FSA9529

Nutrient Analysis of Poultry Litter

Andrew Sharpley
Professor
Crop, Soil and Environmental Sciences

Nathan Slaton
Professor
Crop, Soil and Environmental Sciences

Tom Tabler, Jr.
Project/Program Manager
Poultry Science

Karl VanDevender
Professor/Engineer

Mike Daniels
Professor
Water Quality and Nutrient Management

Frank Jones
Professor
Poultry

Tommy Daniel
Professor
Crop, Soil and Environmental Sciences

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Introduction

Poultry litter management is an increasingly important issue for Arkansas farmers, state/federal agencies, the poultry industry and the general public. New and innovative methods of utilizing litter continue to evolve, but land application remains the most sustainable option.

From a practical standpoint, with recent fertilizer costs nearly doubling, farmers are developing a renewed interest in litter for its fertilizer value alone. Land application of litter is also being closely scrutinized regarding short- and long-term environmental impacts, especially as it relates to phosphorus (P) runoff and its potential role in accelerating eutrophication. For example, farmers in the Eucha-Spavinaw Watershed apply litter at rates determined by an interstate court order, and those in the Illinois River Watershed potentially will be influenced by an ongoing lawsuit between the Oklahoma Attorney General and Arkansas poultry integrators (DeLaune et al., 2005; Sharpley et al., 2009).

Because of this and other concerns, the Arkansas legislature passed several acts (Acts 1059-1061) to preserve water quality without creating an unnecessary burden on agricultural interests. For example, poultry operations must, among other things, register with their local county Soil and Water Conservation Districts each year, follow a nutrient management plan developed by a certified planner and ensure that only certified applicators apply litter (Goodwin et al., 2003).

The amount of litter produced annually per house varies between 105 and 135 tons depending on, among other things, the size of the house (40' × 400' to 42' × 500') and number of flocks of birds. Since there are an estimated 13,000 broiler houses in Arkansas, this means an estimated 1.4 to 1.7 million tons of litter are produced in the state annually (Tabler, 2000; Tabler et al., 2003).

While the fertilizer value of litter is well recognized, the nutrient concentration of litter can be extremely variable, depending on a variety of factors (VanDevender et al., 2000). Thus, without correctly sampling and analyzing litter before it is spread, there is no way to know its fertilizer value. In addition, soil testing is necessary if land application of litter is to accurately meet crop nutrient needs. Regular analysis of both litter and soil should be important parts of the overall farm operation. In fact, having an approved nutrient management plan for your farm requires soil and litter analyses.

Sampling Poultry Litter

Poultry litter is a mixture of bedding materials (rice hulls, sawdust, wood chips, etc.) and animal excreta (Figure 1). The nutrient content of

Figure 1. Typical broiler litter with bedding, feathers and manure.

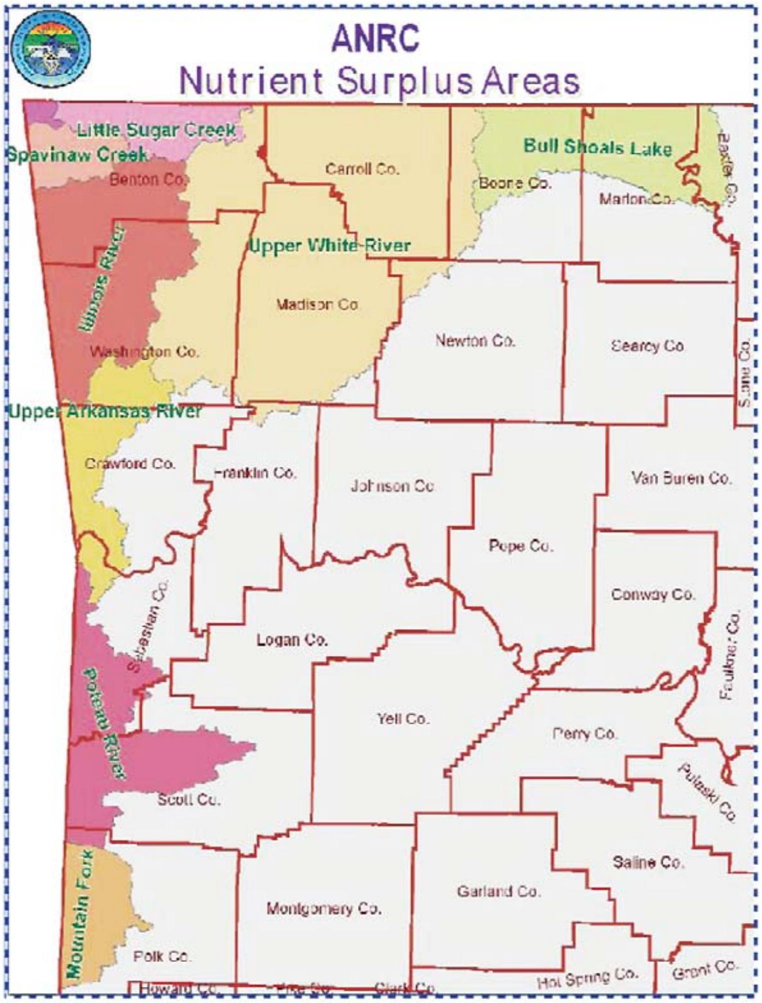

Figure 2. Nutrient surplus areas in Arkansas.

litter varies between houses and within the same house depending on location and management. Litter testing is important for farmers utilizing their own litter as a fertilizer source as well as for farmers buying litter for its fertilizer value. Testing litter is the most reliable means of accurately determining its nutrient content. In fact, litter sampling and analysis is required by law for those poultry operations located in the state's Nutrient Surplus Area (Figure 2).

In this area, all poultry operations must submit one litter sample per farm every five years for nitrogen (N) and P analyses for the purpose of developing or updating a nutrient management plan. As a result of escalating environmental concerns, litter must also be analyzed to determine its water-extractable P (WEP) content. In fact, the WEP content of litter is one of the major input parameters in the Arkansas Phosphorus Index, which determines the relative risk for P loss from individual fields and the actual litter rates that can be applied to the field. A copy of the litter analysis results should be given to the county conservation district office where the farm is located and be retained by the producer for five years. If the operation requires a nutrient plan, the sample's nutrient analysis report should be kept with the nutrient management plan records.

Table 1. Steps for taking in-house and stockpiled litter samples.

<table>
<tr><th colspan="3">In-house litter sample</th><th colspan="2">Stockpiled litter sample</th></tr>
<tr><td>Steps
1</td><td colspan="2">Survey sampling area.</td><td>Steps
1</td><td>Survey sampling area.</td></tr>
<tr><td>2</td><td colspan="2">Take 15-20 subsamples from all areas of one poultry house at full depth of the litter.</td><td>2</td><td>Take several subsamples at different depths and locations around the stack to represent the entire stack.</td></tr>
<tr><td>3</td><td colspan="2">Thoroughly mix the subsamples to make a composite sample.</td><td>3</td><td>Thoroughly mix the subsamples to make a composite sample.</td></tr>
<tr><td>4</td><td colspan="2">Repeat steps 1-3 for each individual poultry house.</td><td>4</td><td>Collect one pint of composite sample and place in sealable freezer bag.</td></tr>
<tr><th colspan="2">House managed differently</th><th>House managed similarly</th><td rowspan="3">5</td><td rowspan="3">Label bag with the following:
• Stockpiled litter
• Sample name/ID
• Date sampled
• Number of flocks
• Size of birds
• Bedding material
• Length of storage time</td></tr>
<tr><td>5</td><td>Collect one pint of composite sample per house and put in sealable freezer bag.</td><td>Combine equal amounts of composite from each house and mix thoroughly. Place one pint of composite in sealable freezer bag.</td></tr>
<tr><td>6</td><td>Label bag with the following:
• In-house litter sample
• Sample name/ID
• Date sampled
• Number of flocks
• Size of birds
• Bedding material</td><td>Label bag with the following:
• In-house litter sample
• Sample name/ID
• Date sampled
• Number of flocks
• Size of birds
• Bedding material</td></tr>
</table>

Table 2. Broiler litter analyses on an "as is" basis. Data collected over a three-year period (2005-2007) and analyzed by the Division's Fayetteville Agricultural Diagnostic Laboratory.

Parameter†	Sample size	Mean	Median	Maximum	Minimum	Standard deviation
Moisture, %	297	30.8	28.7	67.2	13.0	8.9
pH	297	8.4	8.4	9.4	5.6	0.5
Total N, %	297	3.1	3.1	4.4	1.0	5
lb/ton		62	62	88	20	
NH_4-N, ppm	296	3,853	3,548	8,873	57	1,473
lb/ton		7.7	7.1	17.8	0.1	
NO_3-N, ppm	296	409	119	8,910	57	816
lb/ton		0.8	0.2	17.8	0.1	
Total P, %‡	297	1.5	1.5	2.6	0.62	0.3
P lb/ton		30	30	52	12	
P_2O_5 lb/ton		68.7	68.7	119.1	27.5	
WEP10, ppm	297	972	907	4,970	259	404
lb/ton		1.9	1.8	9.9	0.5	
Total K, %§	297	2.5	2.6	3.4	1.1	0.4
K lb/ton		50	52	68	2.2	
K_2O lb/ton		60	62.4	81.6	2.6	
Total Ca, %	296	2.5	2.4	5.8	0.8	0.6
lb/ton		50	48	116	16	
Total C, %	289	25.2	25.8	33.0	12.2	3.5
lb/ton		504	516	660	24	

†Total nitrogen (total N), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total phosphorus (total P), WEP10 P (liter to distilled water extraction ratio of 1:10), total potassium (total K), total calcium (total Ca) and total carbon (total C).

‡To convert elemental P to P_2O_5, multiply P by 2.29.

§To convert elemental K to K_2O, multiply K by 1.2.

Collecting a representative sample of litter can be difficult, but it is critical to ensure the nutrient analysis results are representative of the primary litter source. Information in Table 1 summarizes guidelines for collecting litter samples. For more precise information on acquiring a litter sample, see the University of Arkansas Division of Agriculture's recommendations for sampling poultry litter in-house as well as in intermediate storage (e.g., stacked) (Wilson et al., 2006).

Where to Submit Samples for Testing

Samples should be taken to the local county extension office where any additional information needed to complete the submission form will be collected. A check for the amount of total analysis and shipping costs should be sent with the sample. As of May 4, 2009, the cost of routine litter analysis is $20. A test for WEP can be obtained for an additional $8. Contact your local extension office for the most up-to-date costs of analysis. Sample analysis results are normally returned to the client by mail within two to three weeks of sample submission.

Litter Nutrient Analyses

Litter varies widely in nutrient content (Table 2), and we have probably all wondered how nutrient concentration changes with successive flocks. Figure 3 demonstrates nutrient content of nine flocks of six-week birds grown on the same litter starting with a 50/50 mix of rice hulls and pine shavings/sawdust. Caked litter was removed after each flock, but samples were taken prior to cake removal. Values depicted in Figure 3 represent averages of four 40' x 400' houses under similar management. Generally, the moisture (% H_20) remains around 30%, while the N, P and potassium (K) show a slight but steady increase.

Separate litter analyses over a three-year period are presented in Table 2 on an "as is" basis, meaning the values are not corrected for moisture content by converting to a "dry weight" basis. The average litter

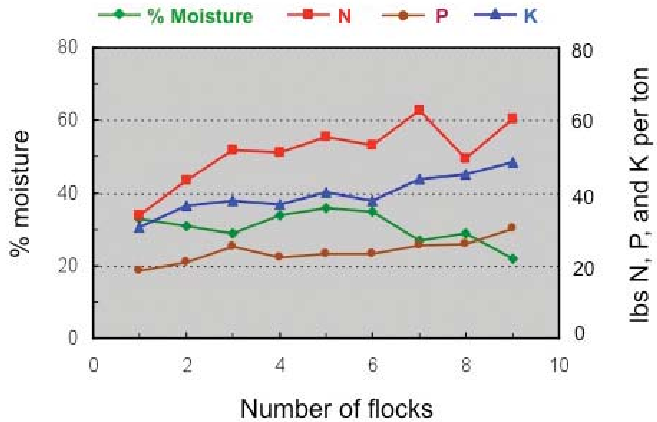

Figure 3. The relationship between flock number and poultry litter composition. To convert elemental P to P_2O_5, multiply P by 2.29 and K to K_2O multiply K by 1.2.

pH is 8.3, ranging from 5.6 to 9.4. Average moisture content is similar to Figure 3, with an average of 30.8% and range of 13.0 to 67.2%.

Inorganic forms of N (NH_4-N and NO_3-N) account for ~14% of the total N and are readily available for plant uptake or volatilization losses, depending on temperature and moisture content. The remaining portion of the total N (73%) is in the organic form and must be mineralized prior to becoming available for plant uptake. Most of the P in litter is inorganic (~90%; Sharpley and Moyer, 2000), with the remainder in organic forms that can become plant-available upon mineralization. However, only about 6% of the total P is water extractable (WEP10). The WEP parameter is an important environmental parameter primarily because it represents that portion of the P pool that is available to runoff, and research has shown a close correlation between the WEP content of the litter and total P loss in the runoff. The average WEP value is 972 ppm, ranging from 259 to 4,970 ppm. The K and Ca content average 2.5% with K ranging from 1.1 to 3.4% and Ca from 0.8 to 5.8%. Poultry litter is also an excellent organic soil amendment due to its high organic carbon (C) content, averaging 25.2% and ranging from 12 to 33% (Table 2).

Fertilizer Value of Litter

Table 3 presents average fertilizer costs for the South Central region of the United States for the last five years (USDA-NASS, 2008). Assuming 0.6 mineralization coefficients for N and 1.0 for P and K, the fertilizer value per ton of litter can be calculated using Tables 2 and 3. After converting to the oxide form of P (P_2O_5) and K (K_2O), this translates into dollar values for

Nitrogen = 62 lb N/ton × \$0.40/lb N × 0.6 mineralization coefficient = **\$14.88**
Phosphorus = 30 lb P/ton × 2.29 × \$0.48/lb P × 1.0 mineralization coefficient = **\$32.30**
Potassium = 50 lb K/ton × 1.2 x \$0.25/lb K × 1.0 mineralization coefficient = **\$15.06**
Total = **\$62.24**

This assumes the crop receiving the litter needs all the N, P and K supplied by the litter. If litter oversupplies a nutrient (typically P), the fertilizer value is reduced somewhat.

Obviously, as fertilizer costs escalate, as they did in 2007 and 2008, fertilizer value of litter also increases. For instance, between 2004 and 2008, the nutrient value (N, P and K; from Table 3) of poultry litter increased from \$36 to \$107/ton. While poultry litter provides the traditional macronutrients (N, P and K) needed by plants, other benefits of litter include the addition of micronutrients, as well as increases in soil pH, water-holding capacity and organic matter content (Risse et al., 2006). As a result of these benefits, several studies have documented that manure application can increase crop yields while decreasing surface runoff (up to 60%) and erosion (up to 65%) (Gilley and Risse, 2000; Mueller et al., 1984). However, there is a soil and management specific application rate of manure, above which the addition of nutrients in excess of crop needs negates these benefits by increasing nutrient runoff (Edwards and Daniel, 1993; Sharpley et al., 2007).

Table 3. Five-year average cost of nitrogen, phosphorus and potassium fertilizer in the South Central region (USDA National Agricultural Statistics Service, 2008).

Year	Average price paid for fertilizer†					
	Urea		Triple superphosphate		Muriate of potash	
	\$/ton	\$/lb N	\$/ton	\$/lb P	\$/ton	\$/lb K
2004	253	0.28	245	0.28	175	0.14
2005	318	0.35	267	0.30	241	0.20
2006	327	0.36	283	0.31	259	0.22
2007	443	0.49	395	0.44	271	0.22
2008	513	0.57	887	0.98	556	0.45
Five-year average	371	0.40	442	0.48	300	0.25

†Based on April prices in each year for urea (44-46% N), triple superphosphate (44-46% P_2O_5) and muriate of potash (60-62% K_2O).

Even in areas where there is a high density of concentrated animal feeding operations, there are soils adjacent or even within the area itself which are deficient in nutrients, especially P. Applying litter to these areas is the most sustainable use of the litter as a resource. How far we can economically transport or haul the litter is an interesting question and a hard one to answer because of all the inherent fixed and variable costs (i.e., fuel, litter, labor, insurance, etc.). However, with some general assumptions, the question can be put in perspective.

A well-managed 25,000-bird poultry house usually produces 5.5 flocks of birds a year and generates about 125 tons of litter, which, because of the increase in fertilizer prices (Table 3), could now be transported greater distances (Doye et al., 1992). Recent litter hauling costs are estimated at $0.15/mile/ton of litter (Sheri Herron, personal communication). Given the one-time house clean-out, loading and spreading costs of $28.50/ton, at 2004 fertilizer prices ($36/ton; Table 3), litter could be transported about 63 miles. At 2008 fertilizer prices ($107/ton litter), hauling distances had increased to more than 580 miles.

Alternative Uses for Litter

While litter is still a valuable fertilizer resource needed in many areas, litter generated in poultry-producing regions cannot be properly utilized in those regions alone. By some estimates, alternative uses for perhaps as much as half the litter generated in concentrated production areas must be found. This may mean transporting litter to areas in need of its fertilizer and organic matter, and how best to do this is currently being investigated. Another alternative being examined is using litter as an energy source. Although there are numerous advantages associated with large-scale, centralized, litter-to-energy options, to operate efficiently such systems would require long-term contracts (10 to 15 years) to supply most, if not all, the poultry litter produced in a given area. Litter can be pelletized or granulated into forms more user-friendly with large agricultural production systems, but this adds additional costs to the litter. If fertilizer prices remain high, then some of the alternative uses and markets for poultry litter will become more economically viable.

Summary

The approximate 1.4 million tons of litter produced in Arkansas are a valuable resource and must be used wisely to ensure sustainability both from an agronomic and environmental standpoint. The nutrient content of poultry litter is inherently variable, and the only way to know the exact nutrient value is to have it analyzed. In fact, poultry producers in the Nutrient Surplus Areas must have their litter analyzed every five years. Also, farmers buying litter need to know its nutrient value in order to determine appropriate application rates for crop yield goals. While all costs continue to rise, the increased value of litter as a fertilizer fosters transport and use of the litter further distances from its origin.

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Printed by University of Arkansas Cooperative Extension Service Printing Services.

DR. ANDREW SHARPLEY and **DR. NATHAN SLATON** are professors with the Crop, Soil and Environmental Sciences department at the University of Arkansas in Fayetteville. **DR. TOM TABLER** is project/program manager with the Poultry Science department at the University of Arkansas in Fayetteville. **DR. KARL VANDEVENDER** is a professor/engineer and **DR. MIKE DANIELS** is a professor - water quality and nutrient management with the University of Arkansas Division of Agriculture in Little Rock. **DR. FRANK JONES** is a professor with the Poultry Science Department and **DR. TOMMY DANIEL** is a professor with the Crop, Soil and Environmental Sciences department at the University of Arkansas in Fayetteville.

FSA9529-PD-6-09N