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AMMONIA CONCENTRATIONS IN POULTRY BROILER PRODUCTION UNITS TREATED WITH LIQUID ALUM

K. A. Armstrong, R. T. Burns, F. R. Walker, L. R. Wilhelm, and D. R. Raman

ABSTRACT

High ammonia concentrations in commercial broiler production houses can result in poor bird performance, lower feed conversion ratios, and higher mortalities. Growers have traditionally controlled in-house ammonia levels by increasing ventilation. During cold weather, increased ventilation rates result in higher heating energy requirements. Granular alum (aluminum sulfate, Al2(SO4)3 · 14H2O) has been successfully used as a litter amendment to reduce ammonia volatilization from litter inside broiler production houses. In this study, liquid aluminum sulfate was investigated as a litter amendment for ammonia suppression in four commercial poultry-broiler units. This project investigates four treatment levels of liquid alum in four adjacent broiler facilities of the same design. The houses were treated with the following rates of liquid alum: 0, 0.82, 1.64 and 2.46 L/m², equivalent to 0, 45, 90, and 135 kilograms of dry aluminum sulfate per 93 m² of floor area on an aluminum sulfate basis. In-house gaseous ammonia levels, temperature, relative humidity, fan flow-rates and mortalities are reported over one grow-out cycle in this paper. The lowest rate of liquid alum application, 0.82 L/m², was effective at maintaining in-house ammonia levels below 25 ppm for the first two weeks of the grow-out. Both the 1.64 L/m² and 2.46 L/m² alum application rates were found to provide effective control of in-house ammonia concentrations for the first three weeks of the grow-out.

KEYWORDS. Alum, Aluminum sulfate, Ammonia emissions.

INTRODUCTION

High levels of ammonia gas have been a recognized problem in the poultry industry for many years. Researchers have used various chemical amendments to control ammonia gas (Arogo et al., 2001). Work by Carlile indicates that in-house ammonia levels exceeding 25 ppm can result in decreased bird performance (Carlile, 1984). During the past decade, the University of Arkansas and the United States Department of Agriculture (USDA) conducted assessments of various potential chemical amendments. It was concluded that the application of alum to chicken litter results in the best combination of environmental and economic benefits (Moore et al., 1999). The litter in a broiler production house consists of the chicken manure and the bedding material. The rate of ammonia volatilization from litter is dependent on pH, moisture content, air velocity, ammonium concentration, and temperature. The pH of the broiler litter is one of the most important factors in controlling ammonia volatilization because it determines the ratio of volatile ammonia to ammonium, the ionic and non-volatile form of ammonical nitrogen. The application of alum reduces the litter pH and therefore suppresses ammonia emissions. The reduction of in-house ammonia emissions can improve bird performance. During the first 14 days of the grow-out, while the birds are young, ammonia has the greatest negative effect on a bird’s performance. Therefore, ammonia control during the first half of a grow-out provides the greatest benefits to bird performance during the grow-out. The effective suppression of in-house ammonia levels reduces ventilation requirements. During the winter months when exchanged air
must be heated upon entry to the broiler houses, a reduction in ventilation results in lower heating costs to the producer.

The majority of research reported to-date on alum use in broiler facilities concerns the use of dry granular alum. Recently, producers have begun to use liquid alum as well as dry material. This paper reports the initial findings from an on-going study using three rates of liquid alum (Al+Clear® Liquid Alum, General Chemical Corporation, Parsippany, New Jersey) as a broiler litter amendment. The broiler production houses used in this study are new tunnel ventilated units measuring 152.4 meters by 12.2 meters. The liquid alum rates applied to each house were as follows: Unit 1 was treated with 0.82 L/m², unit 2 with 1.64 L/m², unit 3 with 2.46 L/m² and unit 4 served as the control and received no alum treatment (0 L/m² rate). Each of the study poultry houses produced six flocks of birds per year. Approximately 40 days were required to complete the grow-out of a flock from day old hatchlings to 2.25 kg slaughter weight birds. Data collection was initiated following a complete litter cleanout in the four production houses. Alum was not applied to the litter prior to the first grow-out (grow-out 1) The first alum treatment was applied after litter build-up between grow-out 1 and grow-out 2. Alum treatments continued for each grow-out and were applied after the grower removed approximately 5-10 cm of litter and spread approximately 5-10 cm of clean pine shavings on the house floor. The alum was applied by a commercial applicator using a truck equipped with a spray boom. The three liquid alum rates applied in units 1, 2, and 3 were equivalent to 45, 90, and 135 kg dry aluminum sulfate per 93 m² of house area on an aluminum basis respectively.

**MATERIALS AND METHODOLOGY**

**Production Unit Instrumentation Overview**

The four adjacent commercial broiler houses of the same design were instrumented to measure gaseous ammonia, fan on/off status, differential pressure, temperature, relative humidity and feed motor run-time using a system similar to that developed by Wilhelm et al. (1999). Only ammonia, temperature and relative humidity data are reported in this paper. The basic data acquisition system design is shown in Figure 1. Wilhelm et al., 1999 provides more detailed cost and other information on the data acquisition system design and gives a history of the system since its inception in 1994. The instrumentation system used in this project was updated with newer model components wherever we found a newer unit available that provided advantages over the component types originally used. A set of data collection equipment was enclosed in a PVC manufactured enclosure located in control houses 2 and 4. Each PVC enclosure with the components noted in figure 1 collected data from a pair of houses. Therefore, house 1 and 2 inputs were connected to the 23X data logger and components in the house 2 collection set. House 3 and 4 inputs were connected to the second 23X data logger in house 4 collection set. A brief description of the principal components used in this study is provided below.

**Phone and Modem**

A cellular phone/modem system was connected to a Campbell Scientific Inc. (CSI) 23X Microloggers (Campbell Scientific, Inc., Logan, UT). This allowed the viewing of real-time data remotely and allowed the remote downloading of data. CSI DC112 modems were used and provided a data transfer speed of 1200 baud. A CSI YAGI directional antenna was used with the units to improve the signal strength. Using CSI PC208W software, designed for use with the CSI data loggers, the field system was contacted by telephone to upload data periodically.

**Multiplexers**
Four multiplexers were used to scan the environmental input parameters. A CSI AM416 and an AM32 were used in production units 2 and 4. The CSI AM416 model permitted scanning of up to 32 differential inputs. It had two signal channels, permitting thermocouple measurements and 0-5V (or other range) measurements via the same multiplexer. The AM32 was less flexible, having only one signal channel for all 32 differential inputs. Thus, two AM32 multiplexers were used to separately measure fan tilt switch voltage inputs from each production unit.

**Electrical/Electronic Equipment Enclosures**

Two polyvinylchloride (PVC) boxes were used to house the key instrumentation components. The data logger, the phone/modem unit, an AM416 and an AM32 multiplexer were mounted inside one PVC box located in production unit 2. The second enclosure, located in production unit 4, contained the same components.

**Ammonia Gas Sensors**

All ammonia sensors were Dräger Inc. (Dräger Safety, Inc., Pittsburgh, PA) electrochemical devices. These units consisted of a transmitter enclosure with the necessary electronics and a replaceable sensor. Initially, Dräger Polytron II sensors were used for ammonia detection. The 4-20 mA output from each transmitter was converted to a voltage signal through a 243-ohm precision resistor. This allowed the CSI 23X data logger to use the 5V full-scale measurement range to improve the resolution of recorded data. The electrochemical sensors required periodic calibration to ensure accuracy. A warm-up period of at least 12 hours was required before calibration. The zero calibration required 100% Ultra High Purity (UHP) nitrogen and the span calibration required a specific ammonia gas calibration concentration (50 ppm in N₂). The Polytron II sensor head accuracy is reported by the manufacturer to be ±5% for a range 21 - 100 ppm. The Polytron II units were provided by Dräger as direct replacements to the Polytron I units originally used by Wilhelm, but the Polytron II proved to be unsuitable for ammonia detection in broiler production units. The Polytron II units were prone to provide decreasing and negative ammonia values; even while ammonia concentrations increased in the production units. It is believed that the sensors used with the Polytron II units became saturated when exposed to continuous ammonia concentrations. Following the failure of the Polytron II units, Dräger determined that the Polytron I units which they initially indicated were unavailable, were available in the European market. Between the fourth and fifth grow-outs, the Dräger Polytron II units were removed and replaced with Dräger Polytron I units. The manufacturer has been unable to provide information concerning the accuracy of the new Polytron I sensor heads at this writing. Documentation provided with the Polytron I units used by Wilhelm et al.,(1999), was reported as ±2% in a range of 0-100 ppm. Ammonia sensors were scanned at 5 s intervals,
averaged, and recorded for each 30 min period. Thus, the recorded ammonia value represents an average ammonia gas level concentration for a given 30 min. period.

Gas Sensor Housing

The gas sensors in the four production units were mounted inside PVC housing approximately 0.5 m long x 0.22 m x 0.020 m deep, open at the bottom and at each end. This housing provided significant dust protection while allowing air movement over the sensors. Also, the housing permitted all sensors to be handled as a single unit during installation and removal. Each sensor was bolted to the PVC housing to ensure the sensor head was parallel to the house floor. All gas sensor-housing assemblies were attached to nylon ropes and hung by a pulley arrangement from the production unit ceiling 46 cm above the house floor. The University of Tennessee Biosystems Engineering and Environmental Science shop fabricated the gas sensor housings.

Fan Sensors

Mercury tilt switches were installed to sense fan operating status. A switch was mounted on a fan louver with rivets downstream of each fan such that the tilt switch contacts would open when the louver tilted during fan operation. This tilt switch was connected to a continuous analog output (CAO) of the data logger via a pull-up resistor. This system provided an output signal of 5V when the fan was operating and 0V when there was no airflow. These signals were scanned at 5s intervals, averaged, and recorded for each 30 min period. Thus, the recorded value represented an average “on” time for each fan during that period. Each production unit contained two 91 cm fans and nine 130 cm fans.

Power

In units 2 and 4, a 12-V battery provided power for the data logger, and a ‘smart’ charger maintained the battery voltage for long-term use 24 h/day. This approach assured uninterrupted power, which is necessary to avoid loss of gas sensor data. The six NH₃ Polytron I sensors were powered by a small 120V AC to 24V DC power supply.

Temperature and Humidity

In each production unit, a combined temperature (T) and relative humidity (RH) sensor (HMP45C, Campbell Scientific, Inc., Logan, UT) was mounted adjacent to the gas sensor. Rated sensor accuracies were ± 0.4 °C for and ± 2% RH from 0 to 90% RH.

Wiring and Connections

To allow speed and flexibility in connecting the various components, connectors were installed for almost all wiring entering the equipment enclosures. Individual connectors were also used for cables to each gas sensor. All signal connections used AMP Series 2 circular plastic shell and plug connectors with exception of the thermocouple connections. Thermocouple connections were made using quick disconnect thermocouple plugs and jacks. Approximately 2.7 Km of cable was installed for the instrumentation of the four production facilities.

RESULTS AND DISCUSSION

Ammonia data is presented for the fifth grow-out (October to November 2002). Figure 2 summarizes the half-hour averages of ammonia gas concentrations taken from the beginning to the end of the grow-out. All three rates of liquid alum application were equally effective at maintaining ammonia concentrations below 25 ppm for the first 13 days of the grow-out. The ammonia concentration in the control (unit 4) consistently exceeded 25 ppm by day 6 of the grow-out. By day 17, the ammonia levels begin to differ among treatments. Unit 1, the unit with the lowest alum application rate, follows Unit 4, the control, more closely. The unit 2 and unit 3 gas concentrations essentially track each other until the end of the grow-out and are lower than unit 1 and unit 4. Furthermore, at day 23 the ammonia levels in all four units consistently surpass 25 ppm. This suggests that liquid alum applied at a rate 0.82 L/m² can suppress in-house ammonia levels to below 25 ppm for approximately the first two weeks of the grow-out. Liquid
alum applications of 1.64 L/m² and 2.46 L/m² suppressed in-house ammonia levels to below 25 ppm for approximately the first three weeks of the grow-out. Additional ammonia results are provided in Table 1.

Table 1. Ammonia level information for grow-out five.

<table>
<thead>
<tr>
<th>House</th>
<th>Treatment (L/m²)</th>
<th>Maximum ppm</th>
<th>Maximum ppm, 1st two weeks</th>
<th>Average ppm</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>0.82</td>
<td>68</td>
<td>24</td>
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</tr>
<tr>
<td>2</td>
<td>1.64</td>
<td>58</td>
<td>47</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>2.46</td>
<td>71</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>74</td>
<td>74</td>
<td>29</td>
</tr>
</tbody>
</table>

Figure 3 illustrates the fan ventilation rate for production unit 4 when one or more ventilation fans were operating. The measured differential pressure was applied to the appropriate manufacturer fan curve (91-cm or 130-cm) and used to calculate the proper airflow rate from each ventilation fan. Each of the 11 individual fan flow-rates was summed to attain the overall airflow for house 4. The ventilation rates recorded for houses 1, 2, and 3 were very similar to unit 4.

All four of the production houses were identical, chicks were introduced to all four houses within a 48 h period, and the grower was asked to continue normal operation, therefore the ventilation patterns in units 1, 2, and 3 were expected to behave similarly. For the first 14 days of the grow-out the birds remain in the brooder end of the house and only two 91-cm fans are used to provide ventilation. At day 14 of the grow-out, the grower raises the divider curtain allowing the birds to occupy the entire production unit. At this time all eleven fans can be used as needed. If temperature increases enough the unit will be placed into full tunnel ventilation using all nine 130-cm fans.
Figure 3. Ventilation Rate in Unit 4 for Grow-out Five.

Figure 4 shows temperature and relative humidity as recorded at the center of unit 4. House 4 had an average inside temperature of 25-30°C. As ventilation increases relative humidity decreases as drier air from the outside enters the production house.

Figure 4. Temperature and Relative Humidity in Unit 4 for Grow-out Five

The mortalities for house 1, 2, 3, and 4 were 1,082, 989, 939, and 1,100 broilers, respectively. The untreated (control) house had the highest number of mortalities. At the highest alum application rate (2.64 L/m²) the lowest number of mortalities were observed. While no determinations can be made concerning the reduction of mortalities from one grow-out, the data suggests that the effect of liquid alum applications on broiler mortalities provides some advantage.
CONCLUSION

Ammonia concentration data from one grow-out suggests that liquid alum is effective at suppressing in-house ammonia levels for up to three weeks in modern broiler production houses. The lowest rate of liquid alum application, 0.82 L/m², was effective at maintaining in-house ammonia levels below 25 ppm for the first two weeks of the grow-out. Both the 1.64 L/m² and 2.46 L/m² alum application rates provided effective control of in-house ammonia concentrations for the first three weeks of the grow-out. The application of liquid alum at all of the three treatment levels was found to be very effective at reducing in-house ammonia levels as compared to no alum application. By the third week following application the ammonia reduction in the treated houses has ceased. The study will be continued for additional grow-out periods to provide complete treatment replication in time over both summer and winter months. While no determination on mortalities can be made from data from one grow-out, the data suggest that the use of liquid alum has the potential to reduce mortalities in broiler production cycles.

Acknowledgements

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REFERENCES