Ruminal Dry Matter and Fiber Characteristics of Rice Hulls-bedded Broiler Litter Compared with Rice Straw*

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ABSTRACT : Ruminal digestion of dry matter (DM) and neutral detergent fiber (NDF) of processed (ensiled, deepstacked or composted) broiler litter (BL) was determined *in situ* and *in vitro*, and compared with rice straw (RS). DM disappearances at 24 and 48 h and digestion of differently processed BL were higher than those of RS. Compared with RS, processed BL was low in NDF disappearance at 72 h incubation, digestion rate (K_dB) and digestibility at 0.025 of passage rate; however, deepstacked BL was similar in these NDF characteristics. Processing of BL affected ruminal digestion of nutrients such as DM and NDF adversely. NDF of composted BL, especially, was the most indigestible. This *in situ* nutritional evaluation indicated that deepstacked BL, the most widely used form of BL, was superior in DM characteristics (fractions, ruminal disappearance and digestibility) and similar in NDF characteristics (ruminal disappearance and digestibility) to RS. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 2 : 207-212)***

Key Words : Broiler Litter, Rice Straw, Rice Hulls, Fiber, Digestion, *In Situ*, *In Vitro*

INTRODUCTION

Poultry waste has been widely used by farmers in the United States, Europe, Asia and other areas of the world during the past 40 years (Muller, 1980; Fontenot, 1991; Li et al., 2002). Animal wastes should be processed for use as feedstuffs to destroy pathogens (CAST, 1978). Poultry litter used for feed is processed and stored primarily by deepstacking, but it may also be processed by ensiling and composting.

Broiler litter is a good source of crude protein, fiber, and minerals. Especially, BL bedded with rice hulls, the most widely used bedding material in Asian broiler farms, contains more fiber (Kwak et al., 2000) than that bedded with wood shavings or other materials commonly used in the United States (Martin et al., 1983; Ruffin and McCaskey, 1990; Patil et al., 1993). Therefore, these characteristics may make it more preferable as a cheap roughage source for ruminants. Rice straw is one of the major roughage sources for beef cattle in many countries in Asia; however, it may be more expensive than broiler litter in many cases. By a previous study (Kwak et al., 2000), partial replacement (2/3) of RS with BL in beef cattle diets resulted in improved weight gain and feed efficiency. Processing methods may alter digestion of litter DM and NDF in the rumen, but *in situ* or *in vitro* information is not available to describe these characteristics of processed BL.

Therefore, this *in situ* and *in vitro* study was conducted to compare processed BL with RS as a roughage source for ruminants and to determine effects of different processing methods (ensiling, deepstacking and composting) on fiber characteristics of BL.

MATERIALS AND METHODS

Processing of broiler

Broiler litter, collected fresh from a local broiler farm, was prepared for raw broiler litter (RBL), ensiled broiler litter (EBL), deepstacked broiler litter (DBL) and composted broiler litter (CBL) in an experiment station of our university. For RBL, the litter was screened through a 4 cm^2 diameter to remove lumps. For EBL, the RBL was ensiled in a 200 L plastic container double lined with polyethylene bags and sealed in an airtight manner. DBL and CBL were prepared in wooden cells with length of 1.0 m, depth of 1.2 m, and width of 1.0 m in a covered shed open on all sides. CBL was aerated once daily during the first week of the processing period, every other day during the second week, and weekly for the next 2 weeks. Meanwhile, DBL was not disturbed during the whole period of processing (4 weeks). Rice hulls (RH) and RS were also collected fresh from the experiment station and used as negative and positive controls, respectively. All the samples of BL were collected from the center of the ferments after the 4 week processing period and stored at -20°C.

Animal and *in situ* experiment

Four *in situ* dacron bag digestion trials were carried out

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Table 1. Chemical composition of substrates

Item	Rice hulls	Rice straw	Broiler litter[1]			
			RBL	EBL	DBL	CBL
Dry matter, %	91.9	88.9	69.7	69.2	72.0	76.7
	---------- % DM ----------					
Organic matter	87.1	89.3	80.7	82.9	83.2	82.6
Crude protein	2.2	4.1	19.2	18.2	20.9	19.0
Ether extract	1.0	0.8	1.1	1.9	1.6	1.4
Neutral detergent fiber	79.3	71.6	59.2	55.5	54.8	58.8
Acid detergent fiber	59.8	40.9	36.6	37.5	36.3	41.4
Hemicellulose	19.5	30.7	22.6	18.0	18.5	17.4
Crude ash	12.9	10.7	19.3	17.1	16.8	17.5

[1] RBL=raw broiler litter; EBL=ensiled broiler litter; DBL=deepstacked broiler litter; CBL=composted broiler litter.

using a ruminally cannulated sheep fed twice daily (09:00 h and 17:00 h) with 60% concentrate and 40% forage diet. The sheep was adapted to the diet for 7 d prior to the trial and given free access to water and mineral-vitamin block during the whole experiment.

The *in situ* dacron bag technique was that of Nocek (1985) with modifications. Samples (RH, RS, RBL, EBL, DBL and CBL) were dried at 65°C for 24 h and were prepared by grinding through a 2 mm mesh screen of a Wiley Mill. In order to minimize the washout portion of fine sample particles through dacron bag pores, the ground samples were mechanically sieved and particle sizes in the range of 250 μm and 1.14 mm were used for ruminal incubations. Dacron bags were 5×10 cm and 53 μm porosity. Approximately 1.5 g of samples were weighed into bags. The ratio of sample size to bag surface area was approximately 15 mg/cm^2. *In situ* DM and NDF disappearances were determined by suspending the dacron bags in the rumen of sheep. A set of bags across the treatments was incubated for 24, 48 and 72 h in the rumen. All bags were removed at the end of the incubation period and rinsed in a continuous flow of tap water for approximately 24 h until the water appeared clear. Bags were dried at 60°C for 48 h and weighed to determine *in situ* DM and NDF disappearances. NDF was determined according to Van Soest et al. (1991).

Feed DM was classified into three fractions (Armentano et al., 1986). Fractionation of NDF was made using the method of Smith et al. (1971). The method for determination of NDF digestion rates was that of Nocek and English (1986) with no lag time. The concentration of NDF remaining after 72 h of *in situ* digestion was used as an estimate of non-digestible NDF concentration. Residues at each incubation time minus the non-digestible fraction were converted to percentage, transformed to the natural logarithm, and subjected to linear regression. The model used to estimate digestion for DM and NDF was that of Mertens and Loften (1980). Slope of the regression line was a rate of digestible B fraction (K_dB). Computed digestion rates were used to estimate digestion for DM and NDF, using the model suggested by Mertens and Loften (1980). The assumed passage rates (K_dB) were 0.025 or 0.05/h (Miller, 1982).

In vitro experiment

A cannulated sheep of approximately 40 kg body weight was used as a donor of rumen fluid. The sheep was *ad libitum* fed twice daily (09:00 h and 17:00 h) with 60% concentrate and 40% forage diet and given free access to water and mineral-vitamin block. Samples (RH, RS, RBL, EBL, DBL and CBL) were prepared as described at the above *in situ* experiment.

This *in vitro* experiment was conducted according to Tilley and Terry's method (1963) with modifications. Fresh rumen fluid was obtained from the rumen of a cannulated sheep, 3 h after feeding. The fluid was collected in a thermos bottle previously kept warm (39°C) and filled with O_2-free CO_2 gas and later strained through four layers of surgical gauze. Buffer mixture by McDougall (1948) was used for medium. The rumen fluid was mixed with buffer medium at the ratio of 1:4 (v/v). Forty ml of rumen fluid-buffer mixture was placed in 50 ml test tubes containing 0.5 g of samples as substrate under a CO_2 gas phase. The test tubes were sealed with butyl rubber stoppers and aluminum seals. Duplicate was prepared for each treatment. To account for potential substrates contained in inoculum, one test tube per sample was prepared with inoculum and no added sample as a blank. Test tubes were incubated in 39°C incubator for 24, 48 and 72 h.

Dry matter, organic matter, crude ash, and ether extract were determined as described by AOAC (1990). At the each incubation period, the cultures were transferred into centrifuge tube and centrifuged at 14,000×g for 20 min. Residual pellets were harvested for analyses of DM and NDF disappearances. NDF was determined according to Van Soest et al. (1991). *In vitro* DM disappearances were measured by drying residual pellets at 60°C for 48 h. Blank without sample was used to correct effects of potential substrates contained in inoculum.

Data obtained were analyzed by one-way analysis of

Table 2. *In situ* DM water-soluble and 53 μm filterable, insoluble digestible, and non-digestible fractions and disappearance at each incubation period of substrates dry matter[1] (%)

Item	Rice hulls	Rice straw	Broiler litter[2]				SE
			RBL	EBL	DBL	CBL	
Fractions							
Water-soluble and 53 μm filterable	2.4[a]	11.9[b]	17.5	19.7	21.0	19.1	2.5
Insoluble digestible	3.7[a]	32.4	43.4[c]	31.8	30.6	24.4	2.6
Non-digestible	93.9[a]	55.7	39.1[c]	48.5	48.4[d]	56.5	2.0
Disappearance at incubation period (h)							
0	0.3[a]	12.9[b]	18.5	18.9	18.8	16.5	1.0
24	0.3[a]	23.0[b]	42.2	36.7	40.9	34.0	2.9
48	1.7[a]	31.1[b]	48.5	43.1	45.4	38.4	2.4
72	3.3[a]	44.2	60.8[c]	48.9	51.4[d]	42.8	1.6

[1] Least square means of 5 observations. [2] RBL=raw broiler litter; EBL=ensiled broiler litter; DBL=deepstacked broiler litter; CBL=composted broiler litter [a] RH differs from BL ($p<0.0001$). [b] RS differs from processed BL ($p<0.05$). [c] RBL differs from processed BL ($p<0.05$). [d] DBL differs from CBL ($p<0.05$).

Table 3. *In situ* digestion rate of digestible fraction (K_dB) and digestibility at two rates of passage of substrates dry matter[1]

Item	Rice hulls	Rice straw	Broiler litter[2]				SE
			RBL	EBL	DBL	CBL	
K_dB (%/h)	2.0	3.4	4.7	4.3	3.4	3.4	0.7
Digestibility at K_pB[3] (%)							
0.025	3.7[a]	25.7[b]	41.4	36.8	38.4	34.1	1.9
0.05	3.1[a]	21.1[b]	35.9	31.7	33.5	30.1	2.0

[1] Least square means of 5 observations. [2] RBL=raw broiler litter; EBL=ensiled broiler litter; DBL=deepstacked broiler litter; CBL=composted broiler litter. [3] Rates of passage (K_pB) were assumed to be 0.025 and 0.05/h. [a] RH differs from BL ($p<0.0001$). [b] RS differs from processed BL ($p<0.0005$).

variance (SAS Institute, Inc., 1990). Contrasts of means among treatments were RH vs. BL (RBL, EBL, DBL and CBL), RS vs. processed BL (EBL, DBL and CBL), RBL vs. processed BL, EBL vs. DBL and CBL, and DBL vs. CBL (SAS Institute, Inc., 1990).

RESULTS AND DISCUSSION

Chemical compositions of substrates

Chemical composition of substrates is presented in Table 1. For RH, contents of ether extract, NDF, and ash were similar and contents of crude protein and acid detergent fiber were somewhat low (2.2 vs. 3.1% for crude protein and 59.8 vs. 68.7% for acid detergent fiber) compared with those in NRC (1996). For RS, contents of crude protein, NDF and acid detergent fiber were similar to values in KNRC (1992). For BL, contents of DM and crude protein were lower and contents of NDF and acid detergent fiber were much higher than those reported from the United States (Martin et al., 1983; Ruffin and McCaskey, 1990; Patil et al., 1993). Park et al. (2000) in Korea reported that the average of DM and NDF levels of 57 BL samples collected from 47 farms in Korea were 62.2 and 46.5%, respectively. These differences in chemical composition between samples from two countries were attributed mainly to different bedding materials and frequency of litter collection.

Among the processed BL, CBL showed the highest DM. When compared with RH and RS, processed BL were remarkably higher in CP and ash contents, but lower in NDF content. It is difficult to quantify the origin of BL fiber between bedding materials and excreta. In consideration of the report by Ko and An (1987) that broiler excreta without bedding materials contained 45% of NDF and 25% of acid detergent fiber, majority of BL fiber must originate from the indigested excreta. In addition, NDF content in poultry excreta is affected by the nutritional plane of poultry diets (Evans et al., 1978).

Contents of NDF in processed BL were similar to that of RBL, whereas contents of hemicellulose in BL were decreased after processing. Therefore, hemicellulose fraction of BL appeared to be the primary fiber component degradable during the processing.

In situ experiment

In situ DM fractions and disappearance of substrates are presented in Table 2. Compared with BL, RH had absolutely low ($p<0.0001$) soluble and insoluble digestible fractions, and high ($p<0.0001$) non-digestible fraction. Compared with RS, processed BL had high ($p<0.05$) soluble and 53 μm filterable DM fraction and similar insoluble digestible and non-digestible DM fractions. Processing BL decreased insoluble digestible fraction ($p<0.05$) and increased non-digestible fraction ($p<0.05$). Composting litter increased ($p<0.05$) non-digestible DM fraction compared with deepstacking.

In situ DM disappearance of RH, as expected from the highest non-digestible DM fraction, was extremely low compared with those of BL ($p<0.0001$). Processed BL had consistently higher ($p<0.05$) disappearance at all the

Table 4. *In situ* digestible and non-digestible fractions and disappearance at each incubation period of substrates neutral detergent fiber[1] (%)

Item	Rice hulls	Rice straw	Broiler litter[2]				SE
			RBL	EBL	DBL	CBL	
Fractions							
Digestible	7.9[a]	41.0[b]	44.9[c]	31.8	35.1	29.9	2.0
Non-digestible	92.1[a]	59.0[b]	55.1[c]	68.1	64.9	70.1	2.0
Disappearance at incubation period (h)							
0	3.8	6.6	4.5	5.0	5.4	8.4	1.8
24	3.7[a]	17.6	25.4	14.9	20.5	20.0	3.1
48	5.0[a]	25.5	35.8[c]	23.3	26.7	24.8	3.7
72	8.0[a]	41.1[b]	48.8[c]	30.9	35.0	29.9	2.5

[1] Least square means of 5 observations. [2] RBL=raw broiler litter; EBL=ensiled broiler litter; DBL=deepstacked broiler litter; CBL=composted broiler litter. [a] RH differs from BL ($p<0.0001$). [b] RS differs from processed BL ($p<0.05$). [c] RBL differs from processed BL ($p<0.05$).

Table 5. *In situ* digestion rate of digestible fraction (K_dB) and digestibility at two rates of passage of substrates neutral detergent fiber[1]

Item	Rice hulls	Rice straw	Broiler litter[2]				SE
			RBL	EBL	DBL	CBL	
K_dB (%/h)	0.17[a]	1.84[b]	2.06[c]	1.51	1.68[d]	1.35	0.07
Digestibility at K_pB[3] (%)							
0.025	0.2[a]	15.1[b]	20.1[c]	13.1	13.5[d]	9.0	1.0
0.05	0.1[a]	9.4	13.0[c]	8.2	8.4[d]	5.4	0.7

[1] Least square means of 5 observations. [2] RBL=raw broiler litter; EBL=ensiled broiler litter; DBL=deepstacked broiler litter; CBL=composted broiler litter. [3] Rates of passage (K_pB) were assumed to be 0.025 and 0.05/h. [a] RH differs from BL ($p<0.0001$). [b] RS differs from processed BL ($p<0.05$). [c] RBL differs from processed BL ($p<0.0001$). [d] DBL differs from CBL ($p<0.05$).

incubation periods except 72 h than RS. Processing and especially composting litter reduced ($p<0.05$) DM disappearance at 72 h incubation period.

In situ digestion rate of digestible fraction (K_dB) and digestibility of DM are shown in Table 3. There was no significant difference detected in K_dB among the treatment groups. However, digestibilities at rates of passages (K_pB) of 0.025 as well as 0.05/h were extremely low ($p<0.0001$) in RH compared to BL and considerably high ($p<0.0005$) in processed BL compared with RS. Processing methods of litter did not affect *in situ* DM digestibility. The low values for RH may be due to high contents of ash, silica, fiber, lignin and cutin in RH, as suggested by Muller (1980). The values of K_dB and *in situ* digestibility of rice hulls-bedded BL DM in the present study were much lower than those of wood shavings-bedded BL which contained relatively 2.5-fold more soluble fraction and less non-digestible fraction (Kwak et al., 1998).

In situ NDF fractions and disappearance are presented in Table 4. Compared with BL, RH was extremely low in digestible NDF fraction and considerably high in non-digestible NDF fraction ($p<0.0001$). Processed BL showed obviously lower digestible and higher non-digestible fractions of NDF than RS ($p<0.05$). In addition, processing litter resulted in lower digestible and higher non-digestible fractions of NDF ($p<0.05$); however, significant differences were not detected among processed BL.

With regard to *in situ* NDF disappearance at each incubation period, RH had much lower NDF disappearances than BL at 24, 48 and 72 h incubation ($p<0.0001$). When compared with RS, processed BL had similar NDF disappearance at 0, 24 and 48 h incubation and lower ($p<0.05$) disappearance only at 72 h incubation. Processing litter decreased NDF disappearance ($p<0.05$). Among processed BL, there was no significant difference detected. In general, NDF in RS and processed BL was slowly and consistently digested through the 72 h incubation period. These values were much lower than those of BL bedded with RS and pine shavings reported by Park et al. (1997).

Digestion rate of digestible fraction (K_dB) and digestibility of NDF are shown in Table 5. RH showed extremely lower ($p<0.0001$) K_dB than BL. Processed BL had lower K_dB than RS ($p<0.05$) and RBL ($p<0.0001$). DBL had higher ($p<0.05$) K_dB than CBL.

NDF digestibilities at rates of passages (K_pB) of 0.025 and 0.05/h were extremely lower ($p<0.0001$) for RH than those for BL. RS had higher ($p<0.05$) NDF digestibility than processed BL. Processing litter resulted in lower NDF digestibility, indicating that litter fiber left through anaerobic or aerobic fermentation becomes less digestible, probably due to the hydrolysis of the readily digestible hemicellulose fraction. Among processed BL, DBL had higher ($p<0.05$) NDF digestibility than CBL. In other words, composting litter did not improve nutrient utilization, as reported by Rude et al. (1994). Based on an *in vivo* study conducted by Kwak et al. (2002), acid detergent fiber in composted BL tended to be digested more in the hindgut of sheep. NDF digestibilities at both rates of passages of DBL, which were the most desirable among processed BL, were

Table 6. *In vitro* dry matter (DM) and neutral detergent fiber (NDF) disappearance of substrates at each incubation period[1] (%)

Item	Rice hulls	Rice straw	Broiler litter[2]				SE
			RBL	EBL	DBL	CBL	
DM disappearance at incubation period (h)							
24	0.1[a]	17.5	31.1	25.0	31.5	27.5	3.4
48	9.4[a]	23.1	35.8	33.2	32.3	30.0	5.5
72	11.8[a]	28.7	42.6	35.4	34.2	31.8	5.7
NDF disappearance at incubation period (h)							
24	3.1	8.5	24.4	18.0	21.1	15.0	4.8
48	5.7[a]	11.4	33.8	19.0	21.5	18.9	3.9
72	7.7	23.6	33.6	18.7	26.4	24.8	5.9

[1] Least square means of 4 observations. [2] RBL=raw broiler litter; EBL=ensiled broiler litter; DBL=deepstacked broiler litter; CBL=composted broiler litter. [a] RH differs from BL ($p<0.05$).

comparable to those of RS.

In vitro experiment

In vitro DM and NDF disappearances of substrates are presented in Table 6. At all incubation periods, *in vitro* DM disappearances of RH were significantly lower ($p<0.05$) than those of BL. RS was similar to processed BL in *in vitro* DM disappearance due to the large variation. Among BL, differences did not exist. In general, *in vitro* DM disappearances for BL were not different from those (an average of 40%) reported in the United States (McCaskey et al., 1990). Israeli researchers (Silanikove and Tiomkin, 1992) reported a higher level (46%) of *in vitro* DM disappearance. In the present study, *in situ* DM disappearance was consistently higher than *in vitro* DM disappearance across treatments; however, the direct comparison could not be qualified because of different rumen contents used and incubation environment between two techniques.

With regard to *in vitro* NDF disappearance, there was no significant difference detected among substrates at all incubation periods with the exception of lower ($p<0.05$) NDF disappearance of RH at 48 h incubation period. In general, intrinsically high variation of *in vitro* experiments resulted in no differences detected among substrates except RH, which had significantly low nutrients disappearance. *In vitro* NDF disappearance of DBL in this experiment was similar to that reported by Patil et al. (1993). Smith and Lindahl (1977) reported that cell wall digestibility of poultry excreta was similar to that of alfalfa. This means that RH used as a bedding material must lower the quality of litter fiber. In addition, nutrient quality of poultry litter will be inversely proportional to quantity of bedding materials used in the poultry farm.

CONCLUSIONS

Our results indicate that rice hulls-bedded BL had absolutely better nutrient characteristics such as *in situ* DM and NDF fraction, ruminal disappearance and digestion than rice hulls. Processing or preservation of BL must affect adversely the quality of litter fiber left thereafter. Our *in situ* DM data suggest that the nutrient characteristics of RH-bedded BL appeared to be inferior to those of wood shavings-bedded BL, which is widely used in other continents of the world. DBL was more desirable in *in situ* DM parameters than and comparable in *in situ* NDF parameters to RS. This fact may explain why beef cattle fed DBL in partial replacement of RS performed better. Broiler litter in substitute for RS can be utilized as an economical roughage source at low to medium production of ruminants.

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