# Digestion and Nitrogen Utilization by Sheep Fed Diets Supplemented with Processed Broiler Litter

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**ABSTRACT :** *In vivo* digestion and metabolism trials were conducted with 10 wethers equipped with ruminal, abomasal, and ileal cannulae to evaluate digestion of ensiled broiler litter (EBL), deepstacked broiler litter (DBL), and composted broiler litter (CBL). Wethers were fed a low protein (6.3% CP) basal diet alone or supplemented to 10.3% CP with EBL, DBL, CBL or soybean meal (SBM). All diets were formulated to be isoenergetic (56% TDN, DM basis). Apparent digestibilities of DM, OM, and ADF were not affected ($p<0.05$) by diet, but digestibility of CP was improved ($p<0.05$) by N supplementation. Apparent digestibility of CP was lower ($p<0.05$) for diets supplemented with CBL and DBL than for diets supplemented with SBM and EBL. Ruminal $NH_3$ concentration was 20 to 24 mg/dl at 2 h after feeding litter-supplemented diets compared with 13 mg/dl for SBM. Abomasal N, $NH_3$ N, and nonammonia N flows were increased ($p<0.05$) by N supplementation, whereas microbial N flow was not influenced ($p<0.05$) by diet. Compared with SBM and EBL, undegraded dietary CP flow to the abomasum tended to be greater ($p<0.1$) when wethers were fed DBL and CBL-supplemented diets. Retention of N (g/d) also was greater ($p<0.05$) due to greater ($p<0.05$) N intake and lower ($p<0.05$) urinary N excretion when wethers were fed diets supplemented with litter (especially EBL) vs. SBM. Overall, characteristics of ruminal fermentation and digestion indicated that broiler litter N was utilized efficiently by wethers, but ensiling may be preferable to deepstacking or composting. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 11 : 1634-1641)***

**Key Words** : Digestibility, Digesta Passage, Microbial Protein, Broiler Litter, Protein Degradation

## INTRODUCTION

Interest in feeding animal wastes has intensified due to the high costs of conventional feeds, potential nutritional value of wastes, environmental pollution considerations, and shortage of feeds in developing countries. Among animal wastes, poultry litter has the highest nutritional value for ruminants (Bhattacharya and Taylor, 1975). Broiler litter has been used as a source of N, energy, and minerals for ruminants. Ensiling of animal waste is desirable because it is an economical means of preservation and it effectively eliminates pathogenic bacteria. Deepstacking and composting also are effective in destroying pathogenic bacteria (CAST, 1978). These effective processing methods of poultry waste have been widely studied for ruminant feeding (Chester-Jones and Fontenot, 1981; Kwak et al., 2000; Li et al., 2002). Evaluation of broiler litter utilization by ruminants on the basis of the ruminally undegradable protein system described by NRC (1985b), however, has not been attempted. Also, nutrient utilization of differently processed broiler litter compared with soybean meal as a protein supplement has not been determined sectionally within the digestive tract of ruminants.

The objective of this experiment was to evaluate the effects of supplementing a low energy, N-deficient diet with broiler litter processed by ensiling, deepstacking, or composting as well as with soybean meal on site and describe the extent of OM, ADF, and CP digestion, ruminal fermentation characteristics, microbial efficiency, blood urea-N concentration and N balance in sheep.

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## MATERIALS AND METHODS

### Animals and diets

Ten crossbred (1/2 Dorset×1/4 Finn×1/4 Rambouillet) wethers (average BW=38 kg) were fitted with cannulas in the rumen, abomasum, and ileum. Ruminal and abomasal cannulas (plexiglass-polyethylene) were surgically placed in the dorsal region of the rumen and approximately 10 cm from the pylorus, respectively. A T-shaped stainless–steel cannula was installed in the distal ileum 10 to 15 cm from the ileocecal juncture. Surgical procedures and postoperative care were administered by a veterinary surgeon after approval of the project by the Virginia Tech Animal Care Committee.

Wethers were allowed 3 wk to recover from surgery, placed in metabolism stalls (1.6×0.5 m) similar to those described by Briggs and Gallup (1949). For the first trial the 10 wethers were allotted at random to five dietary treatments. The lambs were re-allotted to the five diets for the second trial. The five diets included a basal diet (6.3% CP, DM basis) without a source of supplemental N and four

**Table 1.** Chemical composition of differently processed broiler litter

| Item | Ensiling | Deepstacking | Composting |
|---|---|---|---|
| | ----------%---------- | | |
| Dry matter | 59.5 | 78.5 | 83.0 |
| Organic matter[1] | 76.3 | 72.7 | 70.0 |
| Crude protein[1] | 33.6 | 29.1 | 25.9 |
| Acid detergent fiber[1] | 29.2 | 33.7 | 36.0 |
| Crude ash[1] | 23.7 | 27.3 | 30.0 |

[1] DM basis.

diets (average CP=10.3%) supplemented with either SBM or wood shaving-based broiler litter processed by ensiling (EBL), deepstacking (DBL), or composting (CBL). Water was added to the litter to obtain 40% moisture prior to processing. A portion was ensiled in 200 L metal drums double-lined with polyethylene bags, and the remaining litter placed in open cells (1.4 m×1.4 m×1.4 m) with plywood on three sides and expanded metal in front. Drums and cells were kept in an open-sided shed to allow adequate ventilation. Composted litter was aerated once daily during the first wk, every other day during the second wk, then weekly for the next 4 wk. Deepstacked litter was not disturbed during the 6 wk processing period. The chemical composition of differently processed BL was presented in Table 1. Losses of volatile ammonia for composting and deepstacking reduced CP contents compared with ensiling.

All diets were formulated to be isoenergetic (56% TDN, DM basis) (Table 2). Dietary ingredients were mixed daily and 825 g of diet DM (approximately 2.2% of BW) were fed in equal portions at 07:00 and 19:00 h. The amount of diet DM offered was limited to the quantity of the SBM-supplemented diet needed to meet requirements (NRC, 1985a) for maintaining BW and N balance. The basal diet, however, was N-deficient and served as a negative control. The reason why this negative control was used was because diets may be deficient in crude protein in many countries of the world. Sultan and Loerch (1992) fed 800 g of a 9.5% CP, low-quality roughage diet containing SBM, and reported positive N balance at 700 g DM intake in wethers similar to those used in the present study. For reference, chemical composition of differently processed broiler litter was presented in Table 1. Water was available to the sheep at all times.

**Measurements and sampling**

The experiment included three trials. Initially, the experiment was intended to include 10 wethers in a randomized block design with two trials. However, data for two wethers in the first trial and one in the second were not reliable due to chronic leakage around the abomasal or ileal cannula during the digesta sampling period. Therefore, five wethers were selected to conduct a third trial in which all completed the collection period and three continued through the digesta sampling period. Diets were randomly assigned to wethers at the start of each trial with the restriction that wethers would not receive the same diet in consecutive trials. Body weight was determined on the first and last day of each trial. Each trial consisted of 5 d transition, 10 d preliminary, 10 d collection, and 6 d digesta sampling periods.

All wethers were fed the SBM diet as the first meal at the start of the transition period, and then 10% of the allotment at each feeding was replaced by the assigned diet to obtain 100% of assigned diet per meal by the start of the preliminary period. Wethers were removed from metabolism stalls daily during the transition period for exercise.

Diet ingredients and orts were sampled daily from 2 d

**Table 2.** Ingredient and chemical compositions of diets

| Item | Nitrogen supplement | | | | |
|---|---|---|---|---|---|
| | None | Soybean meal | Processed broiler litter | | |
| | | | Ensiled | Deep stacked | Composted |
| | ----------%---------- | | | | |
| Ingredient composition[1] | | | | | |
| Chopped orchard grass hay | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Corn cob fraction[2] | 64.3 | 63.7 | 54.9 | 51.2 | 48.0 |
| Ground corn | 24.1 | 14.9 | 19.1 | 20.5 | 21.9 |
| Soybean meal | - | 10.0 | - | - | - |
| Broiler litter | - | - | 15.5 | 17.8 | 19.6 |
| Dicalcium phosphate | 0.9 | 0.7 | - | - | - |
| Limestone | 0.2 | 0.2 | - | - | - |
| $Cr_2O_3$ | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Chemical composition[1] | | | | | |
| Dry matter | 90.3 | 90.4 | 84.0 | 87.4 | 89.0 |
| Organic matter | 94.5 | 94.0 | 92.3 | 91.0 | 90.2 |
| Crude protein | 6.3 | 10.1 | 10.4 | 10.6 | 10.3 |
| Acid detergent fiber | 30.9 | 30.9 | 31.4 | 31.6 | 31.4 |
| Total digestible nutrients[3] | 56.0 | 56.0 | 56.0 | 56.0 | 56.0 |

[1] DM basis. [2] Lite-R-Cobs, pellets : The Andersons, Maumee, Ohio. [3] Calculated values and that of broiler litter was assumed to be 60%.

before the beginning to 2 d before the end of collection period, and during the digesta sampling period. Samples were sealed in plastic bags and stored at -20°C until determination of chemical composition. Daily fecal output during the collection period was dried at 60°C. Feces were thoroughly mixed at the end of the collection period to obtain a composite sample, which was ground through a 2 mm screen prior to storage. Daily urine output was collected in plastic bottles containing 15 ml of 13.5 N $H_2SO_4$. After weighing, 2% of the urine volume was refrigerated and bulked for the collection period.

Dual markers were administrated to calculate digesta flow rates during the digesta sampling period. Cobalt ethylenediaminetetraacetic acid (Co-EDTA), used as a liquid phase marker, was prepared according to the method of Uden et al. (1980). Wethers received 0.5 g of Co-EDTA via the ruminal cannula at each feeding from d 7 of the preliminary period until the end of each trial. Chromic oxide powder, used as a solid phase marker, was mixed with feed ingredients and fed at 0.5% of dietary DM (Table 2) throughout each trial.

About 100 ml of abomasal and ileal samples, respectively and about 200 g of fecal samples were collected twice daily at 02:00 and 14:00 h, 04:00 and 16:00 h, 06:00 and 18:00 h, 08:00 and 20:00 h, 10:00 and 22:00 h, or 12:00 and 24:00 h during the digesta sampling period, with one of the sampling time pairs randomly assigned to each of the 6 d to yield 12 samples per sampling site. After pH of abomasal fluid was determined, all samples were frozen at -20°C. Samples were thawed at the end of each trial and composited. Abomasal and ileal samples then were separated into solid and liquid phases by centrifugation at 2,000×g for 10 min. After removal of an aliquot of abomasal liquid for later determination of $NH_3$-N and cytosine, solid and liquid digesta were frozen at -20°C until lyophilized to determine DM content. Solid phases were ground through a 1 mm screen. Composited fecal samples were dried at 60°C to determine DM, then ground through a 2 mm screen.

About 250 ml of ruminal fluid was obtained via the cannula 2 h following the last meal of the digesta sampling phase. Fluid was strained through four layers of cheese cloth prior to determination of pH. Five ml were transferred to a tube containing two drops of concentrated $H_2SO_4$ and another 5 ml to a tube containing 1 ml of 25% wt/vol of metaphosphoric acid plus 5 ml isocaproic acid (internal standard) for determination of $NH_3$ N and VFA, respectively. Samples were stored at -20°C. Also on the last day of each trial, blood was obtained in heparinized vacutainers via jugular venipuncture 6 h after feeding, deproteinized, then stored at -20°C for subsequent urea analysis.

**Chemical analyses and calculations**

After thawing, DM content of feed ingredients and orts was determined by drying at 60°C. Feed and orts then were ground through a 2 mm screen. Ash content of feed, orts, abomasal and ileal samples, and feces was determined by heating at 600°C for 3 h. Acid detergent fiber content was determined according to Goering and Van Soest (1970), and N was determined by the Kjeldahl procedure (AOAC, 1990). Concentrations of Cr and Co were determined according to the method of Hern (1979). Rates of OM, ADF, and N flow in solid and liquid phases at the duodenum and ileum were calculated according to the method of Armentano and Russell (1985) for a dual marker system.

Cytosine, as a microbial marker, in abomasal samples was analyzed by high performance liquid chromatography (Varian model 5000, Palo Alto, CA, USA) using the following modifications to the procedure described by Koenig (1980). After thawing, approximately 10 ml of liquid phase were weighed into a 15 ml screw-cap extraction tube and dried in a forced-air oven at 90°C for 24 h, then reweighed to determine DM. Approximately 0.25 g of previously lyophilized and ground solid phase was placed into a 15 ml tube for extraction. Perchloric acid (2.5 ml, 70% vol/vol) was added to all tubes, thoroughly mixed by vortexing, and incubated at room temperature for at least 12 h. Samples then were hydrolyzed for 1 h in a water bath at 90°C. Tubes were rotated every 10 min during hydrolysis. After cooling, contents of each tube were diluted to approximately 10 ml with deionized water. Solid phase samples were tranferred to 100 ml volumetric flasks and liquid phase samples to 50 ml volumetric flasks. Tubes and caps were scraped with a glass rod and washed with deionized water. Next, 10 ml of 1.97 M $NH_4H_2PO_4$ buffer and approximately 2.3 ml of concentrated $NH_4OH$ were added to adjust pH to 3.5. Deionized water was added to obtain the appropriate volume. An aliquot of the final solution was filtered through a 0.45 μm Millipore filter prior to analysis.

Cytosine was separated by a 25 cm partisil-10 SCX L column (Whatman Inc., Clifton, NJ, USA) at room temperature. The mobile phase was 0.15 M $NH_4H_2PO_4$ (pH adjusted to 3.55 with concentrated HCl), and flow rate was 0.6 ml/min. Injection volume was 25 μl, and detection was at 254 nm. Cytosine standards (10, 20, 30, 40, and 50 μm) were prepared in 1.75% $HClO_4$ in 0.2 M $NH_4H_2PO_4$, and pH was adjusted to 3.5 with concentrated $NH_4OH$. Cytosine content of abomasal solid and liquid digesta was within the range of the standards, which provided a linear response.

Ruminal fluid was obtained from each wether on the last day of each trial to determine N and cytosine content of preserved rumen bacteria, but the samples were damaged during storage. The ratio of N to cytosine in mixed rumen

**Table 3.** Effect of supplementing a N-deficient diet with soybean meal or broiler litter on total tract apparent digestibility of dry matter, organic matter, acid detergent fiber, and crude protein and N balance of wethers[1]

| Item | Nitrogen supplement | | | | | SEM |
|---|---|---|---|---|---|---|
| | None | Soybean meal | Processed broiler litter | | | |
| | | | Ensiled | Deep stacked | Composted | |
| Apparent digestibility | ---------- | ---------- | ----------%---------- | ---------- | ---------- | ---------- |
| Dry matter | 51.1 | 53.8 | 55.2 | 51.3 | 55.1 | 2.1 |
| Organic matter | 54.2 | 57.5 | 58.0 | 55.2 | 59.1 | 2.0 |
| Acid detergent fiber | 42.4 | 43.5 | 45.0 | 40.6 | 45.6 | 3.3 |
| Crude protein | 28.9[a] | 56.9 | 61.1[c] | 48.2 | 49.9 | 2.6 |
| N balance | ---------- | ---------- | ----------g/d---------- | ---------- | ---------- | ---------- |
| Intake | 7.4[a] | 12.4[b] | 13.4 | 13.9 | 13.3 | 0.3 |
| Excretion | | | | | | |
| Fecal | 5.2[a] | 5.2[b] | 5.2[c] | 7.2 | 6.6 | 0.3 |
| Urinary | 3.2[a] | 7.5[b] | 6.6 | 5.8 | 6.0 | 0.3 |
| Retention | -1.0[a] | -0.4[b] | 1.6 | 0.9 | 0.7 | 0.6 |

[1] Least squares means, n=5. [a] Unsupplemented differs from N-supplemented diets ($p<0.05$). [b] Soybean meal differs from litter-supplemented diets ($p<0.05$). [c] Ensiled differs from deepstacked and composted ($p<0.05$).

**Table 4.** Ruminal and blood parameters of wethers fed a N-deficient diet supplemented with soybean meal or broiler litter[1]

| Item | Nitrogen supplement | | | | | SEM |
|---|---|---|---|---|---|---|
| | None | Soybean meal | Processed broiler litter | | | |
| | | | Ensiled | Deep stacked | Composted | |
| Total VFA (mmol/L) | 79.5 | 100.6 | 102.9[c] | 79.0 | 82.2 | 7.4 |
| VFA (%) | | | | | | |
| Acetate | 68.0 | 67.7[b] | 71.7 | 70.3 | 69.6 | 1.1 |
| Propionate | 20.5[a] | 17.6 | 16.4 | 17.2 | 17.7 | 0.9 |
| Isobutyrate | 0.4[a] | 0.8 | 0.7 | 0.8 | 0.7 | 0.1 |
| Butyrate | 9.9 | 11.8 | 9.4 | 10.1 | 10.5 | 0.8 |
| Isovalerate | 0.6[a] | 1.1 | 0.9 | 0.8 | 0.7 | 0.1 |
| Valerate | 0.5[a] | 0.8[b] | 0.7[c] | 0.6 | 0.5 | 0.1 |
| Ruminal pH | 6.4 | 6.3 | 6.5 | 6.5 | 6.6 | 0.1 |
| Ruminal $NH_3$ N, (mg/dl) | 3.3[a] | 13.3[b] | 23.9 | 20.5 | 19.3 | 2.1 |
| Blood urea N, (mg/dl) | 2.3[a] | 10.0 | 9.2 | 6.6 | 8.1 | 1.0 |

[1] Least squares means, n=5. [a] Unsupplemented differs from N-supplemented diets ($p<0.05$). [b] Soybean meal differs from litter-supplemented diets ($p<0.05$). [c] Ensiled differs from deepstacked and composted ($p<0.05$).

bacteria, as determined in this laboratory (Seymour et al., 1992), is relatively constant and not influenced by diet. Therefore, microbial N in abomasal solid and liquid phase was calculated (Schelling and Byers, 1984) as follows: MN=1.838(AC)-3.374, where MN=microbial N (mg/g of DM) and AC=cytosine (μmol of DM) in solid or liquid phase.

Blood urea N was determined according to Coulombe and Favreau (1963). Ruminal and abomasal digesta $NH_3$ N concentrations were determined according to Chaney and Marbach (1962). Ruminal VFA was determined by gas-liquid chromatography (Vista 6000, Varian, Palo Alto, CA, USA) according to Nocek and Polan (1984).

### Statistical analysis

There were 10, 10, and five observations for collection periods in consecutive trials yielding five observations per dietary treatment, and eight, nine, and three observations for digesta sampling periods in consecutive trials yielding four observations per dietary treatment. Data were analyzed by ANOVA using the GLM procedure (SAS Institute, Inc., 1990) for a completely random design. The model included diet, trial, interaction between diet and trial, and covariate (BW at the start of each trial). Interaction effects for all dependent variables were non-significant ($p>0.1$), and removed from the model. Significant dietary effects were evaluated using linear orthogonal contrasts: 1) basal vs. N-supplemented, 2) SBM vs. EBL, DBL, and CBL, 3) EBL vs. DBL and CBL, and 4) DBL vs. CBL. Orthogonal contrasts (2, 3, and 4 listed above) were used for mean comparisons when effects due to N supplement were significant ($p<0.05$).

## RESULTS

### Total tract apparent digestibility

Total tract apparent digestibilities of DM, OM and ADF were not affected ($p>0.05$) by N supplementation or source of supplemented N (Table 3). Compared with all N-supplemented diets, however, CP digestibility was lowest ($p<0.05$) when wethers were fed the basal diet. Digestibility

**Table 5.** Organic matter flow and apparent digestion in wethers fed a N-deficient diet supplemented with soybean meal or broiler litter[1]

| Item | Nitrogen supplement | | | | | SEM |
|---|---|---|---|---|---|---|
| | None | Soybean meal | Processed broiler litter | | | |
| | | | Ensiled | Deep stacked | Composted | |
| Intake (g/d) | 694 | 745 | 760 | 679 | 745 | 33 |
| Flow (g/d) | | | | | | |
| Abomasum | 571 | 473 | 528 | 493 | 492 | 33 |
| Ileum | 458[a] | 348 | 358 | 372 | 377 | 30 |
| Feces | 292 | 266 | 279 | 247 | 278 | 23 |
| Apparent digestion | | | | | | |
| Pre-intestinal (g/d) | 123[a] | 271 | 231 | 186 | 252 | 27 |
| % of intake | 17.7[a] | 36.4 | 30.4 | 27.4 | 33.9 | 3.5 |
| Small intestine (g/d) | 113 | 125 | 170 | 121 | 115 | 29 |
| % of intake | 16.3 | 16.8 | 22.4 | 17.8 | 15.4 | 4.0 |
| Large intestine (g/d) | 166[a] | 82 | 79 | 125 | 99 | 18 |
| % of intake | 23.9[a] | 11.0 | 10.4 | 18.4 | 13.3 | 2.4 |

[1] Least squares means. n=4. [a] Unsupplemented differs from N-supplemented diets ($p<0.05$).

of CP was higher ($p<0.05$) when wethers were fed EBL than when fed DBL or CBL.

**Nitrogen balance**

Lower ($p<0.05$) N intake when wethers were fed the basal diet was accompanied by lower ($p<0.05$) fecal and urinary N excretion and lower ($p<0.05$) N retention (negative). The negative N retention was caused by greater total N excretion than actual N intake. Overall, feeding broiler litter instead of SBM resulted in greater ($p<0.05$) N intake, fecal output, and retention. Urinary N was lower ($p<0.05$) for lambs fed litter. Although N retention by wethers when fed the broiler litter diets was similar ($p>0.05$), feeding DBL or CBL resulted in greater ($p<0.05$) fecal and lower ($p<0.1$) urinary N excretion, compared with N excretion in response to feeding EBL.

**Ruminal and blood parameters**

Total VFA concentration in ruminal fluid (Table 4) was greater ($p<0.05$) when wethers were fed EBL compared with DBL and CBL. Despite the higher concentration of total VFA, however, molar percentages of individual VFA, with the exception of valerate, were similar ($p>0.05$) when wethers were fed EBL, DBL, or CBL. Molar percentage of acetate was higher ($p<0.05$) and butyrate lower ($p<0.05$) due to feeding EBL, DBL, or CBL compared with SBM; whereas, limited N availability in the basal diet resulted in higher ($p<0.05$) propionate and lower ($p<0.05$) isobutyrate, isovalerate, and valerate molar percentages when compared with N-supplemented diets.

Ruminal pH was not affected ($p<0.05$) by diet, and was within the optimum range for microbial proteolysis and deamination (Lewis and Emery, 1962). Ruminal $NH_3$ N concentration, however, was greater ($p<0.05$) when wethers were fed N-supplemented diets, with highest ($p<0.05$) $NH_3$ N concentrations resulting from feeding broiler litter diets.

Despite the approximately 60% greater ruminal $NH_3$ N due to feeding broiler litter, compared with SBM, blood urea N was lower ($p<0.05$) when wethers were fed EBL, DBL, or CBL. Positive correlation between these two parameters may not be expected probably due to effects of sampling time interval (4 h) between ruminal fluid and blood, and remarkably different CP characteristics of SBM and BL. Overall, concentration of blood urea N was proportional to urinary N excretion across diets.

**Organic matter flow and apparent digestion**

The pH of abomasal digesta, which ranged from 2.54 to 2.65, was similar ($p>0.05$) across dietary treatments. Intake and flow of DM and OM through the digestive tract in response to dietary treatments were similar, so only OM data are presented (Table 5). Abomasal OM flows tended to be higher ($p<0.1$) when wethers were fed the basal diet compared with N-supplemented diets. A similar response ($p<0.05$) was noted at the distal ileum. As a result, a lower ($p<0.05$) percentage of OM intake was apparently digested in the reticulorumen and a greater ($p<0.05$) percentage in the large intestine when wethers were fed the basal diet. Percentage of OM apparently digested in the large intestine also tended to be influenced ($p<0.1$) by type of broiler litter, with the mean of DBL and CBL>EBL. Overall, apparent digestibility (%) of OM (basal=58, SBM=64, EBL=63, DBL=64, CBL=63, SE=3), calculated using digesta markers to estimate fecal OM output, was not influenced ($p>0.05$) by dietary treatment. A similar response was noted during the collection period (Table 3); however, percentages were uniformly lower when using actual fecal output. The slight overestimation of marker concentrations induced higher values in digestibilities determined by the marker method.

**Acid detergent fiber flow and digestion**

Abomasal ADF flow was lowest ($p<0.05$) for SBM, due to greater ($p<0.05$) digestion (g/d and % of intake) in the reticulorumen (Table 6). Ileal ADF flow tended to be

**Table 6.** Acid detergent fiber flow and apparent digestion in wethers fed a N-deficient diet supplemented with soybean meal or broiler litter[1]

| Item | Nitrogen supplement | | | | | SEM |
|---|---|---|---|---|---|---|
| | None | Soybean meal | Processed broiler litter | | | |
| | | | Ensiled | Deep stacked | Composted | |
| Intake (g/d) | 237 | 250 | 267 | 238 | 267 | 13 |
| Flow (g/d) | | | | | | |
| Abomasum | 197 | 156[b] | 192 | 196 | 197 | 16 |
| Ileum | 205 | 139 | 151 | 170 | 181 | 21 |
| Feces | 131 | 108 | 120 | 128 | 124 | 10 |
| Apparent digestion | | | | | | |
| Pre-intestinal (g/d) | 40[a] | 94[b] | 75 | 42 | 70 | 12 |
| % of intake | 16.9[a] | 37.6[b] | 28.1 | 17.6 | 26.2 | 4.5 |
| Small intestine (g/d) | -8 | 17 | 41 | 26 | 16 | 17 |
| % of intake | -3.4 | 6.8 | 15.4 | 10.9 | 6.0 | 7.2 |
| Large intestine (g/d) | 74 | 31 | 31 | 42 | 57 | 16 |
| % of intake | 31.2[a] | 12.4 | 11.6 | 17.6 | 21.3 | 6.2 |

[1] Least squares means. n=4. [a] Unsupplemented differs from N-supplemented diets ($p<0.05$). [b] Soybean meal differs from litter-supplemented diets ($p<0.05$).

**Table 7.** Nitrogen flow and apparent digestion in wethers fed a N-deficient diet supplemented with soybean meal or broiler litter[1]

| Item | Nitrogen supplement | | | | | SEM |
|---|---|---|---|---|---|---|
| | None | Soybean meal | Processed broiler litter | | | |
| | | | Ensiled | Deep stacked | Composted | |
| N Intake (g/d) | 7.4[a] | 12.6 | 13.6 | 12.8 | 13.7 | 0.6 |
| Abomasal N flow (g/d) | | | | | | |
| Total | 13.5[a] | 15.2 | 15.3 | 15.0 | 16.1 | 0.7 |
| Ammonia N | 0.13[a] | 0.46 | 0.41 | 0.34 | 0.41 | 0.04 |
| Nonammonia N | 13.3[a] | 14.7 | 14.9 | 14.6 | 15.7 | 0.7 |
| Microbial N | 10.1 | 10.2 | 10.2 | 8.7 | 9.3 | 0.6 |
| Nonammonia, nonmicrobial N | 3.2[a] | 4.5 | 4.6 | 5.9 | 6.3 | 0.6 |
| Ileal N flow (g/d) | 5.4[a] | 6.3[b] | 7.0 | 7.7 | 7.7 | 0.5 |
| Fecal N flow (g/d) | 4.5[a] | 4.4[b] | 5.2[c] | 6.2 | 6.1 | 0.2 |
| EMPS[2] | 3.88 | 2.91 | 2.83 | 2.70 | 2.96 | 0.47 |
| Apparent digestion | | | | | | |
| Pre-intestinal (g/d) | -6.1[a] | -2.5 | -1.6 | -2.1 | -2.3 | 0.4 |
| Small intestine (g/d) | 8.1 | 8.9 | 8.2 | 7.2 | 8.4 | 0.6 |
| % of intake | 109.7[a] | 70.8[b] | 60.6 | 56.4 | 61.6 | 4.6 |
| Large intestine (g/d) | 0.9 | 1.9 | 1.8 | 1.4 | 1.5 | 0.4 |
| % of intake | 12.4 | 15.2 | 13.4 | 10.7 | 11.5 | 3.1 |

[1] Least squares means. n=4. [2] Efficiency of microbial protein synthesis (grams of microbial N / 100 grams of organic matter truly fermented).
[a] Unsupplemented differs from N-supplemented diets ($p<0.05$). [b] Soybean meal differs from litter-supplemented diets ($p<0.05$). [c] Ensiled differs from deepstacked and composted ($p<0.05$).

greater ($p<0.1$) when wethers were fed the basal diet, due to lower ($p<0.05$) digestion in the small intestine. As a result, the primary site of ADF digestion was the large intestine when wethers were fed the basal diet. Broiler litter reduced ($p<0.05$) ADF digestion (g/d and % of intake) in the reticulorumen when compared with SBM. Especially, the low pre-intestinal digestion for the DBL-fed group comparable to that of the basal group may be related to the low OM intake and total VFA concentration. The negative apparent digestion in the small intestine was a reflection of inevitable analytical errors.

**Nitrogen flow**

In general, total abomasal N flow (Table 7) was approximately 17% greater than N intake when wethers were fed N-supplemented diets, but was approximately 82% greater when fed the basal diet. In response to lower ($p<0.05$) N intake when fed the basal diet compared with supplemented diets, wethers had lower ($p<0.05$) total N flows at the abomasum due to lower ($p<0.05$) $NH_3$ N, nonammonia N, and nonammonia, nonmicrobial N flows. As a result, ileal N flows were lower ($p<0.05$). Efficiency of microbial protein synthesis tended to be higher ($p<0.1$) when wethers were fed the basal diet due to a higher rate of undegraded OM flow (Table 5) to the abomasum.

Differences due to feeding litter compared with SBM-supplemented diets included higher ($p<0.05$) ileal N flows, and higher ($p<0.05$) fecal N flow. The only difference

among litter-supplemented diets at the abomasum was nonammonia, nonmicrobial N flow, which tended to be higher ($p<0.1$) for DBL and CBL compared with EBL. Ileal and fecal N flows also were higher ($p<0.05$) for DBL and CBL, suggesting reduced digestibility of ruminally undegradable protein in these diets. Despite differences in flow rates across N-supplemented diets, however, amounts (g/d) of N absorbed from the small and large intestines were similar ($p>0.05$).

## DISCUSSION

Apparent digestibilities of DM, OM, and ADF in the total tract were not influenced by feeding the N-supplemented diets when compared with feeding N-deficient basal diet of similar energy content. Fonnesback et al. (1981) reported that DM digestion was highly correlated with digestible energy, which also was observed by de Faria and Huber (1984) and Ortigues et al. (1988). Rihani et al. (1993) found no influence of dietary N content on apparent digestibility of OM or ADF in the rumen or total tract when a low-quality, 5.3% CP diet was supplemented with urea to 9.5 or 12.5% CP. When wethers were fed the basal diet (6.3% CP) in the present study, ruminal digestion of OM and ADF was lower than when fed the N-supplemented diets. As a result, a higher proportion of OM and ADF intake flowed to the large intestine, which became the primary site of their digestion. This response may have been partially due to the low digestibility of the corn cob fraction, relative to that of other feedstuffs (Van Soest and Robertson 1976), and the susceptibility of cellulolytic bacteria to low concentrations (Table 4) of ruminal ammonia and branched-chain C4 and C5 acids (NRC, 1985b)

Despite the possibly impaired cellulolytic capacity in response to feeding the basal diet, rate of total microbial N flow from the rumen (Table 7) was similar across treatments, and apparently was sustained by recycling of N via salivary and blood urea. When wethers were fed the basal diet, approximately 60% of abomasal microbial N flow apparently was derived from recycling and 40% from degradation of dietary CP in the rumen. Recycled N, therefore, accounted for the approximately 45% of the nonammonia N absorbed from the intestines and the undigested fecal N residue, compared with 8 to 14% for other diets. As a result of excretion of more recycled N in the feces, apparent digestibility of CP in the total tract was lower ($p<0.05$) when wethers were fed the basal diet compared with N-supplemented diets. Similar responses were noted by Sultan and Loerch (1992) and Rihani et al. (1993) when diets containing 9.5 and 12.5% CP were compared. Digestion coefficients for DM, OM, and CP in our SBM diet were similar to those reported by Sultan and Loerch (1992) for cannulated (ruminal and abomasal) wethers consuming a low-energy, low-protein (9.5%) diet containing SBM.

A previous study (Kwak et al., 1998) indicated broiler litter CP was primarily soluble, and contained a relatively small true protein fraction that was degraded in the rumen at a slower rate than that of SBM. The soluble fraction of broiler litter probably was responsible for the high ($p<0.05$) ruminal $NH_3$ concentration 2 h after feeding observed in this study. Rihani et al. (1993) found that ruminal $NH_3$ concentration peaked between 1 and 2 h after feeding diets supplemented with urea, but returned to prefeeding level by approximately 4 h. The authors concluded that microbial N flow to the abomasum and efficiency of microbial protein synthesis were similar whether ruminal $NH_3$ release was pulsatile in response to consuming a meal or kept constant by continous infusion of urea. Assuming a constant rate of $NH_3$ release due to degradation of the large degradable CP fraction in SBM vs. a pulsatile release of $NH_3$ from the soluble fraction of broiler litter, our data support the conclusion of Rihani et al. (1993).

In situ estimates by Kwak et al. (1998) indicated the ruminally undegradable CP fraction of broiler litter was greater than that of SBM, with composted>deepstacked>ensiled. In the present study the estimate of values of ruminally undegradable CP supports results of in vivo flows of nonammonia, nonmicrobial N from the abomasum, which indicated greater amounts of ruminally undegraded N available for digestion in the small intestine when wethers were fed two (DBL and CBL) of the three types of broiler litter compared with SBM. For reference, undegradable intake protein (%) of N supplemented diets was 35.7 for SBM, 33.8 for EBL, 46.0 for DBL, and 46.0 for CBL.

Digestibility of protein in the small intestine, however, was lower ($p<0.05$) when wethers were fed diets supplemented with broiler litter compared with SBM, whether expressed as a percentage of intake N or a percentage of nonammonia, nonmicrobial N flow to the small intestine (data not shown). The lower digestibility of litter may be an inherent characteristic of a feedstuff that has previously undergone digestion, or may be due to increased ADF-CP content caused by overheating during deepstacking or composting (Ruffin and McCaskey, 1990). In the future, amino acid profile and digestibility of ruminally undegraded broiler litter related to desirable N retention deserve further consideration.

## IMPLICATIONS

Broiler litter processed by ensiling, deepstacking, or composting was equivalent to SBM as a N supplement for a low quality, N-deficient diet fed to ruminants. A slight increase in fecal N excretion was offset by lower urinary N excretion and resulted in positive N retention when SBM

was replaced by broiler litter. Overall, fermentation and digestion characteristics of broiler litters in this study indicated that preservation by ensiling may be more desirable than composting or deepstacking.

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