Effects of Bedding Materials and Season on the Composition and Production Rate of Broiler Litter as a Nutrient Resource for Ruminants

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ABSTRACT : Broiler litter can be used as a feedstuff for ruminants. Fifty seven litter samples collected from 47 farms in Kyungkee Province of Korea were analyzed to assess the effects of type and amount of bedding (rice hulls vs. sawdust), season (winter vs. summer) and drinkers (bell- vs. trough-type) on composition of broiler litter. Rearing conditions of broilers were also surveyed from the farms to estimate annual production rate of litter. Nutrient composition of broiler litter varied widely and moisture and ash concentrations were higher than observed by other researchers. Ash concentration was higher ($p<0.05$) for samples taken in winter than in summer and higher ($p<0.05$) in the rice hulls- than in the sawdust-based litter both in winter and summer. Only minor differences in litter composition were noted between drinkers. Ash was negatively correlated with crude protein and neutral detergent fiber ($p<0.01$), and acid detergent fiber ($p<0.05$). The estimated litter production rate was 2.7 kg per bird per flock on a wet basis (60% DM) and the annual production rate was 12.7 kg per bird per yr (60% DM). Therefore, the 42 million broilers per month grown in Korea in 1999 produced a total of 533,400 metric tons of litter. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 11 : 1598-1603)*

Key Words : Broiler Litter, Bedding Material, Litter Composition, Litter Production Rate, Waste Management

INTRODUCTION

Broiler production is prevalent in most countries of the world, resulting in a vast amount of litter in need of disposal. Currently, most broiler litter is used as a source of nutrients for plants. However, the value of broiler litter is much greater when used as a ruminant feedstuff (Fontenot, 1990). The economic feasibility of using broiler litter as a dietary ingredient is enhanced in countries such as Korea in which most feed ingredients are imported.

A fundamental step in establishing any waste management or recycling plan is to accurately assess the amount and composition of the litter generated. Estimates of these parameters on a per bird basis are often extremely variable due to many factors, including type and amount of bedding materials, frequency of litter cleanout, length of growing period, type of equipment and most importantly the general management of farms (Malone, 1992b). Length of stockpiling can also affect nutrient composition of broiler litter (Park et al., 1995a, b).

Undoubtedly, broiler management practices vary widely both among countries and between broiler production areas. The objectives of this study were to evaluate the amount and composition of litter produced, based on different types of bedding, season and drinkers. Precautions and indices of selecting the litter used as a ruminant diet are also presented.

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Received April 6, 2000; Accepted June 28, 2000

MATERIALS AND METHODS

Sample collection

A total of 57 samples of broiler litter were collected from 47 farms scattered in Kyungkee Province of Korea over winter (December to March) and summer (June to September). Samples were taken from several locations in the broiler house, composited, and a representative sample taken for analysis. The house region, flock number, growing period, type of bedding and drinker were recorded for each sample. The flock number indicates the number of batches of broiler production per year, each requiring 5 to 6 weeks for grow-out (final weight 1.5 kg) since the litter had been cleaned out. A questionnaire was also provided to farm owners to investigate the general management and facilities including type and amount of bedding, drinker type, growing period, flock density and flock number.

All litter samples were from dirt floor broiler houses. The most commonly used bedding material was rice hulls because of its relatively high availability and low price. Use of sawdust as a bedding was found in a very limited number of cases (approximately 10% of all farms) and was normally specific to a certain broiler production region. However, a comparable number of samples for the sawdust-based litter was collected to assess the effects of bedding type on litter composition in winter (n=9) and summer (n=12). Drinker was either bell- or 2.4 m trough-type.

Measurements

An aliquot of sample was analyzed wet for determining concentrations of crude protein (CP; AOAC, 1984) and nonprotein nitrogen (NPN; Prigge et al., 1976) to prevent loss of ammonia by drying. Another larger aliquot was dried in a forced-air oven at 55℃ for 24 h, allowed to air-equilibrate, and ground through a 2 mm screen. Thereafter, samples were analyzed for DM, ash (AOAC, 1984), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and acid detergent insoluble nitrogen (ADIN; Goering and Van Soest, 1970). Fiber analyses were performed on an ash-free basis to avoid potential influence of soil contamination of broiler litter. Bedding materials (rice hulls and pine sawdust) obtained from different farms were also composited respectively and analyzed for DM, ash, NDF, ADF and ADL.

Statistical analyses

Data were analyzed by General Linear Models (GLM) procedures of the SAS (1990). Data from samples containing excessive amounts of ash (3 samples) or ADIN (2 samples) were omitted when assessing effects of bedding (rice hulls vs. sawdust), season (winter vs. summer) and drinkers (bell- vs. trough-type) because litters highly contaminated with soil or extremely composted will not be chosen for animal feeds.

Differences among means were determined by least significant difference procedures when the F-test was significant ($p<0.05$). Coefficients were calculated for the correlation of ash concentration with the other components of litter.

RESULTS AND DISCUSSION

Rearing conditions of broilers

Rearing conditions of broilers surveyed in this study are presented in table 1. Differences in rearing conditions among broiler farms were small except for the amount of bedding used per flock. Typically, broiler market weight in Korea is lower than that in other countries. For instance, Malone (1992b) reported that growing periods of broilers in Delaware, USA, averaged 51 days with 2.1 kg of market weight. In this survey, growing period averaged 37.2 days with approximately 1.5 kg weight. However, average number of flocks per year was only 4.7 and this number was fairly consistent among farms regardless of type of bedding used.

The amount of rice hulls used per flock was 464 g/bird or 6.6 kg/m^2. Density of bedding materials was 104 g/l and 174 g/l for rice hulls and sawdust, respectively. Bedding depth of 10 cm is generally recommended for rice hulls in summer. Based on the calculation from bedding density and recommended bedding depth, the amount of rice hulls used in farms is 36% less than the recommended level.

It is therefore a common practice that producers using rice hulls remove litter after each flock and often add extra bedding on wet areas in the broiler house during the growing period of birds. In a rare case, producers use briquette ash to reduce litter moisture. For instance, three samples in this study were extremely high in ash (60.7, 75.6 and 80.0%; DM basis) and low in CP (16.8, 8.4 and 9.5%; DM basis). Contrarily, producers using sawdust remove the litter once every 0.5 to 2.0 yr (average 1.0 yr) with removal of caked litter after each flock.

The selling price of the rice hulls litter as a fertilizer ranged from 0 to 16.7 US dollars, whereas the price of the sawdust litter ranged from 25.0 to 50 dollars. The average selling price was 6.7 times higher for the sawdust litter. Consequently, a part of expense to purchase sawdust can be offset by selling the litter.

Composition of broiler litter

The average and range of nutrient components of broiler litter collected in Korea, along with data from different researchers, are presented in table 2. The average DM level of the samples in this study was considerably lower than others and the lowest value was 39.2% (60.8% moisture). Based on the farm survey in this study, high moisture litter was caused by several factors: 1) type of beddings (rice hulls vs. sawdust); 2) amount of bedding used; and 3) ventilation rates of broiler house associated with inadequate insulation.

The most popular and frequently used bedding in

Table 1. Rearing conditions of broilers

Bedding	Growing period (Day)	Flock no. per year	Amount of bedding (g/bird)	Bird density (No./m^2)	Selling price of litter (US $/ton)[2]
Rice hulls	37.3±3.3	4.8±0.5	464±70.8	14.3±1.8	5.3±2.5
Sawdust	37.1±3.5	4.7±0.5	932±150.6[3], 264±40.1[4]	14.1±0.6	35.6±4.2
Total	37.2±3.5	4.7±0.5		14.2±1.2	

[1] Values are means±SD.

[2] US $ 1=Korea ₩ 1,200.

[3] Amount of bedding used after complete cleanout of litter.

[4] Additional amount of bedding used after each flock.

Korea was rice hulls. It could compare favorably to wood shavings or sawdust in both physical characteristics and poultry performance (Hester et al., 1984; Veltmann et al., 1984). However, water holding capacity of rice hulls is approximately one half that of the sawdust (1.0 vs. 1.9~2.5; Malone, 1992a). This indicates that bedding depth must be high enough to exert its bedding effects. Producers in Korea have empirically found that the ideal bedding depth for rice hulls is 10 cm in summer, and 15 cm, to exclude cold air from the floor, in winter. Actual amounts of bedding used in common broiler farms were however far less than this recommended level mainly due to the high cost of bedding materials.

Bird density was higher (average 14.2 birds/m^2) than the recommended level (10~12 birds/m^2; North, 1984). The difference between 11 vs. 14 birds/m^2 in a 660m^2 broiler house represents a difference of 2,112 more birds growing in the house, resulting in higher litter moisture due to increased manure production.

Although not estimated in this study, an equally important factor affecting litter moisture is ventilation rate. Undergoing a relatively long and cold winter in Korea, producers tend to reduce ventilation rates of broiler houses to save heating costs. Furthermore, conventional broiler houses with insufficient insulation are still prevalent, and not suitable for adequate ventilation in cold winter.

On the contrary, in a hot and humid summer with occasional heavy rainfalls, producers often do not realize the need for a higher ventilation rate. Kunkle et al. (1981) noted an 8.5% higher litter moisture and 5% lower CP in test pens with ventilation rates at one-half standard rate than at double the standard rate. Weaver and Meijerhof (1991) also reported that reduced or low ventilation rates increase litter moisture.

It is a common practice to add extra bedding on wet spots, especially in case of rice hulls bedding, but often this is useless because the problem is associated with many factors that contribute to higher litter moisture and result in diluted litter nutrient density, increased handling and transportation costs, and a greater potential for odor problems. Furthermore, wet litter and associated caking problems lead to poultry health problems such as foot pad lesions and coccidiosis, retarded growth (Martland, 1985), increased incidence of breast blisters and higher bedding replacement cost (Malone, 1992a). Therefore, litter with high moisture would not only influence quality of litter generated, but also reduce productivity and income of broiler farms.

Table 2. Nutrient composition of broiler litter

Component	Reference[1]	Minimum	Maximum	Mean	SD
DM, %	A	34.5	82.9	62.2	13.8
	B			84.7	4.2
	C	60.8	89.1	75.0	
	D	61.0	95.3	80.5	
Ash[2]	A	13.8	80.0	30.5	15.1
	B			15.0	3.2
	C	10.8	30.1	17.5	
	D	8.9	54.4	24.7	
CP[2]	A	8.4	44.1	26.1	7.8
	B			31.3	2.9
	C	18.8	38.1	28.8	
	D	14.4	37.5	24.9	
NPN[3]	A	6.8	85.2	50.5	19.5
ADIN[3]	A	5.5	67.0	14.9	12.3
	D	5.1	64.3	15.0	
NDF[2]	A	23.4	66.5	46.5	8.3
ADF[2]	A	14.3	64.9	33.4	12.0
	D	18.0	69.1	41.1	
ADL[2]	A	3.6	45.2	10.7	7.2

[1] A: the present study (n=57); B: Bhattacharya and Taylor (1975, average of different data); C: Flachowsky and Hennig (1990, n=90), D: Stephenson et al. (1990, n=106).
[2] % of DM.
[3] % of total nitrogen.

The ash concentration in litter was extremely variable, averaged 30.5% and ranged from 13.8 to 80.0%. According to a survey by Stephenson et al. (1990), ash concentration in broiler litter also varied widely (table 1), mainly because of differing degrees of soil contamination during its removal from dirt floor houses. Ruffin and McCaskey (1990) recommended that for broiler litter to be effectively used in ruminant diets, ash should not be more than 28% of DM.

The average CP was similar to those found by other researchers but the range was more variable, especially in lowermost values. Nonprotein nitrogen comprised 50.5% of total N, indicating that true protein is approximately a half of total CP in broiler litter.

Concentration of ADIN, meaning unavailable N for ruminants, averaged 14.9% of total N and ranged from 5.5 to 67.0%. Ruffin and McCaskey (1990) suggested that for efficient use of litter as a ruminant feed stuff, ADIN should be no more than 25% of total N. High level of ADIN must arise from the deterioration of protein and low level may be a good sign of protein quality of litter. However, too low an ADIN value may also indicate low CP or insufficient fermentation of litter.

Interestingly, two samples collected from charred and combusted litter were extremely high in ADIN, 66.1 and 67.0%. The combusted litter, used sawdust as a bedding, was stored in plastic gunny bags and stacked outside in a well aerated area. The farm owner noted smoke rising from the litter stacks and sprinkled water on it, but it resulted in completely charred litter and a part of the plastic bags was melted away.

Fiber in broiler litter is principally derived from the bedding material used and can be utilized as a substitute for hay and other sources of dietary fiber (Stephenson et al., 1990). However, the beddings are usually finely ground or short fibrous materials. Thus, the fiber in the litter cannot effectively meet the need of fiber for ruminants. Rossi et al. (1996) suggested that a minimum of 15% DM intake (0.6% BW) in the litter-based diets should be provided in the form of long hay for bloat prevention and high intake. Neutral detergent fiber values were not provided by authors cited in table 2. However, the level of ash-free NDF was similar to those found by Mandebvu et al. (46.5, 49.1, 44.1 and 43.1% without ash; 1995) though generally higher than observed by others (Silanikove and Tiomkin, 1992 : 44%; Patil et al., 1993 : 40 and 44%; Rossi et al., 1996 : 43.2%). The average ADF concentration was 33.4%, ranged from 14.3 to 64.7%. The ADL concentration varied from 3.6 to 45.2%, averaged 10.7%.

Bedding effects on litter composition

The bedding effects (winter plus summer samplings) on litter composition are presented in table 3. The DM concentration was a 7.4% unit lower for rice hulls- than for sawdust-based litter though it was not significant. Lower water holding capacity of rice hulls compared to sawdust could explain part of this difference. Most broiler litter fed to ruminants is processed by deep-stacking at approximately 25% moisture, at least 1.4 m high and for a minimum of 3 weeks (Fontenot, 1990; Ruffin and McCaskey, 1990). If moisture is higher than this level, broiler litter can be processed by ensiling with forages and/or grains (Ruffin and McCaskey, 1990).

The ash concentration (DM basis) was significantly higher ($p<0.05$) for rice hulls- than for sawdust-based litter. In part, this may have resulted from a higher concentration of ash in rice hulls (15.7% DM) than in sawdust (1.6% DM). However, the difference in ash concentration between two beddings could also relate to differences in season and litter management.

The CP (DM basis) and NPN (total nitrogen basis) concentrations were similar between the litters from the two beddings, but the ADIN (total nitrogen basis) was significantly lower ($p<0.05$) for the rice hulls (11.2%) than for the sawdust litter (17.1%). Considering the high concentrations of moisture and ash in the rice hulls-based litter, the lower concentration of ADIN than in the sawdust litter may be because the extent of fermentation was less during the growing period of the broilers.

The concentrations of fiber fractions (NDF, ADF and ADL) were significantly higher ($p<0.05$) for the sawdust litter, reflecting the higher level of fiber in sawdust. In this study, the NDF, ADF and ADL concentrations in the beddings were 78.9, 59.9 and 19.3% for rice hulls and 95.0, 80.6 and 29.4% for sawdust, respectively.

The bedding effects separated by season (winter and summer) on litter composition are presented in table 4 and 5. Both in winter and summer, the DM concentration was lower and the ash was significantly higher ($p<0.05$) for rice hulls-based litter, reflecting low water holding capacity and high ash in rice hulls. Comparing between winter and summer, the ash was higher in the winter samples than the summer ones (40.2 vs. 23.5%) and the difference was significant ($p<0.05$). Factors responsible for this result are unclear; however, a higher incidence of soil contamination may have occurred in winter by

Table 3. The composition of broiler litter (winter and summer samplings) as influenced by rice hulls and sawdust bedding materials

Component	Rice hulls[1]		Sawdust[2]	
	Mean	SD	Mean	SD
DM, %	61.2	13.2	68.6	10.2
Ash[3]	30.1[a]	10.5	24.0[b]	7.4
CP[3]	27.4	6.8	24.0	6.9
NPN[4]	51.2	19.6	46.54	22.7
ADIN[4]	11.2[b]	4.0	17.1[a]	5.2
NDF[3]	45.4[b]	4.5	55.0[a]	6.4
ADF[3]	29.4[b]	5.3	40.7[a]	15.2
ADL[3]	8.9[b]	1.8	17.4[a]	10.8

[1] n=31. [2] n=21. [3] % of DM. [4] % of total nitrogen.
[a,b] Means in a row without a common following letter differ ($p<0.05$).

Table 4. The composition of broiler litter (winter sampling) as influenced by rice hulls and sawdust bedding materials

Component	Rice hulls[1]		Sawdust[2]		Total	
	Mean	SD	Mean	SD	Mean	SD
DM, %	59.3	13.9	68.1	10.6	62.2	13.2
Ash[3]	42.8[a]	7.5	34.9[b]	2.3	40.2	10.5
CP[3]	25.9	6.2	25.6	3.1	25.8	4.9
NPN[4]	51.7	11.8	50.9	7.6	51.4	9.8
ADIN[4]	10.6	3.8	9.6	1.6	10.2	3.3
NDF[3]	44.7[b]	3.8	54.1[a]	1.6	47.8	6.7
ADF[3]	24.6	8.3	31.2	3.3	29.0	8.4
ADL[3]	8.5	2.1	10.3	1.3	9.1	2.1

[1] n=10. [2] n=9. [3] % of DM. [4] % of total nitrogen.
[a,b] Means in a row without a common following letter differ ($p<0.05$).

scratching, and from disturbance of the dirt floor during litter collection.

No differences in concentrations of other components were observed between the rice hulls and sawdust litter in winter except NDF; the NDF concentration was higher ($p<0.05$) for the sawdust litter. In summer, the ADIN concentration was significantly higher ($p<0.05$) for the sawdust litter, presumably because of higher and more extensive fermentation of the sawdust litter. The levels of NDF, ADF and ADL were significantly higher ($p<0.05$) for the sawdust litter, reflecting the higher concentration of fiber in sawdust.

There were only minor differences in litter composition between bell- and trough-type drinkers. The levels of DM and NDF tended to be slightly higher for the litter from bell-type drinker.

Overall, these results suggested that sawdust bedding can give benefits for quality of litter generated and probably even for broiler production through reduced health problems and bedding replacement cost. Considering the relatively high price of sawdust, a mixture of rice hulls and sawdust can be an alternative.

Correlation between ash and other components

The fact that ash is a diluent of other components of litter is clearly verified by the data in table 6. For comparison, data from Stephenson et al. (1990) are also listed in the same table. Dry matter tended to be higher as ash level increased because the DM analysis also includes ash. All other components were negatively correlated with ash due to dilution; significant effects were noted for CP, NDF ($p<0.01$) and ADF ($p<0.05$).

Stephenson et al. (1990) reported that ADF was positively correlated with ash. On the contrary, ash-free ADF was determined in this study and was negatively correlated ($p<0.05$) with ash. Relatedly, Mandenvu et al. (1995) found that ash comprised 9, 17, 16 and 14% NDF in four different sources of broiler litter. Therefore, ash-free fiber analysis is recommended for litter which can be highly contaminated with soil.

Table 5. The composition of broiler litter (summer sampling) as influenced by rice hulls and sawdust bedding materials

Component	Rice hulls[1]		Sawdust[2]		Total	
	Mean	SD	Mean	SD	Mean	SD
DM, %	61.9	13.2	68.8	10.8	63.8	12.8
Ash[3]	25.3[a]	6.7	20.0[b]	3.2	23.5	5.3
CP[3]	28.0	7.0	23.5	8.0	26.4	7.6
NPN[4]	51.1	11.4	44.6	7.1	49.0	9.3
ADIN[4]	11.4[b]	4.1	19.4[a]	5.8	17.6	5.1
NDF[3]	45.7[b]	4.8	55.3[a]	7.5	49.0	7.4
ADF[3]	28.6[b]	3.5	46.5[a]	8.4	35.0	10.0
ADL[3]	9.1[b]	1.7	20.0[a]	6.7	12.9	8.7

[1] n=21. [2] n=12. [3] % of DM. [4] % of total nitrogen.

[a,b] Means in a row without a common following letter differ ($p<0.05$).

Litter production rate

As indicated by Malone (1992b), there are substantial variations in reported litter production rates because of numerous factors contributing to a wide range in production values. Some of the data are based solely on manure production without considering the type and amount of bedding used. Production conditions such as flock number, flock density and growing period are neither defined nor consistent among references. Furthermore, the methods for litter calculation differ and frequently are not specified.

The equation for calculation of litter production rate in this study is as follows:

$$LP=((M\times d+R)\times F_1+(M\times d+S)\times F_2)$$
$$ALP=LP\times N$$

Where, LP=litter production rate (kg litter/bird/flock); ALP=annual litter production rate (kg litter/bird/yr); M=daily manure output (0.13 kg/bird in this study); d=average growing period (37 days); R=amount of rice hulls used per flock (0.464 kg); S=amount of sawdust used per flock (0.462 kg); F_1=frequency factor for farms using rice hulls (0.9); F_2=frequency factor for farms using sawdust (0.1); N =number of flocks per year (4.7)

Assumptions in this calculation are: 1) 25% DM of broiler manure, 90% DM of beddings, and 60% DM of litter generated; 2) no decomposition of bedding materials and manure; and 3) only two types of bedding used.

Table 6. Correlation of ash concentration with other litter components

Component	Correlation coefficient (r)	
	Reference A[1]	Reference B[2]
DM	0.023	-0.174
CP	-0.517**	-0.482**
NPN	-0.143	
ADIN	-0.002	-0.078
NDF	-0.523**	-0.204[3]
ADF	-0.272*	0.326*
ADL	-0.243	

[1] The present study (n=52).

[2] Stephenson et al. (1990, n=58).

[3] Correlation coefficient for crude fiber.

* $p<0.05$; ** $p<0.01$.

Based on the equation, the litter production rate was 2.7 kg per bird per flock on a wet basis (60% DM) and the annual production rate was 12.7 kg per bird per yr (60% DM). Thus, the 42 million broilers per month raised in Korea in 1999 (KMAF, 2000) produced total of 533,400 metric tons of litter.

CONCLUSIONS

The results indicate that quality of broiler litter can be influenced by type and amount of bedding, season, and rearing conditions of birds. Thus, care should be taken to select litter for use as a feed ingredient for ruminants and a final decision must be based on nutrient composition.

With increased emphasis on waste management, the type and amount of bedding may require more serious consideration in the future. Implementation of better management systems may be required to produce a more uniform, selective litter. Then, this type of approach will necessitate the commitment and cooperation of both broiler and cattle producers.

ACKNOWLEDGEMENT

This research was funded by Special Grants Research Program provided by the Ministry of Agriculture and Forestry of The Republic of Korea.

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