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Abstract

A multi-state, multi-disciplinary project is developing a comprehensive database of ammonia emission rates (ER) from US poultry facilities. The influence of common management strategies and practical means of reducing ammonia (NH₃) emissions are under study. The measurement of ER under cold weather conditions from 8 broiler houses with re-used ('builtup') litter in Kentucky is described in this paper. Ammonia concentrations were determined using electrochemical sensors; ventilation rate was accurately estimated by monitoring runtime of the ventilation fans whose airflow rates were calibrated with a portable anemometer array, also known as the Fan Assessment Numeration System (FANS). Mean ammonia ER (by site, 2 sequential days, 4 houses) ranged from 0.10 to 0.98 g NH₃ bird⁻¹ d⁻¹. Bird age during ER measurement ranged from 11 to 56 days old. A regression of ER vs bird age is presented. There was high variability for emission rates among the houses, even for houses on the same farm (14-57% coefficient of variation). Day to day variability (consecutive days) was substantially less than house-to-house variability for the same time period, and appeared related to differences in ventilation rates. Additional data are being collected so that there can be a more complete interpretation of the wide range of ER and how it is affected by characteristics including litter re-use, bird and house management, and abatement methods.

Keywords

chicken, ventilation, air quality, poultry

Disciplines

Bioresource and Agricultural Engineering | Poultry or Avian Science

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ABSTRACT

A multi-state, multi-disciplinary project is developing a comprehensive database of ammonia emission rates (ER) from US poultry facilities. The influence of common management strategies and practical means of reducing ammonia (NH₃) emissions are under study. The measurement of ER under cold weather conditions from 8 broiler houses with re-used ('built-up') litter in Kentucky is described in this paper. Ammonia concentrations were determined using electrochemical sensors; ventilation rate was accurately estimated by monitoring runtime of the ventilation fans whose airflow rates were calibrated with a portable anemometer array, also known as the Fan Assessment Numeration System (FANS). Mean ammonia ER (by site, 2 sequential days, 4 houses) ranged from 0.10 to 0.98 g NH₃ bird⁻¹ d⁻¹. Bird age during ER measurement ranged from 11 to 56 days old. A regression of ER vs bird age is presented. There was high variability for emission rates among the houses, even for houses on the same farm (14-57% coefficient of variation). Day to day variability (consecutive days) was substantially less than house-to-house variability for the same time period, and appeared related to differences in ventilation rates. Additional data are being collected so that there can be a more complete interpretation of the wide range of ER and how it is affected by characteristics including litter re-use, bird and house management, and abatement methods.

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INTRODUCTION

Reasonable estimates of ammonia emission rates (ER) from US poultry facilities are needed to guide discussions about the industry's impact on local and regional air quality. Quantitative estimates are also required of the effectiveness of the various major abatement strategies for reducing ammonia emission from facilities to provide guidance to the industry on the most effective strategies for managing ammonia emissions. The purpose of this paper is to outline ongoing measurements of ER during winter-time conditions in eight broiler houses representative of Kentucky. A companion paper (Wheeler et al., 2003) also presented at this conference provides additional detail on the project background, and the reader is referred to that paper for additional detail.

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METHODS

Overview

Data from cold weather conditions at eight mechanically ventilated broiler houses are included in this paper. The data represent 42 study days of data collection, comprising two to seven days of measurement from the eight houses. For much of these flocks, the broiler houses were under minimum ventilation to maintain indoor moisture level and air quality. The US broiler industry typically provides minimum ventilation through timer-controlled fan operation. Timer 'on' time is increased as the birds grow in size to coincide with increased respiratory and excreted moisture levels. All houses were 'tunnel ventilated' houses, although this hot weather ventilation strategy was not used during the study periods reported here. The houses were located in a portion of the United States that is considered a 'mixed humid' climate.

Eight broiler houses in Kentucky, each 12.2 m x 152.5 m, housed a nominal 25,000 birds at Site 1 and 20,000 birds at Site 2. This produced a placement density of 13.44 birds per m² at Site 1 and 10.75 birds per m² at Site 2. Two sites were monitored, each with four houses in the study. Each site was under contract to a different integrator company. Houses at Site 2 were built in 1997 while houses at Site 1 were built in 2000 (except House 4, which was 12.2 m x 157.4 m and built in 1995). All houses had a 670 mm opening (except House 4; 790 mm) along the full length of both sidewalls covered by a single-layer curtain for emergency ventilation. There was an insulated, suspended ceiling in all houses. Ventilation fans included eight 1220 mm (48 in) diameter fans in all houses with three 915 mm (36 in) fans in each house at Site 1 and six 915 mm (36 in) diameter fans in each Site 2 house. Box inlets were located along both sidewalls and were automatically controlled via cable based on maintenance of setpoint static pressure difference. The ventilation system at Site 1 was controlled via an electronic controller while Site 2 houses used individual thermostats and timers on each fan. At Site 1, a single 1220 mm (48 in) fan in the non-brood section of each house was used for minimum ventilation. At Site 2 houses, 10-minute timers were on two 915 mm (36 in), minimum ventilation fans located in the non-brood portions at opposite ends of the house. All houses reused litter with one annual cleanout and practiced half-house brooding. The Site 2 houses used the central half of the house for brooding.

Litter in US broiler houses is typically reused for at least one year. This type of litter reuse is referred to as 'built-up' litter in the industry. For site 1, these flocks represented the 3rd and 4th flock (2 houses each) on the same litter; for site 2, these flocks represented the 2nd flock grown on the litter. Caked litter was removed after each flock, and a small layer of new wood shavings was added at Site 1.

Instrumentation

For the data collected and reported here, ammonia ER was obtained from Portable Measuring Units (PMU) developed for this project. Complete details of the PMU are given in other references and not repeated here (Xin et al., 2002, Liang et al., 2003; Wheeler et al., 2003).

One PMU was installed in each broiler house. The PMU was located near and monitored the primary minimum ventilation timer fan used for cold weather ventilation. A second PMU will be located on the first of the tunnel ventilation fans at Site 2 during warmer conditions when the house is likely to transition into tunnel ventilation mode. PMUs typically collected data at each house for about 48-hours however, for one monitoring period at Site 2, data collection exceeded 72 hours. The interval between collection periods at a site was typically two or three weeks. A 'day' of data collection was nominally from noon of one day to noon of the following day.

The exhaust fan ventilation capacity was determined with a Fan Assessment Numeration System (FANS) unit. Details of this unit's design and performance specifications are provided elsewhere (Gates et al., 2002; Wheeler et al., 2002; Casey et al., 2002). The FANS was used to evaluate each fan at two of the broiler houses, before these ammonia sampling data were collected. Only fans at Site 1 (houses 1 and 3) were evaluated prior to collecting these data. It takes about 1 hour to fully evaluate each fan over a range of typical operating static pressure differences so several trips to each farm were necessary to fully characterize each houses' ventilation system. Under minimum ventilation during cold weather, the fan on-off times were known so that ventilation rate is a constant over the evaluation time period. Fan on-off time was monitored using fan motor loggers. Average static pressure difference over the fan on-time interval was used to determine fan ventilation rate, using fan curves developed for each fan as determined from the FANS testing. For houses at Site 1, in which fans were not yet evaluated, mean fan curves from tested houses were used. For houses at Site 2, fan curves obtained as part of ongoing research on the FANS units from testing an example 915 mm and 1220 mm fan from site 2 in the fan test chamber at the University of Illinois at Urbana Champaign were used.

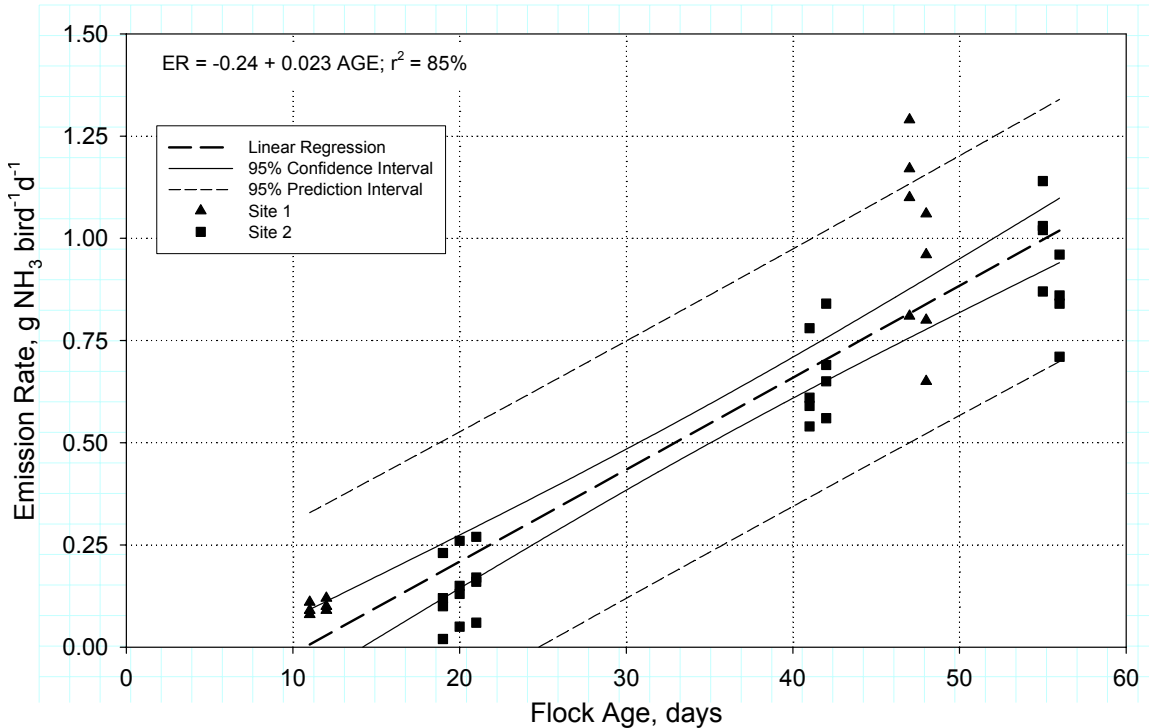
RESULTS AND DISCUSSION

Figures 1 and 2, and Table 1, summarize ER for the eight broiler houses during a cold weather growout during December 2002 and January 2003. The birds were placed at Site 2 on November 28th, 2002 and at Site 1 on November 29th, 2002. Overall, ER varied from 0.08 to 1.29 g NH₃ bird⁻¹ d⁻¹ for 11 to 45 day old birds at Site 1 and from 0.02 to 0.84 g NH₃ bird⁻¹ d⁻¹ for 19 to 56 day old birds at Site 2 (Figure 1). Mean values, listed in Table 1, ranged from 0.12 for smaller birds up to 0.96 g NH₃ bird⁻¹ d⁻¹ for mature broilers.

ER varied among houses within one site where house management and flock characteristics would be assumed to be similar. For example, the coefficient of variation (CV) of ER was 10 and 57% at sites 1 and 2, respectively for small birds (11-21 day old) but reduced to 21 and 14% at these sites for 46-57 day old birds. This is evident in figure 1, where the greater CV at Site 2 (19-21 day old birds) was primarily due to considerable differences between house 1 (ER = 213 g AU⁻¹d⁻¹) and house 4 (ER = 36 g AU⁻¹d⁻¹). This latter ER is below the detection threshold for the instrumentation used in this study. House 1 had an area of wet litter (up to

70% MC_{wb}), the lowest ventilation rate (50% lower than other houses) and a high ammonia concentration whereas, house 4 litter was drier, ventilation rate was the highest and there was minimal ammonia concentration. While variability between houses is large, the mean ER was only about 10% of the value for large birds.

Figure 1. Winter 2002-03 NH_3 Emission Rates – Eight Kentucky Broiler Houses



The daily variability in ER (for consecutive days) from a house was relatively small compared to emission variability among houses at the same site. Daily variability in emission from an individual house was primarily related to variation in ammonia level rather than fluctuations in ventilation rate over this cold weather study period.

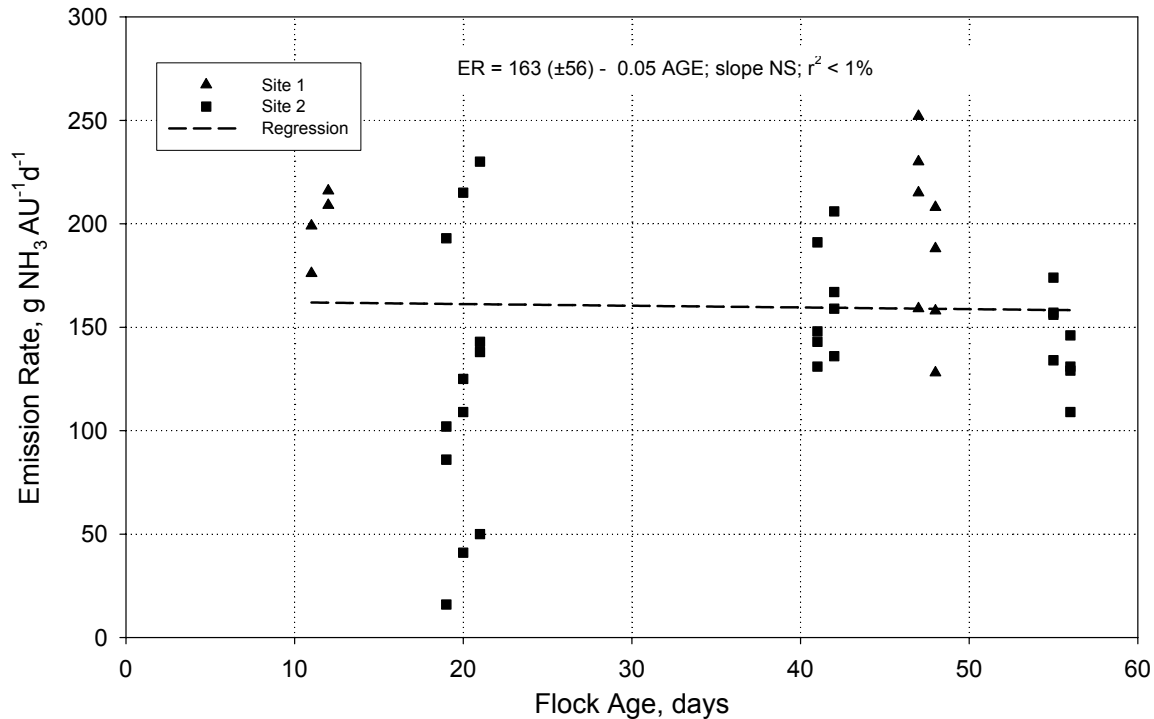
Emissions data are presented in terms of the number of 500 kg animal units (AU) in the house during the study period (Figure 2). The number of birds placed was used for Site 1 and Site 2 AU estimates, and weight estimates were obtained from growth curves provided by the respective integrator. Ammonia emission ranged from 158 to 252 g NH_3 AU⁻¹ d⁻¹ at Site 1 and from 16 to 230 g NH_3 AU⁻¹ d⁻¹ at Site 2. Figure 2 demonstrates that using ER based on animal units for rapidly growing broiler chickens is independent of bird age (hence weight). However, the mean estimate of 163 g NH_3 AU⁻¹ d⁻¹ as given from the regression has a large variance (standard error = 56 g NH_3 AU⁻¹ d⁻¹). This level of variability is between that found in table 1 for ER expressed on a bird basis. Thus, expressing ER on a bird basis may allow better predictive ability for larger birds.

Table 1: Summary Ammonia Emission Rates during Cold Weather in Kentucky

Bird Age	Location	No.	No.	ER (g NH ₃ bird ⁻¹ d ⁻¹)		
		<i>Houses</i>	<i>Days</i>	<i>Mean</i>	<i>Std Dev</i>	<i>CV (%)</i>
11-21 d						
	Site 1	3	2	0.10	0.01	10
	Site 2	4	3	0.14	0.08	57
	Overall	7	5	0.12	0.06	50
47-56 d						
	Site 1	4	2	0.98	0.21	21
	Site 2	4	2	0.93	0.13	14
	Overall	8	2	0.96	0.17	18

The regression equations relating ER to bird age (and indirectly, bird weight) are listed in Figures 1 and 2. As explained previously, ER expressed on an AU basis is independent of bird age (slope not significantly different from zero, $r^2 < 1\%$). However, expressed on a bird basis, the regression between ER and bird age is significant (intercept = -0.24, slope = 0.023, Se = 0.16, $r^2 = 0.85$). The resulting 95% confidence interval is plotted in Figure 1 for reference, as is the 95% limit of prediction for future observations using this data set as the basis of the predictive model. An additional flock of data from all eight houses is being collected as the article is written, and it is expected that this will improve ER predictive capability. This regression can be used to estimate cold weather ER for any bird age between 10-60 d.

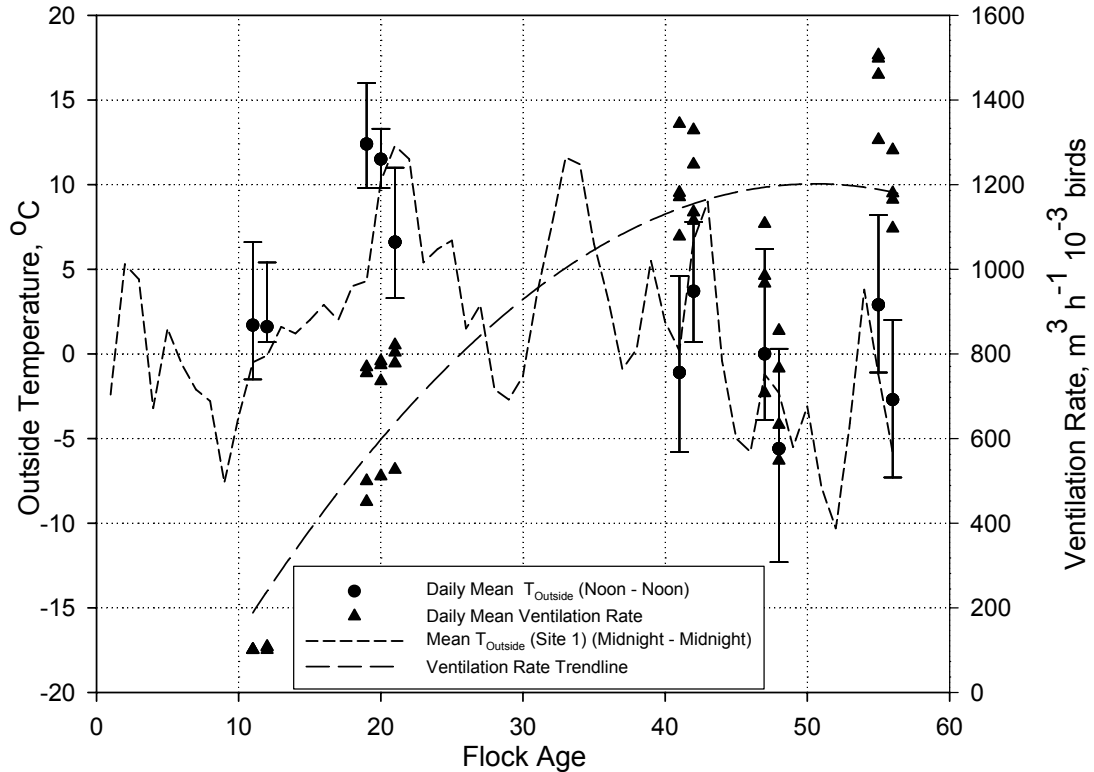
Comparing these results to other published ammonia emissions, Groot Koerkamp et al. (1998) reported 53, 100, 180 or 199 g NH₃ AU⁻¹ d⁻¹ for broilers raised on litter from four European countries (Denmark, The Netherlands, Germany and England, respectively). Four replicates of typical broiler house practices were monitored in each country for a 24-hour summer and winter period. The emission values represent mean values of bird age and manure removal. They found that poultry houses had a significant decrease in internal ammonia level with increasing outside temperature, which can be explained by increased summer ventilation rate.

Figure 2. Winter 2002-03 NH₃ Emission Rates – Eight Kentucky Broiler Houses

Daily mean ventilation rate increased with bird age (and hence bird weight) as shown in figure 3. At the start of the flock, a single 1220 mm fan controlled by an electronic control system ran on a minimum ventilation cycle of 30 seconds in 300 seconds while at Site 2, two, 915 mm fans were run for 3 minutes (5 minutes, Houses 3 and 4) in 10 minutes by individual cycle timers. In the latter stages of the flock, up to two, 1220 mm fans and one, 915 mm fan under temperature control were in use at Site 1 while at Site 2 up to four, 915 mm fans were in use controlled by a combination of individual cycle timers and individual thermostats. The ventilation rate used at Site 1 (days 11,12 and 47, 48) at a given growth stage was generally lower than that used at Site 2 (days 19-21, 41,42 and 55,56). Under minimum ventilation conditions, the ventilation rate at Site 1 was $100 \text{ m}^3 \text{ h}^{-1} 10^{-3} \text{ birds}$ while at Site 2 the ventilation rate is $480 \text{ m}^3 \text{ h}^{-1} 10^{-3} \text{ birds}$, a factor of almost 5-fold greater.

The mean temperature and temperature range for each 24 hour monitoring period running nominally from noon to noon is also shown in the figure. The temperature during this monitoring period was generally colder than average for the area, and typically averaged -3 to 4° C over the entire period.

Figure 3. Winter 2002-03 Ventilation Rates – Eight Kentucky Broiler Houses



CONCLUSIONS

Ammonia emission rates from the 8 broiler houses that were evaluated under cold weather conditions ranged from 0 to $1.29 \text{ g NH}_3 \text{ bird}^{-1} \text{ d}^{-1}$ for birds aged 11 to 57 d. Mean ER by site ranged from 0.10 (CV=10%) to 0.98 (CV=21%) for these same bird ages. Mean ER by bird age was 0.12 (CV=50%) for 11-21d old birds, and 0.96 (CV=18%) for 47-56 d old birds raised during winter conditions. ER expressed per animal unit was independent of bird age. There was high variability for emission rates among the houses, even for houses on the same farm. Day to day variability was less than house-to-house variability.

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