrogen was increased (18.8%) by CLM addition compared to CS silage (8.2%). Harmon et al. (1975a) reported that the organic acid contents and the ratio of ammonia nitrogen to total nitrogen were increased in the CLM added silages.

The chemical composition of silages is shown in table 3. Organic matter content (91.42%) was higher ($p < 0.05$) in CS silage compared to MS silage (86.08%), because CLM contained 23.85% crude ash. Crude protein content in MS silage was 14.24% while CS silage was 6.33%. However, NDF, ADF, hemicellulose, cellulose and gross energy contents were lower in MS silage ($p < 0.05$).

The digestibility of some nutrients and nitrogen balance in feeding trials are shown in table 4. Organic matter and DM digestibilities were higher in MS silage than in CS and US silages. Crude protein digestibilities of CS, US and MS silages were 52.12, 78.21 and 68.51%, respectively. These digestibilities were almost the same to the values reported for the urea or broiler manure supplemented silages (Ko & An, 1988). Harmon et al. (1975b), however, reported that crude protein digestibility of the silage containing 30% of broiler litter was similar to that of the urea supplemented silage. Digestibilities of NDF, ADF, hemicellulose and cellulose were significantly ($p < 0.05$) improved in MS silage, but urea addition had not a consistent effect. On the other hand, digestibilities of acid detergent lignin (ADL) and energy were

TABLE 3. CHEMICAL COMPOSITION OF THE WHOLE CROP CORN ENSILED WITH OR WITHOUT 30% CAGE LAYER MANURE (DM BASIS)

	CS[2]	MS
Dry matter (%)	$19.71^{b} \pm 0.18$[1]	$25.05^{a3} \pm 0.21$
Organic matter (%)	$91.42^{a} \pm 0.28$	$86.08^{b} \pm 0.07$
Crude protein (% DM)	$6.33^{b} \pm 0.09$	$14.24^{a} \pm 0.17$
Neutral detergent fiber (% DM)	$62.19^{a} \pm 0.52$	$55.14^{b} \pm 0.22$
Acid detergent fiber (% DM)	$37.86^{a} \pm 0.28$	$32.97^{b} \pm 0.67$
Acid detergent lignin (% DM)	5.08 ± 0.12	4.84 ± 0.10
Silica (% DM)	2.54 ± 0.15	2.11 ± 0.11
Hemicellulose (% DM)	$24.34^{a} \pm 0.34$	$22.17^{b} \pm 0.47$
Cellulose (% DM)	$32.79^{a} \pm 0.21$	$28.13^{b} \pm 0.59$
Gross energy (Mcal/kg DM)	$4.50^{a} \pm 0.03$	$4.31^{b} \pm 0.03$

[1] Mean ± S.E. (n = 3).
[2] CS: Whole crop corn 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.

TABLE 4. DIGESTIBILITY OF SOME NUTRIENTS AND NITROGEN BALANCE OF GOATS FED WHOLE CROP CORN ENSILED WITH OR WITHOUT CAGE LAYER MANURE AND WHOLE CROP CORN SILAGE WITH UREA

	CS[2]	US	MS
Apparent digestibility (%)			
Dry matter	57.20 ± 1.37[1]	57.18 ± 0.95	58.90 ± 0.68
Organic matter	58.15 ± 1.37	58.18 ± 0.89	60.08 ± 0.68
Crude protein	52.12[c4] ± 2.62	78.21[a] ± 1.69	68.51[b] ± 0.71
Neutral detergent fiber	54.58[b] ± 0.86	54.76[b] ± 0.58	58.39[a] ± 0.88
Acid detergent fiber	56.68[b] ± 0.71	56.56[b] ± 0.74	59.30[a] ± 0.62
Acid detergent lignin	28.91 ± 0.09	26.81 ± 1.96	22.40 ± 2.34
Hemicellulose	51.23[b] ± 1.68	51.94[b] ± 0.37	57.61[a] ± 1.33
Cellulose	60.99[b] ± 1.52	61.18[b] ± 0.83	65.68[a] ± 0.66
Energy	59.81 ± 1.24	61.09 ± 1.90	60.17 ± 0.64
Nitrogen balance (g/day)			
Intaked nitrogen	4.18[b] ± 0.36	8.97[a] ± 0.91	9.56[a] ± 0.46
Fecal nitrogen	1.98[b] ± 0.11	1.93[b] ± 0.12	3.01[a] ± 0.12
Urinary nitrogen	2.21[b] ± 0.13	6.13[a] ± 0.82	6.11[a] ± 0.57
Retained nitrogen	−0.01 ± 0.33	0.91 ± 0.14	0.55 ± 0.29
RN/IN[3] (%)	−1.51 ± 8.78	10.28 ± 1.94	5.94 ± 3.10
Body weight gain (g/day)	−40.00 ± 34.64	13.33 ± 17.64	33.33 ± 29.06

[1] Mean ± S.E. (n = 3).

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

[3] Retained nitrogen/Intake nitrogen.

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

similar in all the silages. Ko and An (1988) reported that nitrogen free extract (NFE) digestibility was significantly improved by adding broiler manure to corn silage, but 0.65% urea addition tended to decrease the digestibility. This could be due to digestibility of the fiber material of silages which was enhanced by microorganism propagation by adding of CLM. Nitrogen intake was greater in goats fed MS or US silages than in goats fed CS silage. Fecal nitrogen was significantly ($p < .05$) higher in MS silage than CS and US silages. Urinary nitrogen was higher in US and MS silages ($p < 0.05$) than in CS silage. Retained nitrogen in CS silage was negative, but positive in US and MS silages, though differences were not significant. No data were available on the nitrogen balance of the goats fed silages ensiled with CLM. However, Harmon et al. (1975b) reported that sheep fed a broiler litter containing corn silage showed a greater nitrogen retention than those fed a corn silage or a urea supplemented silage. These results suggest that ammonia formed in the rumen of sheep fed a urea supplemented silage was not utilized efficiently because the rate of production of ammonia was higher than that of microbial utilization of it. Average daily gain (33 g/day) was highest in MS silage, while goats fed CS silage lost 40 g of their body weight per day. These results may be related to a lower digestibility of crude protein and the negative nitrogen retention in CS silage.

The results on the voluntary feed intake trial are shown in table 5. Total DM intake in 30 minutes each day for MS silage was significantly ($p < 0.05$) higher than US and CS silages. Dry matter intake per body weight and DM intake per metabolic body weight were also in the same tendency with total DM intake. Ko and An (1988) reported that voluntary feed intake of a broiler manure containing silage was increased with an increase of additional levels of it, while the opposite result was shown in the case of urea supplementation by sheep. Harmon et al. (1975b) reported a similar finding with urea and broiler

TABLE 5. VOLUNTARY FEED INTAKE OF GOATS GIVEN WHOLE CROP CORN ENSILED WITH OR WITHOUT CAGE LAYER MANURE AND UREA SUPPLEMENTED WHOLE CROP CORN SILAGE IN 10 MINUTES

	CS[2]	US	MS
Dry matter intake (g)	$98.49^{b} \pm 4.69$[1]	$108.37^{ab} \pm 3.49$	$120.80^{a3} \pm 3.07$
Intake (g)/BW (kg)	$5.33^{b} \pm 0.26$	$5.80^{ab} \pm 0.23$	$6.42^{a} \pm 0.18$
Intake/$BW^{0.75}$ (g)	$11.02^{b} \pm 0.50$	$12.03^{ab} \pm 0.44$	$13.34^{a} \pm 0.35$
Intake/2% of BW (%)	$26.20^{b} \pm 1.46$	$28.53^{ab} \pm 1.11$	$31.60^{a} \pm 0.97$

[1] Mean ± S.E. (n = 9).

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

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

litter additions to corn forage. The increase in voluntary feed intake for MS silage may be also related to the density, which was higher in MS silage than CS and US silages.

This experiment showed that cage layer manure was an excellent source of crude protein and fermentation quality of the CLM containing silage was not so bad; lactic acid was enough for preservation of the silage, although pH value and butyric acid contents were high. Digestibility and voluntary feed intake of CLM containing silage by goats were also high. However, further experiments are required to establish the best method for preparing a corn silage with poultry manure in order to increase ruminant production.

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