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Jeffery C. Lorimor  
Iowa State University

Hongwei Xin  
Iowa State University, hxin@iastate.edu

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Manure Production and Nutrient Concentrations from High-rise Layer Houses

Abstract
Four commercial high-rise layer houses were monitored for a year to determine manure production and nutrient concentration characteristics. Each house contained 80,400 to 124,500 mature Hy-Line W-36 birds. The solid manure collected as it accumulated beneath the cages for a year prior to being hauled out. The objective of the research was to accurately characterize the manure production to facilitate better nutrient planning. Manure volume and bulk density were measured and samples were collected monthly and analyzed for moisture, Kjeldahl nitrogen, ammonia, phosphorus, potassium, calcium, and other chemical constituents. The measured manure production averaged 5.6 Mg (or 6.2 ton)·(1000 birds) –1 (year –1 on a dry basis. On a wet (as-is) basis the measured production was 9.52 Mg (or 10.5 ton)·(1000 birds) –1 (year –1 at 41% moisture. The measured manure N-P 2 O 5 -K 2 O contents were 18.5-41.0- 26.0 kg/Mg (37-82-52 lb/ton) on an “as-is” basis or 30.8-69.0-44.0 kg/Mg (62-138-88 lb/ton) on a dry basis. When manure production and nutrient concentrations were combined, measured nitrogen production was 52.8% less, phosphorus was 29.5% greater, and potassium was 27.8% greater, than the respective current Iowa estimates. The average calcium concentration for all four sites studied for the year was 10.0% (as-is basis). The manure handling system had a significant impact on manure characteristics. Scraper systems had a lower moisture content and a lower percentage of the nitrogen in ammonia form (29.8% moisture, NH 3 = 20% of TKN) than systems that dropped the manure into storage immediately (46.9% moisture, NH 3 = 30% TKN).

Keywords
Poultry, Waste, Water quality

Disciplines
Agriculture | Bioresource and Agricultural Engineering

Comments
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MANURE PRODUCTION AND NUTRIENT CONCENTRATIONS FROM HIGH-RISE LAYER HOUSES

J. C. Lorimor, H. Xin

ABSTRACT. Four commercial high-rise layer houses were monitored for a year to determine manure production and nutrient concentration characteristics. Each house contained 80,400 to 124,500 mature Hy-Line W-36 birds. The solid manure collected as it accumulated beneath the cages for a year prior to being hauled out. The objective of the research was to accurately characterize the manure production to facilitate better nutrient planning. Manure volume and bulk density were measured and samples were collected monthly and analyzed for moisture, Kjeldahl nitrogen, ammonia, phosphorus, potassium, calcium, and other chemical constituents. The measured manure production averaged 5.6 Mg (or 6.2 ton)/(1000 birds)−1/year−1 on a dry basis. On a wet (as-is) basis the measured production was 9.52 Mg (or 10.5 ton)/(1000 birds)−1/year−1 at 41% moisture. The measured manure N-P₂O₅-K₂O contents were 18.5-41.0-26.0 kg/Mg (37-82-52 lb/ton) on an “as-is” basis or 30.8-69.0-44.0 kg/Mg (62-138-88 lb/ton) on a dry basis. When manure production and nutrient concentrations were combined, measured nitrogen production was 52.8% less, phosphorus was 29.5% greater, and potassium was 27.8% greater, than the respective current Iowa estimates. The average calcium concentration for all four sites studied for the year was 10.0% (as-is basis). The manure handling system had a significant impact on manure characteristics. Scraper systems had a lower moisture content and a lower percentage of the nitrogen in ammonia form (29.8% moisture, NH₃ = 20% of TKN) than systems that dropped the manure into storage immediately (46.9% moisture, NH₃ = 30% TKN).

Keywords. Poultry, Waste, Water quality.

There is great concern that land application of manure will pollute both surface and groundwater. Public and government pressure continues to mount, demanding more precise manure handling so that environmental damage will not result from misapplications. Producers want better manure nutrient management to optimize crop production without the need for additional commercial fertilizer. At the same time, literature data on poultry (particularly laying hens) manure production and nutrient contents have been questioned for their accuracy in representing modern housing and manure handling systems (Iowa Poultry Association, 1996). This study was conducted to characterize the manure production from high-rise layer houses in the Midwest, and to update state estimates of crop nutrients contained in the manure. This article will report the manure quantity and quality produced by layers in modern high-rise houses in Iowa.

MATERIALS AND METHODS

EXPERIMENTAL POULTRY HOUSES

Four commercial high-rise layer houses in Iowa were selected for the project. The four facilities are denoted as farm A, B, C, and D. The starting dates of the on-farm measurements were 29/2/97, 30/1/97, 17/1/97, and 18/2/97, respectively, for A, B, C, and D, with corresponding completion dates of 2/12/97, 29/1/98, 24/10/97, and 12/2/98. All facilities used the Hy-Line W36 Leghorn strain. The starting age of the flocks was 30, 54, 60, and 29 weeks, respectively, for farm A, B, C, and D. The number of birds per house ranged from 80,400 to 124,500. Three houses (farm A, B, and C) used a negative pressure ventilation (fans along both sidewalls of the manure storage) and continuous ceiling slot inlets above.

Figure 1–Layer cages with curtains (houses A & B). Manure drops into storage immediately.

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The authors are Jeffery C. Lorimor, ASAE Member Engineer, Assistant Professor, and Hongwei Xin, ASAE Member Engineer, Associate Professor, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa. Corresponding author: Jeffery C. Lorimor, Iowa State University, 200 Davidson Hall, Ames, IA 50011; voice: (515) 294-9806; fax: (515) 294-9973; e-mail: jclorimo@iastate.edu.
each cage row. The remaining house (farm D) used positive pressure ventilation (fans in the attic) and continuous ceiling slot inlets. Manure at sites A and B fell directly into the storage area (fig. 1); whereas, manure at sites C and D collected on dropping boards (fig. 2), and was removed with scrapers three to four times a day.

**DETERMINATION OF MANURE QUANTITY AND QUALITY**

Monthly manure production volume in each house was measured by setting an array of vertical steel rods 15 cm (6 in.) apart across a central row of manure (fig. 3). The array was located near the middle of the manure row and was set perpendicular to the row. Each rod was marked at 2.5-cm (1-in.) increments throughout its length so that the monthly depth across the manure row could be read from the rods without disturbing the manure row. These readings were used to determine the cross-sectional area of the manure row. Cumulative manure volume was calculated by multiplying the cross-sectional area by the length of the manure (cage) row. The row volume was then multiplied by the number of rows in the house to determine the total manure volume for the house. Monthly manure production was calculated as the difference in volume between the current month and the previous month.

Bulk densities of the manure were determined by excavating a uniform cross-section of the pile 30 to 38 cm (12-15 in.) thick, and weighing the material excavated. Early in the study, 5-cm-diameter PVC and steel pipes were tested as probes for monthly bulk density sampling. They did not work. Even though the probes were sharpened, they tended to push and compact the manure-feather mix. The probes were used to obtain the monthly samples. Final bulk densities were determined by weighing known volumes of the manure rows 6.1 to 9.1 m (20-30 ft) long at each site. The measured length of manure was loaded into trucks and weighed.

Samples for determination of chemical constituents were collected from three locations along the length of the manure row at one-eighth, one-fourth, and three-eighths of the total length, within the same manure row that was used for volume determination during each monthly sampling. The sample at each location was collected by probing the manure row horizontally into the center of the row at three heights above the floor to provide a proportional sample of the full depth of manure. The samples were mixed to obtain one composite sample. The composite samples were taken or shipped immediately to Iowa Testing Laboratories, Inc., a commercial testing laboratory in Eagle Grove, Iowa, for chemical analysis shown in table 1.

**RESULTS AND DISCUSSION**

Measured manure production, in Mg (ton) per 1000 birds per year, varied by site from an average low of 8.4 (9.3) to an average high of 11.6 (12.8), as shown in table 2. The overall average was 9.5 (10.5) on an “as-is” basis, or 5.6 (6.2) on a dry matter basis compared to the Pennsylvania study.

The manure handling system affected moisture content. Houses A and B used plastic curtains to prevent manure from being dropped on the birds below. The houses C and D used positive pressure ventilation and continuous ceiling slot inlets. Manure at sites A and B fell directly into the storage area (fig. 1); whereas, manure at sites C and D collected on dropping boards (fig. 2), and was removed with scrapers three to four times a day.

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**Table 1. Physical and chemical properties of layer manure samples tested**

<table>
<thead>
<tr>
<th></th>
<th>Moisture content (%)</th>
<th>Calcium</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>Magnesium</td>
<td>Manganese</td>
<td></td>
</tr>
<tr>
<td>Ammonia nitrogen</td>
<td>pH</td>
<td>Copper</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Sulfur</td>
<td>Iron</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>Sodium</td>
<td>Cobalt</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Manure production (ton/1,000 bird/yr) and nutrient contents (lb/dry ton) of layers from four high-rise houses in Iowa and comparison with the current state estimates**

<table>
<thead>
<tr>
<th>Value Source</th>
<th>Moisture Content (%)</th>
<th>Manure Production</th>
<th>Concentration (lb/dry ton)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“as-is”</td>
<td>Dry</td>
<td>TKN</td>
</tr>
<tr>
<td>Farm A</td>
<td>42.6</td>
<td>9.31</td>
<td>5.34</td>
</tr>
<tr>
<td>Farm B</td>
<td>51.7</td>
<td>9.85</td>
<td>4.76</td>
</tr>
<tr>
<td>Farm C</td>
<td>35.8</td>
<td>12.77</td>
<td>8.20</td>
</tr>
<tr>
<td>Farm D</td>
<td>34.0</td>
<td>10.07</td>
<td>6.65</td>
</tr>
<tr>
<td>Mean</td>
<td>41.0</td>
<td>10.50</td>
<td>6.24</td>
</tr>
<tr>
<td>S.D.</td>
<td>8.0</td>
<td>1.55</td>
<td>1.53</td>
</tr>
<tr>
<td>Ref.†</td>
<td>59.3</td>
<td>13.88</td>
<td>5.66</td>
</tr>
</tbody>
</table>

*Conversion factors: 1 ton = 0.907 Mg; 1 lb/ton = 0.50 kg/Mg.
†From Patterson and Lorenz (1996).
system allowed the manure to fall directly into the storage as soon as the birds defecated. Houses C and D used manure boards below each tier of cages to catch the manure. Ventilation air was pulled across the manure until scrapers pushed the manure into the storage area at predetermined intervals, typically 3 or 4 times a day. The manure in houses A and B averaged 47.1% moisture content and was significantly wetter (P < 0.05) than manure from C and D, which averaged 34.9%. Bulk density of the manure ranged from 502.4 to 689.6 kg/m³ (31.4-43.1 lb/ft³), and averaged 521.6 kg/m³ (35.6 lb/ft³).

As shown in table 1, chemical analyses performed on the manure included total Kjeldahl nitrogen, ammonia, phosphorus, potassium, and pH. The plant nutrients nitrogen (N), phosphate (P₂O₅), and potash (K₂O) are of special interest because they are the primary nutrients needed for crop production. According to Iowa’s 1995 manure law, nutrient management plans submitted to the Iowa Department of Natural Resources (IDNR, 1995) should be based on nitrogen. Current nutrient estimates of layer manure on a pound/ton basis* as specified by IDNR (Lorimer et al., 1996) for planning and permitting purposes are 85-70-45 of N-P₂O₅-K₂O at 20% moisture, or 106-87-56 on a dry basis. As shown in table 2, the measured mean total N concentration was 42% lower than the state estimate (61.7 vs 106 lb/ton). Meanwhile, the mean P₂O₅ and K₂O concentrations were 60% (139 vs 87 lb/ton) and 58% (88.3 vs 56 lb/ton), respectively, higher than the state estimates.

When the measured manure production is combined with the measured nutrient concentration, the annual nutrient output per 1,000 birds can be determined. As shown in table 3, total N output found in the present study was 52.8% lower than the Iowa estimate and 25.9% lower than that of the Pennsylvania study. The P₂O₅ output for the present study was 29.5% and 13.9% higher, and K₂O output was also higher by 27.8% and 26.3%, than the state estimate and the Pennsylvania value, respectively. Moisture differences affect chemical constituents. In drier manure ammonia normally accounts for a lower percentage of the total nitrogen. This is important because the ammonia portion is subject to volatilization and loss during and after land application. The non-ammonia nitrogen is more stable, and is not lost. Ammonia in the manure at the two sites with direct falling systems (47.1% moisture) made up 30.3% of the total N, and 17.6% at the two sites with scrapers (34.9% moisture).

In addition to the primary plant nutrients, a number of other analyses were performed. Table 4 shows most of the measured chemical concentration averages for all four farms. Phosphorus and potassium concentrations are shown in both elemental and combined forms. Calcium concentrations exceeded the concentrations of all other chemicals, including N, P, and K. Calcium averaged 10.0% on a “as-is” basis ranging from 4.4 to 14.9% for individual samples. Measured pH was high, averaging 8.96.

As shown in table 4, the concentration of chemical constituents found in this study generally paralleled those of the Pennsylvania study, with the exception that nitrogen in the current study was considerably (38%) lower.

**CONCLUSIONS**

The one-year field measurement and analysis of manure production and nutrient concentrations from four separate commercial high-rise layer houses in Iowa indicate that:

- Manure production was 9.52 Mg (10.5 t) per 1,000 birds per year at an average moisture content of 41% on an “as-is” basis.
- When manure production and nutrient concentrations were combined, the measured nutrient production was shown to be 175-394-250 kg (385-867-551 lb) per 1,000 birds per year of N-P₂O₅-K₂O, respectively, as compared to the current Iowa state estimate of 371-304-196 kg (816-670-431 lb). Using the state estimate as the base, the measured N-P₂O₅-K₂O production was respectively, 52.8% lower, 29.5% higher, and 27.8% higher.
- The manure handling system had a significant effect of manure moisture content. Manure that was allowed to stay on boards beneath the cages for a period prior to being moved to the storage pile was significantly drier than manure that dropped directly into the storage.
- By using the current research results where site specific sample results are not available, more accurate nutrient management plans can be developed to the benefit of both the producers and the environment.

### Table 3. Comparison of layer nutrient production between current study and literature data

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Nutrient Production, kg (lb) per 1,000 birds per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total N</td>
</tr>
<tr>
<td>Measured value</td>
<td>175 (385.0)</td>
</tr>
<tr>
<td>Iowa estimate</td>
<td>371 (816.2)</td>
</tr>
<tr>
<td>Patterson &amp; Lorenz</td>
<td>236 (519.6)</td>
</tr>
<tr>
<td>% Difference*</td>
<td>−52.8%</td>
</tr>
<tr>
<td>% Difference†</td>
<td>−25.9%</td>
</tr>
</tbody>
</table>

* Difference between the measured value of the present study and the state estimate with state estimate as a base.
† Difference between the measured value of the present study and that of the Pennsylvania study with the Pennsylvania value as a base.

* English units used here and in table 2 for comparison to quoted published data.
ACKNOWLEDGMENTS. The authors express their gratitude to ISU Distinguished Professor Dr. Jerry Sell for his advice and assistance, and to Dr. Akihiro Tanaka, Mr. Peilin Yang, and Dr. Xiwei Li for their assistance in field data collection. Financial support provided by the U.S. Poultry and Egg Association and collaboration from the Iowa Poultry Association and particularly the four cooperating companies are sincerely acknowledged.

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