Ammonia Emissions from Layer Houses

A.S. Leaflet R2011

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Summary and Implication

Ammonia (NH_3) emission rates from six high-rise (HR) and four manure-belt (MB) laying hen houses were measured for one year. Manure was stored in the lower level of the HR houses for a year, but removed daily or semi-weekly from the MB houses. The results revealed an annual average NH_3 emission rate of 0.87 (±0.29) g d^{-1} hen^{-1} for the HR houses, 0.094 (±0.062) for the MB houses with semi-weekly manure removal, and 0.054 (±0.026) g d^{-1} hen^{-1} for the MB houses with daily manure removal. Information of this study contributes to the U.S. national inventory on ammonia emissions from animal feeding operations with different housing and manure handling schemes and geographical locations.

Introduction

Aerial ammonia (NH_3) is the predominant noxious gas in poultry production operations, resulting from microbial decomposition of uric acid in bird feces. Ammonia emission can impact environment by contributing to acidification of soil and water and increased nitrogen deposition in ecosystems, and it is subject to certain federal regulations. Yet, data are lacking concerning ammonia emission rates of U.S. animal feeding operations. The objective of this study was to determine ammonia emission rates of typical commercial laying hen houses in the United States that involved different housing and manure handling schemes.

Materials and Methods

Two types of laying hen houses are mostly typical of the U.S. egg industry, high-rise (HR) houses and manure-belt (MB) houses, and were monitored in this one-year field study. Specifically, the study involved four HR and two MB houses in Iowa (IA) and two HR and two MB houses in Pennsylvania (PA), representing the regions of majority of the U.S. egg production. Manure was stored for one year in the HR houses, but removed daily in IA or semi-weekly in PA from the MB houses. Dimensions of the houses were 48×432 ft for IA-HR houses, 59×522 ft for IA-MB houses and 54×529ft for all PA houses. Table 1 summarizes the main housing and management schemes of the layer houses. All houses except for two IA-HR houses used the industry standard rations for different phases of the production. The two exceptional HR house in IA received a lower dietary crude protein diet, and its effects on building ammonia emission was assessed and reported separately. Hence this report covers ammonia emissions of HR and MB houses that used standard industry rations.

Portable monitoring units (PMUs), two per house, were used to measure NH_3 and CO_2 concentrations of intake and exhaust air and building static pressure. The PMU featured purging and sampling cycles to eliminate measurement errors caused by saturation of the electro-chemical NH_3 sensors. This purging-sampling led to 30-min measurements of the gas concentrations. Quality assurance and quality control protocols were strictly followed in instrument calibration, data collection, and data analysis to ensure data integrity. Each data collection trip involved 48-hr or longer continuous measurements, and was performed weekly (IA-HR houses), bi-weekly (IA-MB houses) or tri-weekly (PA houses). Building ventilation rates were determined using calibrated CO_2 balance method. Mass balance on nitrogen intake through feed and output, including measured NH_3emission from manure, was conducted as a way to validate the emission data. The measurement periods were December 2002 to December 2003 for IA-HR houses, January to December 2003 for IA-MB houses and January 2003 to February 2004 for PA houses.

Results and Discussion

Ammonia Concentrations

Daily mean NH_3 concentrations in the exhaust air were 2.8 parts per million (ppm) and 5.4 ppm for the IA and PA MB houses, respectively, but 44.8 ppm and 35.9 ppm for the IA and PA HR houses. NH_3 concentrations of the HR house exhaust air decreased quite linearly with rising outside temperature and thus ventilation rate.

Ammonia Emission Rates

The annual mean NH_3 emission rate (ER) for the HR and MB houses are summarized in Table 2. The MB houses had an average daily ER of 0.054 (±0.026) with daily manure removal but 0.094 (±0.062) g d^{-1} hen^{-1} with bi-weekly manure removal. In comparison, the HR houses had significantly higher ER, averaging 0.87 (±0.29) g d^{-1} hen^{-1}. These emission rates translate to an annual NH_3 emission factor of 20 (±9.5) to 34 (±22.6) g hen^{-1} for the MB houses, and 317 (±106) g hen^{-1} for the HR houses. Dry matter content of the HR house manure averaged 41-71%.

Ammonia ER of HR houses dropped drastically upon manure removal, followed by a steady increase for about a month (fig. 1). The NH_3 ER increased linearly with time of manure accumulation during the initial 25 days, and leveled off thereafter. It is speculated that as the manure pile grew to a certain dimension, the material inside the pile became primarily anaerobic, giving rise to substantially lower or zero NH_3 volatilization rate. Substrate decomposition and NH_3 volatilization is a complex process and depends on manure age, moisture content and oxygen availability.

Temporal Variations in Ammonia Emission Rates

Ammonia ER of the HR houses showed considerable diurnal variations during 48-h data collection episodes. The trend of semi-hourly NH_3 ER closely followed ventilation rates during the warm season, but was not so clear during the cold season. This result reaffirmed the need for a reasonable length of continuous monitoring to obtain the realistic emission rate values. In comparison, temporal variations among the months or seasons were relatively smaller. Table 3 summarizes the seasonal means of NH_3 ER for IA-HR houses, along with the mean outside temperature. The substantially lower ER during the fall at least partially arose from the annual manure removal.

Acknowledgements

Financial support to this study was provided by the USDA-IFAFS program, the Iowa Egg Council, and the Center for Advanced Technology Development. We sincerely thank the cooperative producers in Iowa and Pennsylvania for their support and cooperation throughout this study.

Table 1. Housing and management characteristics of the commercial layer houses monitored in this study

Building ID[a]	Hen Breed	Manure Removal	Vent. System	No. of Birds at Start
IA-MB-1,2	W-36	Daily	Quasi Tunnel	104860
IA-HR-1,2	W-36	Annually [b]	Cross	73938-82219
PA-MB-1	W-36	Semi weekly	Cross + Tunnel	157822
PA-MB-2	Bovan	Semi weekly	Cross + Tunnel	158117
PA-HR-1	W-98	Annually [c]	Cross	93974
PA-HR-2	W-36	Annually [d]	Cross	95984

[a] IA=Iowa, PA=Pennsylvania, HR=high-rise, MB=manure belt, 1 or 2=house number

[b] Before study: 11/02-11/05/2002 for IA-HR-1 and 11/05-11/08/2002 for IA-HR-2; during study: 10/11-10/14/2003 for IA-HR-1 and 10/15-10/17/2003 for IA-HR-2

[c] Before study: 10/2002, not removed during study

[d] Before study: 10/2002, during study: 11/2003 – 01/2004

Table 2. Annual ammonia emission rates (mean ± standard deviation) for the commercial layer houses

Building ID	Days of Monitoring	NH_3 Emission Rate, g d^{-1} hen^{-1}
IA-MB-1	54	0.045 ± 0.018
IA-MB-2	54	0.062 ± 0.031
PA-MB-1	25	0.10 ± 0.08
PA-MB-2	25	0.087 ± 0.05
IA-HR-1	84	0.84 ± 0.26
IA-HR-2	75	0.95 ± 0.29
PA-HR-1	25	0.88 ± 0.36
PA-HR-2	25	0.78 ± 0.34
Overall	MB, daily manure removal	0.054 ± 0.026
	MB, semi-weekly manure removal	0.094 ± 0.062
	HR	0.87 ± 0.29

IA=Iowa, PA=Pennsylvania, HR=high-rise, MB=manure belt, 1 or 2=house number

Table 3. Seasonal NH_3 emission rates (mean ± standard deviation, g d^{-1} hen^{-1}) of high-rise houses in Iowa.

Time Period	Outside Temp °C	NH_3 Emission Rate (g d^{-1} hen^{-1}) IA-HR-1	IA-HR-2
Winter [a]	-4.4	0.71 ± 0.20	1.00 ± 0.19
Spring [b]	13.2	0.97± 0.30	1.09 ± 0.23
Summer [c]	22.9	0.89 ± 0.24	0.94 ± 0.27
Fall [d]	9.5	0.73 ± 0.24	0.59 ± 031

IA=Iowa, HR=high-rise, 1 or 2=house number

[a] 25 Nov. 2003 – 16 Dec. 2003 and 31 Dec. 2002 – 12 March 2002; [b] 18 March – 4 June 2003; [b] 10 June - 3 September 2003; [b] 26 September – 20

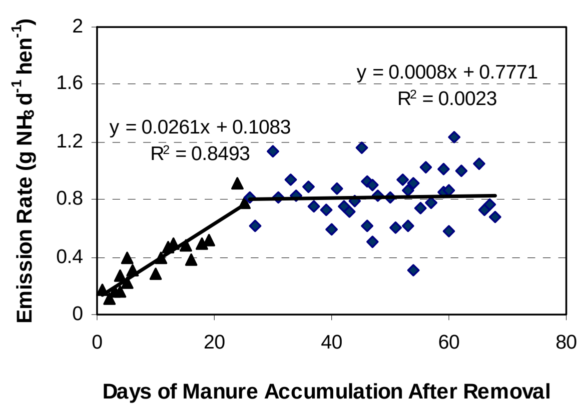

Figure 1. Ammonia emission rate vs. days of manure accumulation after cleanout in high-rise layer houses.