Measurement of Broiler Litter Production Rates and Nutrient Content Using Recycled Litter

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ABSTRACT It is important for broiler producers to know litter production rates and litter nutrient content when developing nutrient management plans. Estimation of broiler litter production varies widely in the literature due to factors such as geographical region, type of housing, size of broiler produced, and number of flocks reared on the same litter. Published data for N, P, and K content are also highly variable. In addition, few data are available regarding the rate of production, characteristics, and nutrient content of caked litter (cake). In this study, 18 consecutive flocks of broilers were reared on the same litter in experimental pens under simulated commercial conditions. The mass of litter and cake produced was measured after each flock. Samples of all litter materials were analyzed for pH, moisture, N, P, and K. Average litter and cake moisture content were 26.4 and 46.9%, respectively. Significant variation in litter and cake nutrient content was observed and can largely be attributed to ambient temperature differences. Average litter, cake, and total litter (litter plus cake) production rates were 153.3, 74.8, and 228.2 g of dry litter material per kg of live broiler weight (g/kg) per flock, respectively. Significant variation in litter production rates among flocks was also observed. Cumulative litter, cake, and total litter production rates after 18 flocks were 170.3, 78.7, and 249.0 g/kg, respectively. The data produced from this research can be used by broiler producers to estimate broiler litter and cake production and the nutrient content of these materials.

Key words: broiler, litter, cake, production rate, nutrient

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INTRODUCTION

Manure management and disposal are 2 of the most important challenges that poultry producers face. Improper management of manure can lead to odor generation, fly breeding, and excess nutrient loading of soil and water resources. For broiler producers, accurate prediction of litter production and nutrient content is important to properly plan for the disposal of litter materials from broiler housing. In commercial broiler production, litter is commonly recycled for several flocks before an entire clean-out is performed. Removal and replacement of all litter varies widely in the industry and can range from 2 flocks to several years of production (Malone, 1992; Chamblee and Todd, 2002). Caked litter (cake) commonly found around drinkers or near evaporative cooling systems is typically greater than 35% moisture (Malone et al., 1992). It is commonly mechanically separated from the loose litter and removed from the house after each flock of broilers is marketed. The loose litter remains in the house and is recycled for the next flock of birds. This type of litter management leads to the production of 2 types of litter waste materials with potentially different characteristics and nutrient content. The removal of caked litter from broiler housing after each flock will also affect the rate of loose litter accumulation in broiler houses.

The rate of litter production and litter nutrient content can be affected by many factors, including the type and amount of bedding material used, number of flocks reared on the litter, feed formulation, litter management techniques, type of housing, ventilation rates and management, drinker management, bird health, performance parameters, stocking density, and age at time of market (Malone, 1992). As a result, estimates of litter production and nutrient content in published literature vary. Litter production data published in the peer-reviewed journal literature also provide little information regarding the amount of cake produced during broiler production. Litter production rates are most commonly reported as tons of litter on an as-is or wet basis per 1,000 broilers. Calculating litter production rates on a wet basis can introduce error into litter production estimates because of variability in moisture content. In addition, litter production calculations based on numbers of birds can also contribute to variability in estimation due to variation in bird size. From commercial broiler houses in Pennsylvania, Patterson et al. (1998) reported considerably different rates of litter production from 2 companies growing birds to different ending body weights. Farms growing smaller

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birds produced litter at a rate of 1.07 tons per 1,000 broilers, and the farms growing larger birds produced litter at a rate of 1.65 tons per 1,000 broilers. Based on several sources, Malone (1992) estimated average broiler litter production rate to be 1.0 dry metric ton per 1,000 broilers per flock with a range of 0.7 to 2.0 metric tons. Chamblee and Todd (2002) estimated broiler litter production from broilers in Mississippi to be 1.6 tons per 1,000 broilers if the houses were cleaned out completely on an annual basis, and a rate of 1 ton per 1,000 broilers if houses were cleaned out completely at the end of 2 yr. The Natural Resource, Agriculture, and Engineering Service (NRAES, 1999) reported whole litter production from broilers to be 1.25 ton per 1,000 birds with cake production at 0.4 ton per 1,000 birds. Thus, in NRAES (1999) cake represented 30 to 35% of the total litter. Depending on frequency of total house clean-out, Malone et al. (1992) reported that cake accounted for 35 to 40% of total litter production.

A great deal of variation exists between sources in the literature regarding litter nutrient content. On an as-is or wet basis, Malone (1992) reported an average of 2.94, 3.22, and 2.03% for N, P_2O_5, and K_2O, respectively, from several sources in the United States. Patterson et al. (1998) reported broiler litter in Pennsylvania to have an average N, P_2O_5, and K_2O content of 3.73, 3.11, and 2.18%, respectively. Mississippi broiler litter was reported to contain 2.85, 1.45, and 2.95% N, P_2O_5, and K_2O, respectively (Chamblee and Todd, 2002). Bowers et al. (2002) reported pine shaving litter used for 9 flocks in Alabama to contain 3.11, 1.94, and 3.28% for N, P, and K, respectively. Previous research has also indicated that the number of flocks reared on the litter has a substantial influence on nutrient densities of broiler litter (Malone et al., 1992; Bowers et al., 2002; Chamblee and Todd, 2002). In addition, very little data were found in the literature regarding the nutrient content of cake. Malone et al. (1992) reported that cake was similar in N content but was 40 to 50% lower in P and K concentrations than loose litter on an as-is basis. In contrast, Malone (1992) stated that cake nutrient density (litter used for 6 flocks) averaged 15% greater than litter on a dry-weight basis. Research is needed to accurately determine the nutrient content of loose and caked broiler litter materials.

The objectives of the current research were to 1) accurately measure litter and cake production rates from broilers reared under simulated commercial conditions over several consecutive flocks using recycled rice hull litter, and 2) characterize the nutrient content, moisture, and pH of the 2 types of litter materials produced.

MATERIALS AND METHODS

This experiment was conducted in 2 phases. In the first phase, 9 flocks of broilers (flocks 1 through 9) were reared in 4 large pens under simulated commercial conditions without any litter treatments or amendments. Prior to flock 10, equal amounts of litter were removed from the original 4 pens and distributed evenly into 2 additional pens in the same building. No litter was moved between pens again after the second phase was started (flocks 10 to 18). Three of the 6 pens continued to be managed as in flocks 1 to 9 (no litter added or litter amendments) for the continuation of this experiment. The data reported herein are from the 4 untreated pens for flocks 1 to 9 and 3 untreated pens for flocks 10 to 18. When the depth of the built-up litter became excessive (after flocks 13 and 16), a portion of the litter was discarded during the weighing process between flocks. The mass of the discarded litter was recorded. Cake was removed from the pens at the end of each flock with a silage fork. Cake mass was recorded before disposal. Loose litter remaining after cake-out was collected, weighed, and returned to each pen and recycled for the next flock.

All materials (day-old chicks (Cobb-Vantress, Siloam Springs, AR), feed, and rice hull litter) used in this study were obtained directly from a commercial broiler integrator. Broilers were reared to 40 to 42 d of age, and feed and water were provided ad libitum. All broiler management practices (lighting, ventilation, supplemental heating, mortality collection, etc.) and stocking densities were followed as previously described in Coufal et al. (2006).

Data and sample collection procedures were followed as previously described (Coufal et al., 2006). The mass of all birds and litter materials entering and leaving the facility was recorded (±0.005 kg). Litter and cake pH were determined by mixing 3 g of litter material in 60 mL of deionized water and measuring with a pH meter (Model 430, Corning Corporation, Corning, NY). Samples of all litter materials were acidified with aluminum sulfate (10 litter:1 $Al_2(SO_4)_3$ by wet weight), dried, and analyzed for total N content on a dry matter basis by the procedures described in Coufal et al. (2006). Nonacidified litter and cake samples were also dried for total P and K content analysis. Duplicate samples (0.300 g ± 0.003 g) were digested in 8 mL of concentrated sulfuric acid at 350°C in a heating block (Model 23540, Labconco Corporation, Kansas City, MO) for 45 min with 1 gram of a catalyst mixture [83.85% lithium sulfate (Mallinckrodt Baker, Inc., Phillipsburg, NJ), 13.86% cupric sulfate (Sigma Chemical Co., St. Louis, MO), and 2.29% selenium dioxide (Mallinckrodt Baker, Inc.)] added to each sample before digestion. After digestion, samples were diluted to a final volume of 50 mL with deionized water. Total P and K content were determined by inductively coupled plasma analysis using a Spectroflame Modula S analyzer (Spectro Analytical Instruments, Fitchburg, MA) at the Texas A&M University Soil, Forage, and Water Testing Laboratory.

All statistical analyses were performed by one-way ANOVA using the GLM procedure of SAS (SAS for Windows, Version 8.01, SAS Inst., Cary, NC). Flock was the source of variation in the model statement. Data from individual pens were the replicates within flock. Means between flocks for the same parameters measured were separated using the PDIFF option of GLM procedure. Statistical significance between means was determined at $P < 0.05$. All calculations for litter and cake production

Table 1. Percent moisture and average pH for recycled rice hull broiler litter and cake at the end of each flock, flocks 1 to 18[1]

Begin date (mo/yr)	End date (mo/yr)	Flock	Litter moisture (%)	Cake moisture (%)	Litter pH[2]	Cake pH[2]
7/01	8/01	1	26.1[cdef]	53.5[ab]	8.59[gh]	8.71[cd]
9/01	10/01	2	23.4[h]	53.3[ab]	8.78[def]	8.72[cd]
11/01	12/01	3	26.9[bcde]	55.6[a]	8.74[ef]	8.52[de]
1/02	2/02	4	26.2[cdef]	49.2[cd]	8.88[ab]	8.92[abc]
2/02	4/02	5	25.7[defg]	41.2[fg]	8.90[a]	8.88[bc]
4/02	5/02	6	26.6[bcde]	43.1[ef]	8.90[a]	9.14[a]
6/02	7/02	7	27.4[abcd]	45.1[ef]	8.85[abc]	8.94[abc]
7/02	9/02	8	26.0[defg]	38.4[g]	8.89[a]	9.03[ab]
9/02	10/02	9	27.2[bcd]	50.8[bc]	8.79[def]	8.38[e]
11/02	12/02	10	25.2[efg]	45.6[de]	8.57[h]	8.71[cd]
1/03	2/03	11	24.2[gh]	44.1[ef]	8.65[g]	8.79[bcd]
2/03	4/03	12	24.4[fgh]	44.8[ef]	8.72[f]	8.77[bcd]
4/03	6/03	13	26.9[bcde]	42.8[ef]	8.80[cde]	8.88[abc]
6/03	7/03	14	29.1[a]	46.4[de]	8.79[def]	8.82[bc]
8/03	9/03	15	28.4[ab]	44.8[ef]	8.82[bcd]	8.91[abc]
9/03	10/03	16	27.9[abc]	44.2[ef]	8.86[abc]	8.89[abc]
11/03	12/03	17	26.8[bcde]	46.2[de]	8.89[a]	8.87[bc]
1/04	2/04	18	28.3[ab]	52.7[abc]	8.90[a]	7.17[f]
Average			26.4	46.9	8.80	8.73
Pooled SEM			0.636	1.502	0.023	0.097

[a–h]Means within a column lacking a common superscript differ ($P < 0.05$).

[1]Flocks 1 to 9, average of 4 pens; flocks 10 to 18, average of 3 pens.

[2]n = 2 per pen.

rates and nutrient content were performed on a dry matter basis.

RESULTS AND DISCUSSION

Moisture and pH

New rice hull litter placed in the pens at the beginning of the experiment had an average moisture content of 9.4% and an average pH of 7.05. Moisture and pH data for litter and cake samples collected at the end of each flock are summarized in Table 1. Litter moisture was relatively consistent from flock to flock and ranged from 23.4 to 29.1% with an average of 26.4%. Cake moisture content was more variable than litter moisture with a range from 38.4 to 55.6% and an average of 46.9%. Cake moisture was approximately 1.5 to 2 times that of the litter. These values are similar to previously reported data by Malone et al. (1992). They reported average litter and cake moisture to be 27 and 42%, respectively, for commercial broiler houses using recycled litter and nipple drinkers. Although significant differences between flocks were observed, no consistent trends or temperature-related effects were found for litter or cake moisture. Differences in litter and cake moisture on a flock-by-flock basis were likely influenced by many factors such as ambient temperature and humidity, bird health, drinker management, and ventilation rate.

The addition of manure to the litter increased litter pH from 7.05 to 8.59 after flock 1. Litter pH increased significantly from flock 1 to flock 2, after which only small changes in pH were noted (Table 1). Average litter pH over all 18 flocks was 8.80. Cake pH was similar to litter pH with an average of 8.73. No consistent trends were observed for cake pH. These values are similar to previously published data. Moore et al. (1996) reported that untreated rice hull litter that had been used for 4 flocks had a pH of 8.75. In contrast, Carey et al. (2000) and Singh et al. (2004) reported broiler litter pH to be 8.4 to 8.5. These differences, although slight, could be due to the type of bedding material used in each study. The pH of new sawdust or wood shaving litter has been reported to be between pH 5 and 6.5 (Nahm, 2003), whereas the pH of new rice hulls used in this study was 7.05.

Nutrient Content

Nutrient content data for litter and cake are presented in Tables 2 and 3, respectively. All litter materials were analyzed on a dry matter basis. New rice hull litter at the beginning of flock 1 contained 0.47, 0.03, and 0.27% total N, P, and K, respectively. Nutrients accumulated more slowly in litter than in cake. Litter N increased significantly for the first 7 flocks, whereas cake N increased much more rapidly with significant differences only through flock 2. A similar trend was observed for P content. Cake nutrient content was also more variable than litter nutrient content. These findings are similar to those of Malone et al. (1992). They also observed large variations in cake nutrient content, and litter age was not an important factor. In this study, cake N was greater than litter N in all flocks on a dry matter basis. In contrast to N content, cake P and K contents were not always higher than litter P and K on a dry matter basis. Litter P was higher than cake P in 6 flocks, and litter K was higher than cake K in 3 flocks.

The variation in litter material nutrient levels observed in both this study and by previous authors is likely due to many of the factors previously discussed. However, one factor that warrants further consideration is that of

Table 2. Nitrogen, P, and K content of recycled rice hull broiler litter at the end of each flock on a dry matter basis, flocks 1 to 18[1]

Begin date (mo/yr)	End date (mo/yr)	Flock	N	P	K
			(%)		
7/01	8/01	1	2.08^{l}	0.85^{k}	1.97^{i}
9/01	10/01	2	2.87^{k}	1.19^{j}	2.50^{h}
11/01	12/01	3	3.18^{j}	1.38^{i}	2.87^{gh}
1/02	2/02	4	3.56^{hi}	1.59^{h}	3.12^{defg}
2/02	4/02	5	3.73^{fg}	1.57^{h}	3.27^{cdefg}
4/02	5/02	6	3.86^{de}	1.81^{g}	3.44^{bcdef}
6/02	7/02	7	3.53^{i}	1.92^{fg}	3.55^{bcde}
7/02	9/02	8	3.64^{ghi}	2.35^{ab}	3.89^{b}
9/02	10/02	9	3.64^{ghi}	2.30^{abc}	3.81^{b}
11/02	12/02	10	3.95^{cd}	2.06^{def}	2.97^{fgh}
1/03	2/03	11	4.08^{bc}	2.11^{cdef}	3.03^{efgh}
2/03	4/03	12	4.33^{a}	2.11^{cdef}	3.03^{efgh}
4/03	6/03	13	3.97^{bcd}	2.05^{ef}	3.10^{defg}
6/03	7/03	14	3.80^{ef}	2.22^{bcde}	3.63^{bcde}
8/03	9/03	15	3.65^{ghi}	2.26^{abcde}	3.68^{bcd}
9/03	10/03	16	3.69^{fgh}	2.26^{abcd}	3.76^{bc}
11/03	12/03	17	4.02^{bc}	2.46^{a}	4.56^{a}
1/04	2/04	18	4.10^{b}	2.12^{cde}	3.15^{cdefg}
Pooled SEM			0.046	0.069	0.202

[a–l]Means within a column lacking a common superscript differ ($P < 0.05$).

[1]Flocks 1 to 9, average of 4 pens; flocks 10 to 18, average of 3 pens.

temperature. The volatilization of N in the form of ammonia from poultry litter has been shown to be largely dependent on temperature and moisture (Elliott and Collins, 1982; Carr et al., 1990). Ambient weather conditions in Texas and other states in the southern United States are hot and humid in the summer. The use of evaporative cooling systems (such as the system used in this study) increases the humidity of air entering the facility. Therefore, warm and humid conditions are common in broiler houses in summer. Combined with high ventilation rates, such an environment is conducive to ammonia generation in the litter and subsequent N loss to the environment. These processes most likely account for the decreases in litter and cake N observed in flocks reared during warmer weather (flocks 7, 8, 14, and 15) compared with flocks grown during cooler periods of the year. Average ambient temperature for flocks 7, 8, 14, and 15 was 27.7°C compared with an average temperature of 12.1°C for flocks 4, 5, 11, 12, and 18 (NCDC, 2005). In contrast, P and K are minerals that are not readily volatilized from the litter, although some small amounts may be lost as dust. For this reason, it would seem logical that litter and cake P

Table 3. Nitrogen, P, and K content of caked rice hull broiler litter at the end of each flock on a dry matter basis, flocks 1 to 18[1]

Begin date (mo/yr)	End date (mo/yr)	Flock	N	P	K
			%		
7/01	8/01	1	3.40^{j}	1.74^{h}	3.64^{efghi}
9/01	10/01	2	4.76^{def}	1.83^{gh}	3.80^{efgh}
11/01	12/01	3	4.48^{fg}	1.94^{fg}	4.02^{defg}
1/02	2/02	4	4.54^{efg}	2.05^{def}	4.13^{cdef}
2/02	4/02	5	4.26^{ghi}	2.06^{def}	4.13^{cdef}
4/02	5/02	6	4.37^{gh}	1.97^{efg}	4.21^{cde}
6/02	7/02	7	4.07^{hi}	2.31^{c}	4.38^{cd}
7/02	9/02	8	4.00^{i}	2.60^{b}	4.60^{bc}
9/02	10/02	9	5.16^{bc}	2.16^{cd}	3.77^{efgh}
11/02	12/02	10	5.04^{cd}	2.19^{cd}	3.77^{efghi}
1/03	2/03	11	5.01^{cd}	2.09^{def}	3.37^{hi}
2/03	4/03	12	5.42^{ab}	2.05^{def}	3.20^{hi}
4/03	6/03	13	4.86^{cde}	2.05^{def}	3.46^{ghi}
6/03	7/03	14	4.53^{efg}	2.17^{de}	3.59^{fghi}
8/03	9/03	15	4.36^{gh}	3.00^{a}	6.89^{a}
9/03	10/03	16	4.96^{cd}	2.58^{b}	5.04^{b}
11/03	12/03	17	5.0^{cd}	2.45^{bc}	5.16^{b}
1/04	12/04	18	5.64^{a}	1.97^{efg}	3.13^{i}
Pooled SEM			0.118	0.059	0.219

[a–j]Means within a column lacking a common superscript differ ($P < 0.05$).

[1]Flocks 1 to 9, average of 4 pens; flocks 10 to 18, average of 3 pens.

Table 4. Broiler litter, caked litter, and total litter production per flock and cumulatively calculated as gram of litter (dry matter basis) per kilogram of live marketed broiler (g/kg), flocks 1 to 18[1]

Begin date (mo/yr)	End date (mo/yr)	Flock	Flock litter	Cumulative litter	Flock cake	Cumulative cake	Flock total litter	Cumulative total litter
			(g/kg)					
7/01	8/01	1	228.7[ab]	629.3[a]	15.4[i]	15.4[i]	244.1[bcd]	644.7[a]
9/01	10/01	2	156.3[cde]	385.0[b]	80.0[bcde]	48.9[h]	236.3[bcde]	433.9[b]
11/01	12/01	3	144.4[cde]	297.5[c]	94.4[b]	65.4[bcdef]	238.8[bcde]	362.8[c]
1/02	2/02	4	191.2[bcd]	269.3[d]	78.8[bcde]	68.9[bc]	270.0[bc]	338.2[d]
2/02	4/02	5	226.3[ab]	260.8[d]	42.2[gh]	63.6[cdefg]	268.5[bc]	324.4[e]
4/02	5/02	6	122.2[ef]	236.6[e]	63.9[defg]	63.7[cdefg]	186.2[ef]	300.2[f]
6/02	7/02	7	106.0[efg]	217.7[f]	46.2[fgh]	61.1[defg]	152.2[f]	278.8[g]
7/02	9/02	8	197.7[bc]	215.2[f]	31.1[hi]	57.4[g]	228.8[cde]	272.6[gh]
9/02	10/02	9	76.6[fg]	198.5[gh]	68.6[cdef]	58.7[fg]	145.3[f]	257.3[ij]
11/02	12/02	10	279.0[a]	207.0[fg]	61.2[defg]	59.0[efg]	341.6[a]	266.0[hi]
1/03	2/03	11	225.8[ab]	208.6[fg]	68.0[cdefg]	59.8[defg]	293.7[ab]	268.4[ghi]
2/03	4/03	12	189.4[bcd]	206.9[fg]	90.7[bcd]	62.6[cdefg]	280.1[abc]	269.5[gh]
4/03	6/03	13	102.0[efg]	198.8[gh]	92.2[bc]	64.8[bcdef]	194.1[def]	263.7[hi]
6/03	7/03	14	62.8[fg]	188.9[hi]	99.8[b]	67.4[bcd]	162.6[f]	256.3[ij]
8/03	9/03	15	107.5[efg]	183.6[ij]	55.9[efgh]	66.7[bcde]	163.4[f]	250.2[j]
9/03	10/03	16	127.2[def]	179.8[ij]	102.6[b]	69.1[bc]	229.8[bcde]	248.9[j]
11/03	12/03	17	147.7[cde]	177.9[ij]	105.7[b]	71.3[ab]	253.4[bcd]	249.2[j]
1/04	2/04	18	45.4[g]	170.3[j]	200.7[a]	78.7[a]	246.1[bcd]	249.0[j]
Average			153.3		74.8		228.2	
Pooled SEM			22.43	4.39	9.70	2.52	21.10	4.11

[a–j]Means within a column lacking a common superscript differ ($P < 0.05$).

[1]Flocks 1 to 9, average of 4 pens; flocks 10 to 18, average of 3 pens.

and K would not vary with temperature to the extent of N. However, just the opposite was observed. From Tables 2 and 3, significant increases in litter and cake P and K levels can be observed for flocks reared during higher temperatures. The increases are most evident in the cake for flocks 8 and 15 in which average temperature was 29.1 and 28.7°C, respectively. This increase in P and K content during warmer weather can be explained by increased P and K excretion by broilers during heat stress. Belay et al. (1992) demonstrated that heat stress in broilers significantly increased urinary excretion of minerals, including P and K. In this study, when cooler weather conditions returned and birds did not experience heat stress, litter and cake P and K content decreased. Therefore, it is evident that ambient temperature can greatly influence litter and cake nutrient content. These findings may help to explain some of the differences in litter nutrient content observed by previous researchers. Therefore, the time of year when litter sampling occurs could significantly affect the results of litter analysis. Combined with factors such as geographical region, diet formulation, bedding type, and management practices, it is clear that litter and cake sampling and analysis are necessary on a routine basis for producers to accurately estimate the nutrient content of the litter materials produced from their operation. Because of the many factors that can alter litter nutrient content, published nutrient values might not be representative of actual litter composition.

Production Rates

The amount of litter and cake produced during each flock was carefully determined by weighing all the litter materials in each pen at the end of each flock. The dry matter content of all litter materials in each pen was determined, and the amount of litter accumulation for each flock was calculated by subtracting the litter dry matter mass from the previous flock from the ending litter dry matter mass of the flock in question. The rate of litter, cake, and total litter production for each flock and on a cumulative basis is presented in Table 4. All values are expressed as grams of dry litter material per kilogram of live broiler marketed (g/kg). Litter and cake production per flock accounts only for the gain in mass from the beginning to the end of each flock, whereas cumulative calculations account for all litter materials that have accumulated since flock 1.

Litter, cake, and total litter production averaged 153.3, 74.8, and 228.2 g/kg per flock, respectively. Significant flock-to-flock variation was observed for litter, cake, and total litter production. Significantly more litter and cake were produced during cooler weather (flocks 4, 11, and 18; average temperature 10.3°C) compared with warmer weather flocks (flocks 7, 14, and 15; average temperature 27.3°C). Flocks 1 and 8 did not follow this same trend and were not different from flocks 4, 11, and 18. Increased composting within the litter and subsequent loss of mass during warm weather could explain these findings. Cooler ambient temperatures would have resulted in a slowed rate of decomposition and a greater accumulation of litter mass. The rate of feed consumption and resulting manure production by the birds could also affect these results. When experiencing heat stress, birds will tend to consume less feed. Decreased feed consumption in such conditions would have resulted in less manure production and, therefore, less litter accumulation. Cake production was significantly lower in flock 1 than all other flocks except flock 8. This would be expected since the starting litter moisture in flock 1 was less than 10%. Cake expressed as a percentage of all litter materials produced varied significantly from 6.3 (flock 1) to 81.6% (flock 18). Cake as a percentage of all litter produced per flock averaged 32.8% on a dry matter basis and 39.8% on an as-is basis. These values are similar to the findings of the NRAES (1999) and Malone et al. (1992). In addition, litter accumulation is inversely related to the rate of cake production, as would be expected. This relationship is easily observed by comparing litter material production for flocks 17 and 18. Total litter production for the 2 flocks was very similar. However, a significant increase in cake production from flock 17 to 18 resulted in a significant decrease in litter production for the same flocks.

Cumulative production was calculated at the end of each flock by dividing the litter and cake mass that had been generated since the start of the experiment by the kilograms of live broilers that had been produced since flock 1. Therefore, the starting litter mass put into the facility at the beginning of the experiment is accounted for in the cumulative calculation and represents the amount of litter material that would have to be disposed of if the facility were completely cleaned-out at that point in time. Cumulative total litter production decreased significantly for the first 7 flocks. Cumulative litter and total litter production rates decreased less with each subsequent flock produced. This is due to the fact that the rate of litter accumulation was less than the rate at which total kilograms of live broiler were being produced. Cumulative cake production rates increased with each flock because there was no starting cake mass at the beginning of the experiment. Cumulative litter, cake, and total litter production were 170.3, 78.7, and 249.0 g/kg, respectively, at the end of 18 consecutive flocks. Calculated on a wet-weight basis, cumulative litter, cake, and total litter production rates after 18 flocks were 236.5, 140.0, and 376.5 g of litter material per kilogram of live broiler weight. For a 2.24 kg broiler (average broiler market weight in this study), litter, cake, and total litter production estimates would be 0.530, 0.314, and 0.843 kg per bird produced. This would equate to a total litter production rate of 1.86 lb/broiler or 0.93 US tons/1,000 broilers on an as-is basis. This figure is lower than the 2.5 lb/broiler or 1.25 US tons/1,000 broilers reported by NRAES (1999). However, these results are similar to litter production rates estimated by Chamblee and Todd (2002). They determined an as-is litter production rate of 1 ton/1,000 broilers after 2 years (10 flocks). Patterson et al. (1998) reported as-is litter production to be 0.558 and 0.488 lb/lb of live weight for litter that was used for 2 to 3 flocks and 1 to 2 flocks, respectively. In the present study, similar results were observed with wet-weight total litter production for flocks 2 and 3 calculated to be 0.606 and 0.550 lb/lb of live weight, respectively. Broiler ending live weight, starting litter depth and density, and litter material moisture could account for the small differences.

The data generated in this study can be used by broiler producers to estimate the amount of litter materials that will be generated over a range of flocks reared on the same litter. Coupled with nutrient analysis of litter materials, broiler producers can then estimate total nutrients available from litter materials.

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