Project #477: Improving in-house air quality and reducing emissions associated with broiler production facilities using an electrostatic space charge system

Casey W. Ritz\textsuperscript{1}
Bailey W. Mitchell\textsuperscript{3}
Brian D. Fairchild\textsuperscript{1}
Michael Czarick III\textsuperscript{2}
John W. Worley\textsuperscript{2}

The University of Georgia, Poultry Science Building, Athens, GA 30602

\textsuperscript{1}Department of Poultry Science
\textsuperscript{2}Department of Biological and Agricultural Engineering
\textsuperscript{3}Southern Poultry Research Laboratory – USDA Agricultural Research Service
Athens, GA 30605

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Improving In-House Air Quality in Broiler Production Facilities Using an Electrostatic Space Charge System

C.W. RITZ
Department of Poultry Science, The University of Georgia
Calhoun, Georgia 30701
Phone: (706) 624-1402
FAX: (706) 624-14-4
e-mail: critz@uga.edu

B.W. MITCHELL
Southeast Poultry Research Laboratory, USDA-Agricultural Research Service
Athens, Georgia 30605

B.D. FAIRCHILD
Department of Poultry Science, The University of Georgia
Athens, Georgia 30602

M. CZARICK III and J.W. WORLEY
Department of Biological and Agricultural Engineering, The University of Georgia
Athens, Georgia 30602

Primary Audience:  Broiler Production Managers, Poultry Producers, Researchers

¹To whom correspondence should be addressed: critz@uga.edu.
SUMMARY

Reducing airborne dust in enclosed animal housing has been shown to result in corresponding reductions in airborne bacteria, ammonia and odor. Technologies that have shown to be effective for reducing airborne dust in animal areas include misting with an oil spray, water mists, extra ventilation, and electrostatic space charge systems. The search for strategies to reduce particulate matter and ammonia discharge from animal housing has led to considerable interest in the poultry industry for practical systems to reduce these air emissions. An electrostatic space charge system (ESCS) was designed to reduce airborne dust and ammonia emissions from a commercial broiler production house. The ESCS for this application was based on patented technology developed to reduce airborne dust and pathogens and proven in numerous research trials in poultry hatchers, caged layer rooms, and broiler breeder pens. Results of this study indicate the ESCS significantly reduced airborne dust by an average of 46 percent and reduced ammonia by an average of 12 percent within a broiler house with built-up litter over a period of seven flocks.

Key words: Electrostatic, ionization, poultry, dust, ammonia
DESCRIPTION OF PROBLEM

Air quality relating to poultry production housing has been a major concern for years. Environmental concerns and the close proximity of many poultry houses to residential and commercial areas are now issues affecting the poultry industry. Of specific concern are particulate matter, ammonia, and odor. While there is considerable research directed at defining the problem and scope of emissions, it is equally important that practical and economical control measures are examined.

Dust concentrations for poultry houses have been reported to vary from 0.02 to 81.33 mg/m³ for inhalable dust and from 0.01 to 6.5 mg/m³ for respirable dust [1]. Sources of dust that have been identified in broiler houses include feed, down feathers, excrement, microorganisms, and crystalline urine [2]. There are several factors that affect dust levels in poultry houses, including animal activity, animal density and moisture conditions [1]. Dust can contain large numbers of microorganisms that could have potential impact on human and bird health. Several studies have focused on dust levels in various animal housing and characterization of the dust components which include microorganisms, endotoxins [3], and odors [4, 5].

Several approaches can be used to reduce dust concentration in animal housing areas. These include adding fat to feed, fogging with water, fogging with an oil-based spray, ionization, electrostatic filtration, vacuum cleaning, filtration and recirculation, cleaning with wet scrubbers, purge ventilation, deep litter, and optimization of air inlet position. Reductions reported with these approaches ranged from 15 percent for weekly washing of pigs and floors, 23 percent with ionizers, to 76 percent with a rapeseed oil spray [6]. Other reports of ionizer efficiency have ranged from 31 percent [7] and 67 percent [8], to 92 percent [9]. Other studies [10, 11] have shown that reducing airborne dust levels by 50 percent can reduce airborne bacteria by 100 fold or more.

Ammonia in broiler houses, like much of the dust, originates from the litter base. Litter type, management, humidity, pH, and temperature affect the ammonia concentration and release [10, 12, 13]. High moisture levels in the air facilitate the absorption of ammonia into dust particles and the inhalation of the dust particles containing ammonia can cause damage to the respiratory tract [14]. For broiler house ammonia, reduction of aerial concentrations has been largely accomplished through ventilation. However, as fuel costs increase particularly during the winter months, poultry growers tend to reduce ventilation to minimize heating costs. Another trend is less frequent complete house clean out resulting in birds being grown on built-up litter with the cake removed and the remaining litter top dressed with new bedding material. The combination of these trends can be detrimental to air quality in broiler houses if dust and NH₃ levels are not managed, particularly during the brooding phase.

The Electrostatic Space Charge System (ESCS) described by Mitchell and Stone, 2000[15] has been shown to significantly improve air quality by reducing airborne pathogens and disease transmission in poultry. In broiler breeder studies [16, 17] ESCS technology showed reductions in airborne pathogens and bird-to-bird or bird-to-egg transmission by reducing airborne dust, ammonia, and bacteria by an average of 60, 56, and 76 percent, respectively. ESCS units have not been shown to produce any adverse health effects to birds of all ages or humans. ESCS technology reduces airborne dust and associated microorganisms by charging the dust in an enclosed space and collecting it on grounded collector plates or on the floor or walls of a room.
Airborne *Salmonella enteritidis* (SE) experiments conducted in controlled environment transmission cabinets with and without an ESCS showed chicks exposed to a naturally generated aerosol of SE beginning at one day of age had no cecal contamination eight days later [18,19]. Experiments conducted in a 15 x 22 ft (3300 ft²) isolation room with SE infected caged layers showed reductions of airborne SE of approximately 95 percent over a test period of 10 d when the room was treated with the ESCS [20].

Evaluation of an ESCS for reducing dust and ammonia concentrations for broiler production on a commercial scale has not been attempted. The primary goals of this research are to determine whether a practical ESCS can be developed and operated in a commercial broiler production house, and to evaluate the effectiveness of this technology for improving air quality in the house and subsequent reductions in emissions of dust and ammonia.

**MATERIALS AND METHODS**

The principle behind the ESCS is to transfer a strong negative electrostatic charge to airborne dust particles. The negatively charged particles will precipitate out of the air as they are attracted to grounded surfaces. Nitrogen compounds attached to the dust should also precipitate out of the air. A custom-made ESCS system was designed and installed within a 500 ft x 40 ft dropped ceiling, tunnel ventilated commercial broiler house. The treatment house (TH) system consisted of four rows of in-line, negative air ionization units; two 200 hundred ft rows on each side of the house in the brood end and two 200 hundred ft rows in the growout end, as shown in FIGURE 1. Separate high voltage (-30 kVdc, 2 mA) power supplies were used to supply -25 kVdc to the ion generators in each half of the house. The high voltage power supply for the ESCS was current limited to a safe level of two mA. The in-line generators consisted of a conductive tube with sharp pointed electrodes at one in. intervals pointing toward the litter. The tubing was attached to a grounded one in. diameter black iron pipe with Teflon insulators at two ft intervals. The iron pipe was located three in. above the discharge points to provide a close proximity ground plane and to increase the negative ion output [15]. The in-line generators were centered between the first row of water lines and the feeders such that they were about 12 ft from the sidewalls. The in-line generators were installed on each end of the house such that it was centered between the center curtain (used for half-house brooding) and the evaporative cooling pads on one end and between the center curtain and the tunnel ventilating fans on the other end. Winches were used to raise the ESCS to a height of seven ft above the litter (sufficiently high to walk under, but as low as possible to concentrate the charge near the birds where dust is being generated). A broiler house adjacent and essentially identical to the treatment house was instrumented for airborne dust and ammonia monitoring but operated as a control house (CH) without ionization. Both the treatment and control houses were operated simultaneously.

Dust and ammonia concentrations, temperature and relative humidity readings were measured at approximately four ft above the litter along the center line at different locations in the house. During the brooding period, measurements were made in the center of the brooding section. After brooding, when birds occupied the entire house, measurements were made in the center of the growout end of the house in front of the tunnel fans. Dust concentrations were measured at 15 min intervals with a TSI DustTrak [23], a laser-based instrument with the capability of measuring dust concentrations from 0.001 to 100 mg/m³. Aerial ammonia was measured every min with a Draeger Polytron I [24] electrochemical sensor with a sensitivity
range of 0 to 100 ppm. The ammonia sensors were calibrated with 50 ppm calibration gas prior to each sampling period.

Temperature and relative humidity were recorded at one min intervals with Hobo data loggers [25]. Special efforts were taken to assure that treatment and control houses were operated at the same temperature and ventilation rate. A computer located at the farm was connected to the house controller system and recorded operation of each fan along with relative humidity and temperatures throughout the houses.

Flock and treatment means data were analyzed by analysis of variance using the General Linear Models procedure of SAS [26]. Results were considered statistically significantly at $P \leq 0.05$.

**RESULTS AND DISCUSSION**

Data were collected for three sampling periods during each of seven flocks. Air samples were collected continuously for approximately 5 d. during each period. Sampling frequency was once every 15 min for dust (4 pr h) and once per min for ammonia (60 pr h). Mean dust and ammonia concentrations were calculated for each sampling period. Due to the large amount of collected data during each sampling period, hourly means were generated ($n = 170$) to calculate the sampling period mean. The three sampling period means were then used to generate a flock mean concentration for dust and ammonia. **TABLE 1** contains the mean dust and ammonia concentrations and reduction efficiencies for aerial dust and ammonia within a broiler production house for each of the seven consecutive flocks.

The results of the present study show that the use of the ESCS produced a significant ($p<0.05$) overall airborne dust reduction of 46 percent in the commercial broiler house (**TABLE 1**). No significant interaction was found between flocks based on dust concentrations. Aerial dust concentrations within the broiler houses were low and ranged from 0.2 to 1.9 mg/m$^3$. Charged dust could often be seen extending from the grounded water and feeder support cables in the treatment house. Besides reducing airborne dust, the ESCS is likely inhibiting aerosolization of dust by keeping surface dust near its source due to the negative space charge. Loose dust on the floor of a treated area will tend not to become airborne because as soon as it leaves the floor it would be charged and re-attracted to the floor. Long term exposure to airborne dust and pathogens in poultry houses can be associated with chronic respiratory problems for workers, therefore, an additional benefit of reducing airborne dust and pathogens in poultry houses would be the improvement of air quality for workers.

Ammonia levels in the study houses ranged from an average of 11 ppm to 54 ppm with concentrations reduced by an overall reduction efficiency of 12 percent with the ESCS (**TABLE 1**). This reduction of ammonia is much lower than the 56 percent average reduction obtained in a breeder pen study by Mitchell et al., 2002 [17], however, the ammonia concentrations recorded in the breeder pen study were much lower than in the present broiler study. A significant interaction of ammonia concentration between flocks was observed and is considered to be a seasonal effect and not one that is induced by the ESCS. Reductions of aerial ammonia levels within the treatment house primarily occur during the evening hours when ammonia concentrations were highest and ventilation rates were lowest.
Examples of recorded data profiles of dust and ammonia concentrations for a flock during the brooding period are shown in FIGURES 2 and 3. Aerial dust levels in TH were consistently lower than in CH and averaged 48 percent lower for the sample period depicted in FIGURE 2. Peak dust levels in the control house in the latter part of the period were noticeably higher than those in the treatment house. Temperature and humidity measurements in the two houses over the same sampling period are shown in FIGURE 4, depicting that very little variation occurred in house operations over the sampling period.

While it is known that a certain amount of ammonia and odors are absorbed in poultry house dust, it is not known what percentage of total ammonia production this represents. Previous studies indicate that a significant portion of airborne ammonia in animal rearing facilities is associated with dust particles [21, 22]. An assumption in the present study was that reduction of airborne dust by the ESCS would result in a similar reduction in airborne ammonia, based on previous work with broiler breeders [17]. In the present study with built-up litter over a period of one year, the ESCS did not significantly reduce ammonia concentrations. The reasons for this discrepancy are not clear. It may be that the ratio of gaseous ammonia compared to the amount bound to dust is much greater resulting in less opportunity for overall ammonia reduction by a dust reduction system. It should be noted that the ammonia levels in the present study were two to three times higher while the dust levels were two to three times lower than in the study reported by Mitchell et al., 2002 [17] which may explain the lower ammonia removal effectiveness of the ESCS in the present study. The relative humidity in the broiler houses may have also been sufficiently low as to not facilitate the adherence of a significant amount of ammonia to the dust particles.

No differences in bird activity were observed in the form of decreased water consumption or increased mortality, and no adverse effects of the continuous charge were observed in the form of stray voltage or static discharge at the feeder and water lines. The incidences of static discharge to workers were minimal. The intensity of a discharge from direct contact with an ESCS ionizer was similar to touching a spark plug wire on a gasoline engine.

Dust collection on the ESCS and the subsequent need for cleaning was not a major issue. Brushing the dust from the equipment every seven to 10 days was sufficient to maintain desired high charge levels in the house. Telescoping brushes were used to clean the ESCS after the power was shut off to the unit. Cleaning time of the prototype system was about one hr. Maintenance of the system during the study period was minimal. It should be noted that there was no effort to optimize the layout of the ESCS for the treatment house beyond the original design and thus it is reasonable to assume that additional rows of in-line chargers and/or higher voltage levels on the ESCS could have improved the removal efficiencies seen in this study.

A potential future application of the ESCS technology for reducing ammonia and dust emissions form poultry houses would be to concentrate ESCS charge on exhaust air where all exhaust air would pass within about 3 ft of an ESCS compared to separations of 13 ft or more in the present study with indoor treatment. This would allow for generating much higher charges on dust particles and with potentially much greater removal of dust and ammonia from the air than can be obtained within the house.
CONCLUSIONS AND APPLICATIONS

1. Broiler house airborne dust concentrations were significantly reduced with the use of an electrostatic space charge system. The effectiveness of the system is increased with higher dust concentrations.

2. Ammonia levels in broiler houses with dust concentrations averaging less than one mg/m³ do not appear to be significantly affected by an ESCS. Significant seasonal differences in ammonia concentration were observed.

3. Reducing ammonia concentrations inside poultry houses with low dust concentrations may require separate control strategies for improving in-house air quality and subsequent emission reductions.

REFERENCES AND NOTES


23. TSI Incorporated, Shoreview, MN 55126.


25. Weltech Agri Data, Charlotte, NC 28256.

TABLE 1. Efficiency of electrostatic space charge system (ESCS) for reduction of broiler house dust and ammonia concentrations.

<table>
<thead>
<tr>
<th>Flock</th>
<th>Period</th>
<th>Dust Concentration (mg/m³)</th>
<th>NH3 Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CH</td>
<td>TH</td>
</tr>
<tr>
<td>1</td>
<td>Jan-Feb</td>
<td>1.13</td>
<td>0.60</td>
</tr>
<tr>
<td>2</td>
<td>Mar-Apr</td>
<td>0.48</td>
<td>0.27</td>
</tr>
<tr>
<td>3</td>
<td>May-Jun</td>
<td>0.14</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>Jun-Jul</td>
<td>0.49</td>
<td>0.36</td>
</tr>
<tr>
<td>5</td>
<td>Aug-Sept</td>
<td>0.47</td>
<td>0.23</td>
</tr>
<tr>
<td>6</td>
<td>Oct-Nov</td>
<td>0.63</td>
<td>0.38</td>
</tr>
<tr>
<td>7</td>
<td>Nov-Dec</td>
<td>1.10</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Yearly Mean</td>
<td>0.63</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Mean ± SEM: 0.51 ± 0.0897, 30 ± 1.458

Treatment Interaction: $p < 0.0508$, NS

Flock Interaction: NS, $p < 0.0001$
FIGURE 1. In-line ionization units hanging from the ceiling of the Treatment House (TH). Four units, two in the brood end and 2 in the growout end were hung on either side from the center of the house.

FIGURE 2. Data profile showing dust concentration comparison between Treatment House (TH) and Control House (CH) during brooding.

FIGURE 3. Data profile showing ammonia concentration comparison between Treatment House (TH) and Control House (CH) during brooding.

FIGURE 4. Data profile showing temperature and relative humidity comparisons between Treatment House (TH) and Control House (CH) during brooding.
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FIGURE 4. Data profile showing temperature and relative humidity comparisons between Treatment House (TH) and Control House (CH) during brooding.
LIST OF PRESENTATIONS AND PUBLICATIONS

Presentations


Publications

INDUSTRY SUMMARY

Commercial poultry production operations are known to generate large quantities of dust and ammonia. Airborne dust can be a primary carrier of pathogenic bacteria and viruses. Aerosol ammonia research has demonstrated that broiler performance is reduced when ammonia levels exceed 25 ppm. Dust and ammonia can also serve as a source for nuisance complaints against individual growers or poultry companies. Dust levels in a typical broiler production house may exceed 10 mg/m^3 (well above the recommended threshold for extended human exposure). High moisture levels in the air facilitate the absorption of ammonia into dust particles. Dust control strategies may facilitate reductions in ammonia concentrations as well. Technologies that assist poultry operations toward improving the in-house air quality will result in improved bird performance and reduced house emissions.

The primary goals of this research were to determine whether a practical ESCS can be developed and operated in a commercial broiler production house, and to evaluate the effectiveness of this technology for improving air quality in the broiler houses. The ESCS for this application was based on patented technology developed to reduce airborne dust and pathogens and proven in numerous research trials in poultry hatchers, caged layer rooms, and broiler breeder pens.

Results of this study within a commercial broiler house with built-up litter over a period of seven flocks indicate that the ESCS significantly reduced airborne dust concentrations by an average of 46 percent and reduced ammonia by an average of 12 percent compared to a comparably management control house. Dust concentrations were typically found to be less than 1.0 mg/m^3, ranging from 0.09 to 0.60 mg/m^3 in the treatment house and 0.14 to 1.13 mg/m^3 in the control house. The 12 percent reduction in ammonia concentration by the ESCS was not statistically significant. Conditions with higher dust concentrations will likely result in greater efficiency of the ESCS and potential improvement in ammonia control. The implications of this study indicate that the use of an ESCS can be an effective in-house dust control technology. Though not evaluated within this study, the reduction in dust concentrations may have a direct impact on levels of airborne pathogens.

A potential future application of the ESCS technology for reducing ammonia and dust emissions from poultry houses would be to concentrate ESCS charge on exhaust air. This would allow for generating much higher charges on dust particles and with potentially much greater removal of dust and ammonia from the air than can be obtained within the house. Further research is needed to evaluate the effectiveness of an ESCS as an exterior emission control technology.