Effects of Whole Crop Corn Ensiled With Cage Layer Manure on Nutritional Quality and Microbial Protein Synthesis in Sheep

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ABSTRACT : An experiment was conducted to study the nutritional quality of whole crop corn silage ensiled with cage layer manure in sheep. Treatments were designed as a 3×3 Latin square with 16-day periods. Sheep were allotted in one of three diet-treatments, which were whole crop corn silage (CS), whole crop corn+30% cage layer manure (CLM) silage (based on DM; MS) and rice straw+concentrate (SC) mixed at 8:2 ratio (on DM basis). Silage ensiled with CLM significantly increased ($p<0.05$) digestibilities of crude protein, NDF and ADF, TDN over the other treatments. Ruminal pH in sheep fed SC was significantly ($p<0.05$) higher than that of the other diets at 0.5, 1, 2, 4 and 8 h after feeding. Ruminal ammonia nitrogen concentration of the MS treatment was significantly ($p<0.05$) higher than that of the other treatments at 0, 1, 2 h after feeding. The MS treatment highly increased ($p<0.05$) feed intake, digestibility of organic matter and crude protein, nitrogen intake and retained nitrogen. The MS treatment highly increased ($p<0.05$) purine derivative (PD) excretion leading to higher microbial protein synthesis. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 11 : 1548-1553)*

Key Words : Corn Manure Silage, Cage Layer Manure, Feed Intake, Microbial Protein Synthesis

INTRODUCTION

The capacity of 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 diet for ruminants. Although it contains high energy, crude protein (CP) content is low and the digestibility is also low due to zein. Some essential minerals, 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 is high in crude protein and mineral contents (Bhattacharya and Fontenot, 1965). Its chemical composition, especially the crude protein content, makes poultry manure a potentially valuable material to ensile with corn forage. Although the major harzard areas associated to feeding of animal waste such as pathogenic organisms, heavy metals, pesticides and drug residues have been identified (McCaskey et al., 1985), processing of broiler litter or CLM before its use as an animal feed, destroys pathogens and may enhance the preservation quality and palatability. Ensiling poultry manure with corn forage (Chaudhry et al., 1993) and sorghum (Al-Rokayan et al., 1998) has shown a promising effect in eliminating pathogen. 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 (Spoelstra et al., 1985; Kim et al., 1993a). Therefore, it has been shown that whole crop corn forage ensiled with CLM can be a useful feed to ruminants.

The overall objective of the experiment reported here was to study the nutritional quality of whole crop corn silage ensiled with layer manure and to estimate microbial synthesis in the rumen of sheep fed the silage ensiled with manure.

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MATERIALS AND METHODS

Animals and their management

Three healthy mature Corriedale sheep were used in the experiment. Average body weights of the animals were approximately 53.7 kg at the start of the experiment. They were individually reared in metabolism cages and fed a diet daily at 2% of the body weight in dry matter basis. Food was given in two equal meals at 08:00 and 17:00. Water and mineral blocks were freely accessed.

Experimental design and treatments

Three animals were used in a 3×3 Latin square with 3 periods. Sheep were allocated in one of three diet-treatments, which were whole crop corn silage (CS), whole crop corn+30% CLM silage (based on DM; MS) and rice strw+concentrate (SC) mixed at 8:2 ratio (on DM basis). The chemical composition of the experimental diets is shown in table 1. The dry matter and the concentration of crude protein for SC, CS and MS were 883, 292, 327 (g/kg) and 147, 75, 146 (g/kg

DM) respectively.

Whole crop corn forage was cultivated at a local farm located in Sanchung, Korea, harvested at dough stage on August 1998, cut into 2 to 3 cm in length with a forage cutter. The cage layer manure used in the study was collected from a local poultry farm 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 ensiled in an experimental trench silo of a ton capacity. Another group of the corn forage was well mixed with 30% CLM (based on DM of corn forage) and ensiled in an experimental trench silo of a ton capacity. The silages were opened in 3 months after preparation and fed to the animals for the experiment.

Experimental procedure

Each metabolism trial consisted of a 10 day preliminary period and a 5 day collection period for total feces and urine, which were collected just before the morning ration. The complete output of urine was collected into 15 ml of 4 M H_2SO_4. The rumen fluid samples were collected on day 15 from a stomach tube at 0 h (just before the feeding in the morning), 0.5, 1, 2, 4 and 8 h after the morning feeding. The ruminal fluid was filtered through a double cheese cloth and the pH value was measured. After addition of a few drops of mercuric chloride to stop further fermentation, the ruminal fluid was stored at -20℃ until analysis. After all the metabolism trials, palatability was estimated. Voluntary food intake (palatability) was measured in 15 minutes each at 09:00, 12:00 and 15:00 for 3 days. After measurement at 15:00, total amounts of intake were calculated for the day.

Table 1. The chemical composition (g/kg DM unless stated otherwise) of experimental diets

	Treatments[1]		
	SC	CS	MS[2]
Dry matter (g/kg)[3]	883.8	292.4	327.1
Organic matter	916.5	862.6	886.2
Crude protein	146.8	75.3	145.7
Crude fiber	233.5	165.5	155.2
Neutral detergent fiber	542.1	471.6	393.9
Acid detergent fiber	353.3	300.6	249.9
Nitrogen-free extract	511.3	451.0	539.5

[1] SC: Straw+Concentrate; CS: Whole crop corn silage; MS: Whole crop corn silage ensiled with CLM.

[2] MS: Whole crop corn ensiled with 30% cage layer manure (DM basis).

[3] Dry matter of CS and MS silages was measured by toluene distillation.

Chemical analysis

Feed and fecal samples were dried in a forced-air oven at 60℃, ground to pass a l-mm screen, and analyzed for DM, organic matter (OM) and nitrogen (N) (AOAC, 1990). Silage dry matter was determined by toluene distillation (Dewar and McDonald, 1961). Analyses of NDF and ADF were done by the methods of Van Soest and Wine (1967), and Van Soest (1963), respectively. Ruminal ammonia N was analyzed by colorimetry method (Chaney and Marbach, 1962) and total volatile fatty acids (VFA) were determined by steam distillation method (Fenner and Elliot, 1963). Total purine derivatives (PD) in urine were determined, as allantoin, by the method of Borchers (1977). Xanthine, hypoxanthine and uric acid were converted to allantoin using the enzymic procedure by Fujihara et al. (1987). The supply of microbial nitrogen to the small intestine was calculated from the urinary output of PD using the equation of Susmel et al. (1994a).

Statistical analysis

The data were subjected to analysis of variance and statistical significance among treatment means was determined by Duncan's multiple range test using GLM (general linear model) procedures of SAS (1990).

RESULTS and DISSCUSION

Digestibilities of DM and OM were increased ($p<0.05$) in sheep fed CS and MS compared with the rice straw-based diet, whilst MS did not increase the digestibilities over the CS treatment (table 2). Digestibility of CP in the MS treatment was higher ($p<0.05$) by up to 10 and 6% relative to the SC and CS treatments respectively. Digestibilities of DM, OM and CP for MS silage in the experiment were very similar to the values reported for the silages supplemented with broiler litter or cage layer manure (Kim et al., 1993a; Ko and An, 1988). However, it seems unlikely that corn silage ensiled with manure improves the digestibilities of DM and OM compared with untreated corn silage. Feeding corn silages ensiled with or without CLM highly increased ($p<0.05$) crude fiber digestibility compared with feeding straw but the digestibility of crude fiber for both silage treatments were not different from each other. The MS treatment increased ($p<0.05$) digestibility of NDF by 15% over the SC treatment and the digestibility of ADF in sheep fed MS silage was much higher (46% increase; $p<0.05$) than CS silage. Digestibilities of nitrogen-free extract (NFE) and total digestible nutrients (TDN) were significantly improved ($p<0.05$) by MS silage. Ko and An (1988) reported that NFE digestibility was significantly improved by supplementation of broiler manure to corn silage. This could be due to higher digestibility of the fiber material of silages by microorganism propagation by addition of CLM.

Nitrogen intake was twice greater for MS than SC and CS due to the lower intake for SC and the lower CP content in CS. Calculated protein intakes were 66.9, 73.1 and 146.3 g/d for SC, CS and MS diets, respectively. The protein intakes of SC and CS groups were actually lower than the protein requirement for mature lambs (NRC, 1985) due to low dry matter intake of SC diet and low CP content of CS diet. Urinary nitrogen output was also significantly greater ($p<0.05$) in sheep fed MS than SC and CS. Nitrogen in sheep fed all diets was positively retained in body but the silage containing manure supported greater ($p<0.05$) nitrogen retention than the SC or the CS treatments. Harmon et al. (1975b) reported that sheep fed a broiler litter ensiled with corn silage showed greater nitrogen retention than those fed untreated corn silage.

Results of the voluntary feed intake trial on the palatability study are shown in table 3. Total dry matter intake (DMI) in 45 minutes each day for MS was significantly ($p<0.05$) higher than SC and CS, i.e. MS group consumed 53.3 and 22.8 g more DM than SC and CS groups, respectively. When manure was ensiled with corn forage, voluntary DMI was increased (Kim et al., 1993b). Therefore, in the present experiment, a manure addition exerted significant improvement on DMI. Dry matter intake per body weight and per metabolic body weight were also in the same responses with total DMI. A reason for the increase in DMI for the manure containing silages may have been the bulk density of the materials (Harmon et al., 1975b). The manure silages were more compact (greater mass/volume) than the untreated silage.

To provide some insight into the relative patterns of fermentation and utilization of nitrogen, the variation during the day in ruminal pH and concentrations of ammonia and total VFA are shown in table 4. The ruminal pH for the CS treatment was lower ($p<0.05$) than for the other treatments for prefeed (zero time) samples. For all treatments, the minimum pH ($p<0.05$) occurred at 0.5 and 1 h after feeding, the lowest values ($p<0.05$) being seen with both silages. Ruminal pH returned to the value of zero time by 4 h after feeding the diet containing straw and concentrate. In contrast, for both silages, the values at this time were still lower ($p<0.05$) than for SC at around 6.6. The values of pH for both silages did not return to the values seen at zero time until 8 h after feeding. Ruminal concentration of ammonia of the animals on silage treated with CLM was much higher ($p<0.05$) than the SC and CS treatments during the day (i.e. the mean concentrations of ammonia were 68.5, 43.0 and 210. 3 mg/l for the MS, SC and CS treatments respectively). Ammonia concentrations reached their maximum values at 2 h after feeding for the SC and MS treatments but at 1 h after feeding for the CS treatment. The MS treatment also had increased ($p<0.05$) ruminal concentration of total VFA over the SC and CS treatments (the total VFA concentrations for mean were 105.6, 69.8 and 81.6 mmol/l for MS, SC and CS treatments respectively). Total VFA concentration reached the maximum value ($p<0.05$) at 30 minutes after feeding for the SC diet

Table 2. Digestibility (%) of nutrients and nitrogen balance (g/d) in sheep given diets of rice straw supplemented with concentrate and whole crop corn silages ensiled with or without cage layer manure

	Treatments[1]		
	SC	CS	MS[2]
Apparent digestibility			
Dry matter	47.2^{b}	54.6^{a}	58.7^{a}
Organic matter	51.3^{b}	61.5^{a}	60.6^{a}
Crude protein	60.2^{b}	54.3^{c}	70.4^{a}
Crude fiber	37.9^{b}	60.6^{a}	64.2^{a}
Neutral detergent fiber	46.0^{b}	49.4^{ab}	53.1^{a}
Acid detergent fiber	30.8^{ab}	26.2^{b}	38.2^{a}
Nitrogen-free extract	62.3^{b}	64.2^{b}	70.8^{a}
Total digestible nutrients	50.7^{b}	46.7^{b}	67.3^{a}
Nitrogen balance			
Nitrogen intake	10.7^{b}	11.7^{b}	23.4^{a}
Fecal nitrogen	4.2	5.6	6.7
Urinary nitrogen	2.8^{b}	4.1^{b}	9.9^{a}
Retained nitrogen	3.6^{b}	1.9^{c}	6.7^{a}

[1] SC: Straw+Concentrate; CS: Whole crop corn silage; MS: Whole crop corn silage ensiled with CLM.

[2] MS: Whole crop corn ensiled with 30% cage layer manure (DM basis).

[a,b,c] Means in the same row with different superscripts differ significantly ($p<0.05$).

Table 3. Voluntary feed intake in sheep given diets of rice straw supplemented with concentrate and whole crop corn silages ensiled with or without cage layer manure

	Treatments[1]		
	SC	CS	MS[2]
Dry matter intake (g)	70.4^{c}	100.9^{b}	123.7^{a}
Intake (g)/BW (kg)	1.4^{c}	1.9^{b}	2.4^{a}
Intake (g)/$BW^{0.75}$ (kg)	1.8^{c}	2.5^{b}	3.1^{a}

[1] SC: Straw+Concentrate; CS: Whole crop corn silage; MS: Whole crop corn-manure silage.

[2] MS: Whole crop corn ensiled with 30% cage layer manure (DM basis).

[a,b,c] Means in the same row with different superscripts differ significantly ($p<0.05$).

Table 4. The pattern of variation in ruminal pH, ruminal concentrations of ammonia-N and total VFA during the day in sheep given diets of rice straw supplemented with concentrate and whole crop corn silages ensiled with or without cage layer manure

Treatments[1]		Time (h) after feeding					
		0	0.5	1	2	4	8
pH							
	SC	7.2^{aA}	7.0^{bA}	7.0^{bA}	7.1^{aA}	7.2^{aA}	7.2^{aA}
	CS	7.0^{aB}	6.5^{cB}	6.5^{cB}	6.6^{bB}	6.7^{bB}	6.7^{bB}
	MS[2]	7.1^{aA}	6.5^{cB}	6.5^{cB}	6.7^{bB}	6.6^{bB}	6.7^{bB}
NH_3-N (mg/l)							
	SC	60.8^{cB}	77.9^{aB}	74.3^{bB}	79.2^{aB}	58.3^{dB}	60.7^{cB}
	CS	40.9^{cC}	50.1^{bC}	66.8^{aB}	34.2^{dB}	35.0^{dB}	31.1^{eB}
	MS	112.0^{dA}	231.8^{cA}	278.4^{bA}	306.0^{aA}	223.2^{cA}	110.4^{dA}
Total VFA (mmol/l)							
	SC	68.2^{cB}	77.8^{aB}	70.2^{bB}	69.8^{bB}	68.4^{cB}	64.2^{dB}
	CS	56.7^{eC}	88.0^{bAB}	89.3^{aB}	85.0^{cB}	88.0^{bAB}	82.8^{dAB}
	MS	81.3^{eA}	109.3^{cA}	119.1^{aA}	117.6^{aA}	113.3^{bA}	93.1^{dA}

[1] SC: Straw+Concentrate; CS: Whole crop corn silage; MS: Whole crop corn-manure silage.
[2] MS: Whole crop corn ensiled with 30% cage layer manure (DM basis).
[A,B,C,D,E] Means in the same column with different superscripts differ significantly ($p<0.05$).
[a,b,c,d,e] Means in the same row with different superscripts differ significantly ($p<0.05$).

and at 1 h after feeding for both CS silages.

The ruminal pH in the rumen of sheep fed SC remained at high levels (over 7.0) with little variation during the day. This is probably because of the consumption of straw led to high salivation rates, which maintained the ruminal pH at high levels. According to Nolan and Leng (1972), the amount of saliva produced can be greatly influenced by the physical structure of the diet, i.e. it increases with increasing proportion of roughage in diet. Again, SC contains higher crude fiber, ADF and NDF compared with those of both silages in the present experiment. Mertens (1979) suggested that maximal fiber degradation occur between pH 6.7 and 7.1 and that fiber digestion is greatly reduced at a pH below 6.0. Therefore, the ruminal pH values reported in the present study should not greatly inhibit fibrolytic activity in the rumen. However, the lower digestibilities of crude fiber and NDF in sheep fed SC was likely caused by high content of indigestible crude fiber in SC relative to both silages.

Although the pattern of variation in ruminal pH in sheep fed CS and MS silages was similar to each other, the ruminal concentrations of ammonia-N and total VFA in sheep fed the corn silage ensiled with CLM were significantly higher than those of untreated silage. Thus, generally, an increase in total VFA concentration in the ruminal fluid is associated with a reduced ruminal pH. However, in the present study, it seemed that the ruminal pH for MS silage was neutralized with high concentration of ammonia derived from CLM. Samples from the CS treatment except at 0.5 and 1 hr after feeding showed ammonia concentration in the rumen below the level of 50 mg/l required to maximize microbial protein synthesis (Satter and Slyter, 1974). On the contrary, the ruminal concentrations of ammonia in the SC and MS treatments met the minimal requirement which means protein supply should have been sufficient to maximize microbial protein synthesis throughout the day. Again, Hungate (1966) concluded that a shortage of ruminal ammonia N may reduce celluloytic bacterial growth, which could reduce fiber digestion in the rumen. Therefore, nitrogen addition by CLM to whole crop corn silage would highly improve microbial protein synthesis compared with untreated corn silage.

The urinary outputs of purine derivatives (PD) are shown in table 5. The MS treatment highly increased ($p<0.05$) the output of PD above that seen with the SC and CS treatments. The output of PD in sheep fed CS was higher ($p<0.05$) than SC. Table 5 also shows the supplies of microbial nitrogen to the small intestine, calculated from the excretion of PD using the method described by Susmel et al. (1994a). These figures, of course, show a similar pattern to that seen for the outputs of PD. MS silage increased ($p<0.05$) the calculated supply of microbial nitrogen by 14.2 and 9.2 g/d over SC and CS respectively. Microbial proteins supply the majority of amino acids entering the small intestine, accounting for 35-66% in dairy cows (Clark et al., 1992) and even more in sheep, up to 60-90% (Smith, 1975). Therefore, this high increase of microbial protein synthesis by feeding MS silage is a very important protein source for sheep. It is known that the microbial protein synthesis is variable ranging from 14 to 49 g of microbial N/kg of OM apparently digested in the rumen (DOMR; ARC, 1984). Therefore, different types and sources of diets significantly affect microbial protein synthesis. Again, Chen et al. (1992) reported that when OM intake, PD output and nitrogen intake were increased in sheep fed a straw-based diet containing barley grain or unmolassed sugar-beet pulp, microbial protein synthesis was increased. There is also evident that increasing DMI may increase digesta flow and microbial yield (ARC, 1984; Owens and Goetsch, 1986).

Expansion of the database on ruminal microbial yields has been slow because established methods are time-consuming, laborious, and require surgically prepared animals. With this in mind, studies on the urinary excretion of purine derivatives by ruminants have been stimulated by the possible use of their excretion as an estimator of the rumen microbial protein supplied to the host animal because in ruminants nucleic acids (NA) flowing to the small intestines are essentially of rumen microbial origin (McAllan and Smith, 1973). Absorbed purines are degraded to hypoxanthine, xanthine, uric acid and allantoin, which are excreted in urine, and should relate quantitatively to the amount of purines and, hence, microbial protein absorbed. Susmel et al. (1994b) found that more urinary allantoin was excreted by cows receiving the diet that was expected to induce higher microbial synthesis. Therefore, the measurement of PD output in urine would be a useful tool to estimate microbial protein synthesis for the experiments similar to the present one.

From the present study, it appears that ensiling corn forage and cage layer manure could be a beneficial way of utilizing the waste and simultaneously improving the nutritive content of corn silage. It showed that cage layer manure is an excellent supplement of crude protein for whole crop corn silage improving digestibility, voluntary feed intake and microbial protein synthesis. Especially, the increased microbial nitrogen should be an excellent protein source to the host animal given the CLM treated silage for production. Feeding animal waste such as CLM would also solve the pollution production.

Table 5. The daily output of purine derivatives (PD) in urine and the calculated amount of microbial N entering the small intestine in sheep given diets of rice straw supplemented with con- centrate and whole crop corn silages with or without supplementation of cage layer manure

	Treatments[1]		
	SC	CS	MS[2]
PD output (mmol/day)	9.0[c]	13.9[b]	25.5[a]
Microbial N (g/day)	7.8[c]	12.8[b]	22.0[a]

[1] SC: Straw+Concentrate; CS: Whole crop corn silage; MS: Whole crop corn-manure silage.

[2] MS: Whole crop corn ensiled with 30% cage layer manure (DM basis).

[a,b,c] Means in the same row with different superscripts differ significantly ($p<0.05$).

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