APPLICATION OF AN ELECTROSTATIC SPACE CHARGE SYSTEM FOR DUST, AMMONIA, AND PATHOGEN REDUCTION IN A BROILER BREEDER HOUSE

B. W. Mitchell, L. J. Richardson, J. L. Wilson, C. L. Hofacre

ABSTRACT. *Airborne dust in poultry housing is known to be one of the primary means by which disease-causing organisms are spread throughout a house. An electrostatic space charge system (ESCS) was used to reduce airborne dust in a small-scale broiler breeder house. The system used ceiling fans to distribute negatively charged air throughout the room and to move negatively charged dust downward toward the grounded litter where most of it would be captured. The system significantly ($P < 0.0001$) reduced airborne dust by an average of 61%, ammonia by an average of 56% ($P < 0.0001$), and airborne bacteria by 67% ($P < 0.0001$). Earlier studies with an ESCS have resulted in significant reductions of airborne dust, bacteria, and airborne transmission of disease in poultry hatching cabinets, caged layer rooms, and in controlled environment disease transmission cabinets. The ESCS was shown to be a reliable and easily maintained system for reducing airborne dust, ammonia, and bacteria in a small broiler breeder house. Results of this study combined with the results of related ESCS studies suggest that the system could probably be scaled up to full-sized production houses for poultry or other animals for dust reduction, pathogen reduction, and possibly ammonia reduction. All of the applications have potential for improving human health as well as animal health.*

Keywords. *Electrostatic, Dust, Bacteria, Microorganisms, Salmonella, Disease, Food safety, Ammonia, Poultry, Air quality, Broiler.*

Airborne dust is one of the primary means by which disease-causing organisms are spread throughout a poultry house. Reductions in airborne dust levels have been associated with even greater reductions in airborne bacteria. Poultry, meat, and eggs contaminated with Salmonella continue to be important vehicles for Salmonella infections in humans. Pathogens such as Salmonella can be introduced into the food chain at any point – from the breeder house to the processing plant. Interventions are best begun at the breeder house, which is the first part of the chain. Airborne transmission of Salmonella is a major factor for the spread of Salmonella from bird to bird and hatching eggs in breeder houses. It has been shown to be a major factor in the spread of disease in hatching cabinets. Salmonella can also be transmitted from breeding birds to broilers by egg contents or by egg shell contamination (Humphrey, 1998).

Potential sources of Salmonella for a flock of breeder birds include the feed, rodents, insects, drinking water, dust, and air (De Las Casas et al., 1972; Davies and Hinton, 2000; Henzler and Optiz, 1992; Shapcott, 1984). Nakamura et al. (1997) found that airflow patterns had a significant effect on the rapidity of horizontal transmission of *Salmonella enteritidis* (SE). Gast et al. (1998) showed that SE could easily be transmitted between laying hens through the air. A recent study (Leach et al., 1999) has shown that aerosol challenge of hens with *Salmonella typhimurium* resulted in 8 to 15 times more Salmonella in eggs than an oral challenge.

Interventions, other than improvements in biosecurity and the primary breeder flock, which can reduce the incidence of egg contamination in breeder flocks are very limited. The use of Filtered-Air Positive-Pressure (FAPP) housing is one approach used to produce disease-free poultry (Mitchell et al., 1989). Part of the FAPP design involves filtering incoming air through high efficiency filters to assure no viruses or bacteria enter the building through the supply air. Although the eggs produced in these houses are specific pathogen free (SPF), the cost of constructing and operating this type of specialized production house would eliminate it as an intervention approach for poultry houses with the exception of those houses used for valuable elite pedigree stock.

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, regular washing, 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% for weekly washing of pigs and floors, to 23% with ionizers, to 76% with a rapeseed oil spray (CIGR, 1994). Other reports of ionizer efficiency have ranged from 31% (Czarick et al., 1985) to 67% (Veenhuizen and Bundy, 1990) to 92% (Mitchell, 1998). Other studies (Madelin and Wathes, 1988; Carpenter et al., 1986) have shown that

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reducing airborne dust levels by 50% can reduce airborne bacteria by 100 fold or more.

Another function of air ionization can be to kill airborne and surface microorganisms. The potential effect of ions to destroy microorganisms has been suggested in numerous studies (Gabbay et al., 1990; Kingdon, 1960; Krueger, 1985; Krueger and Reed, 1976; Krueger et al., 1975; Marin et al., 1989; Phillips et al., 1964; Robinzon et al., 1983; Rosenthal et al., 1979; Seo et al., 2001; Arnold and Mitchell, 2002). The kill rate of an Electrostatic Space Charge System (ESCS) on airborne and surface SE within about 25 cm has been shown to be 96% or more (Seo et al., 2001). The ESCS has also been shown to reduce biofilms, developed on stainless steel surfaces by using bacteria from poultry carcass rinses, up to 99.8% when used within about 25 cm (Arnold and Mitchell, 2002). The minimum ion density dose and time exposure combinations required to kill organisms and the exact mechanisms that cause air ions to be bactericidal have not been well established.

One approach that has shown promise in a related study (Richardson et al., 2003) uses ESCS technology to reduce airborne pathogens and bird-to-bird or bird-to-egg transmission by reducing airborne dust, which carries the pathogens. The ESCS (Mitchell and Stone, 2000) uses a simple, environmentally friendly process that is harmless to birds and humans to reduce airborne dust and associated microorganisms by charging the dust in an enclosed space and collecting it on special grounded collector plates or on the floor or walls of a room. In laboratory experiments in hatching cabinets, the ESCS system has been shown to have effectiveness comparable to a 95% media filter for removing dust and equal or better effectiveness for removing airborne bacteria and Salmonella (Mitchell et al., 2002). Similar results were obtained with the ESCS in three field studies in commercial hatchers (Mitchell and Waltman, 2003). Salmonella transmission experiments with chicks exposed to Salmonella during hatching have shown that ESCS treatment of the hatching cabinet reduced cecal contamination at 7 days of age by an average of 3.4 logs (Mitchell et al., 2002). Airborne *Salmonella enteritidis* (SE) experiments conducted in controlled environment transmission cabinets with one-week-old chicks exposed to a naturally generated aerosol of SE showed ESCS treatment resulted in no fecal contamination 8 days later (Gast et al., 1999). Experiments conducted in a 4.6- × 6.7-m (30.8-m^3) isolation room with SE-infected caged layers showed reductions of airborne SE of approximately 95% over a test period of 10 days when the room was treated with the ESCS (Holt et al., 1999). Another effect of the space charge, besides reducing dust and microorganisms, which are already airborne, is to keep surface dust near its source. For example, loose dust on the floor of a treated room would tend not to become airborne because as soon as it left the floor it would be charged and re-attracted to the floor. It is known that long-term exposure to airborne dust and pathogens in poultry houses is 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.

The objective of this research was to demonstrate the effectiveness of an electrostatic space charge system in the breeder/layer farm environment for reducing airborne dust, ammonia, and gram-negative bacteria in a several-month-long study. Reductions in these environmental contaminants should result in reduced transmission of Salmonella and other pathogens to breeder hens, eggs, and the resulting broilers. Effects of the ESCS on Salmonella transmission, egg contamination, broiler growout, and bird performance will be described in a related report in *Avian Diseases*.

Materials and Methods

Electrostatic System

A custom-built electrostatic space charge system (ESCS) was installed in one of two isolated breeder rooms – each of which was set up like a commercial breeder house with slat and litter scratch area at the University of Georgia Poultry Research Center. One was set up for the ESCS treatment, and the other served as a control with no treatment. Each room (9.1 m wide × 7.3 m deep × 3 m high) was configured with a litter-covered scratch area in the center third of the room and elevated slatted areas where the nests, hen feeders and nipple waterers were located on either side. Each room had two variable-speed, water-resistant ceiling fans suspended from the ceiling and centered over the scratch area for air mixing. For the treatment room, an ESCS unit was suspended about 30 cm below each ceiling fan – such that the bottom of the ESCS was approximately 2.4 m above the floor, to charge recirculating airborne dust as it was directed toward the grounded litter (figs. 1 and 2) where much of it would be collected by electrostatic attraction. Each ESCS consisted of a 6-bar, 240-pin ionizer with a ground plane located 7.6 cm behind the discharge points. The ESCS units were operated at -30 kVdc by a current-limited (<0.5 mA) power supply.

Environmental Control

Ventilation for each room was controlled by an Aerotech ST-4124 controller (Aerotech, Inc., Mason, Mich.), which proportionally controlled the variable speed exhaust fans to maintain temperature setpoints in the rooms. The controllers were adjusted to give the same ventilation rate for the two rooms for the setpoint error (setpoint – actual temperature) to avoid ventilation differences. Average temperature setpoints were 23°C. Each room had light traps on the air inlets and outlets, and lights were turned on by a timer from 6 A.M. to 8 P.M. each day to provide a typical light cycle for the birds.

Bird Management and Disease Challenge

Spent broiler breeder fowl (720) were purchased from an integrator and used as the experimental birds. Birds moved to the experimental facility were given a regiment of antibiotics as described by Goren (1993) to eliminate the normal intestinal flora, and molted. Fifty (50) Salmonella negative broiler breeder males, 18-weeks of age, were purchased and mixed with the molted hens as egg production was initiated. To simulate a natural challenge of Salmonella, 5% of the birds placed were tagged and inoculated orally with 0.5 mL of *Salmonella enteritidis* at a titer of 1.94×10^7 CFU/mL and allowed to intermingle with the Salmonella-free hens and roosters. The project lasted for a total of 41 weeks.

Microbial Methodology

Gram-negative bacteria were measured in the treatment and control rooms with a SUPER SAS 90 (Bioscience International, Rockville, Md.) impaction-type air-sampling

Figure 1. Upper left: Exhaust end of research house showing separate pairs of exhaust fans for each room. Lower left: Evaporative cooler pads in inlet side of house. Upper right: Breeder room with slatted area, nests, and nipple drinker line (upper left). Hen feeder trough between nest and drinkers not visible. Lower right: Scratch area and rooster feeder.

device utilizing MacConkey agar plates. Following exposure, the plates were incubated at 37°C for 24 h and colonies were counted. Air samples of 1000 L each were taken during daylight hours approximately 75 cm above the litter in the center of the room. Three samples were taken per week from weeks 33 to 35 and daily samples were taken from week 36 and 37 totaling 24 air samples. Since only one sampler was available, samples were taken sequentially within a few minutes of each other in the control and treatment rooms following disinfection with alcohol wipes.

Dust, Ammonia, Temperature, Humidity, and Ammonia Measurements

Dust, temperature, and humidity were measured at 1 m above the floor about halfway between the center of the room and the side wall at 10 min intervals by data loggers throughout the several month long study. Ammonia was measured during the latter part of the study from week 24 to week 41. Dust concentration was measured with a laser-based DustTrak instrument (TSI Inc., Shoreview, Minn.); temperature and humidity with Hobo data loggers (Onset Computer Corp, Bourne, Mass.); and ammonia with Draeger Pak III loggers (Celco Safety, Birmingham, Ala.). The DustTrak instruments had a range of 0.001 to 100 mg/m^3 and a resolution of 1% of the reading with a flow rate of 1.7 L/min. They were calibrated at the factory.

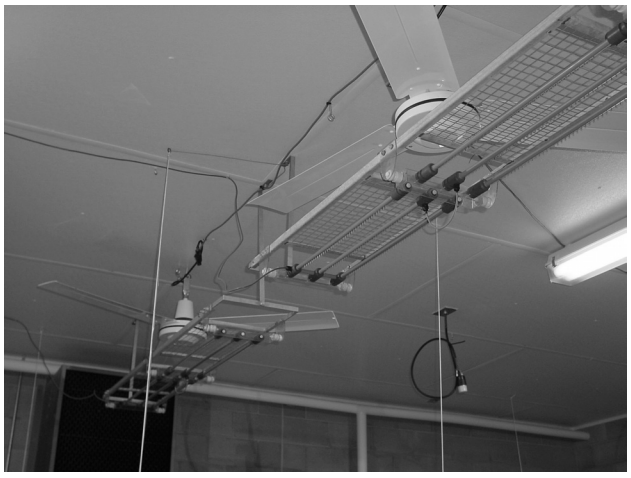

Figure 2. ESCS units suspended below the ceiling fans in the treatment room.

Statistics

Data were analyzed with SAS 8.1 (SAS Institute, Inc., Cary, N.C.) using the general linear model procedure and analysis of variance.

Results and Discussion

General

Results are shown in figures 3 through 7. The ESCS significantly ($P < 0.0001$) reduced dust concentration by an average of 61% over a period of 23 weeks (figs. 3 and 5), ammonia by an average of 56% ($P < 0.0001$) over a period of 18 weeks (figs. 4 and 6), and gram-negative bacteria by an average of 67% over a period of 5 weeks (fig. 7). Dust and ammonia levels were consistently low during the nighttime hours and highest during the afternoon (figs. 3 and 4) suggesting a correlation with bird activity. Although the ceiling fans seemed to help mix air and distribute the negative charge in the treatment room, a follow-up preliminary study with an inline ESCS run lengthwise across the same room, with the same birds, but without the mixing fans, resulted in similar reductions in airborne dust concentration and ammo-

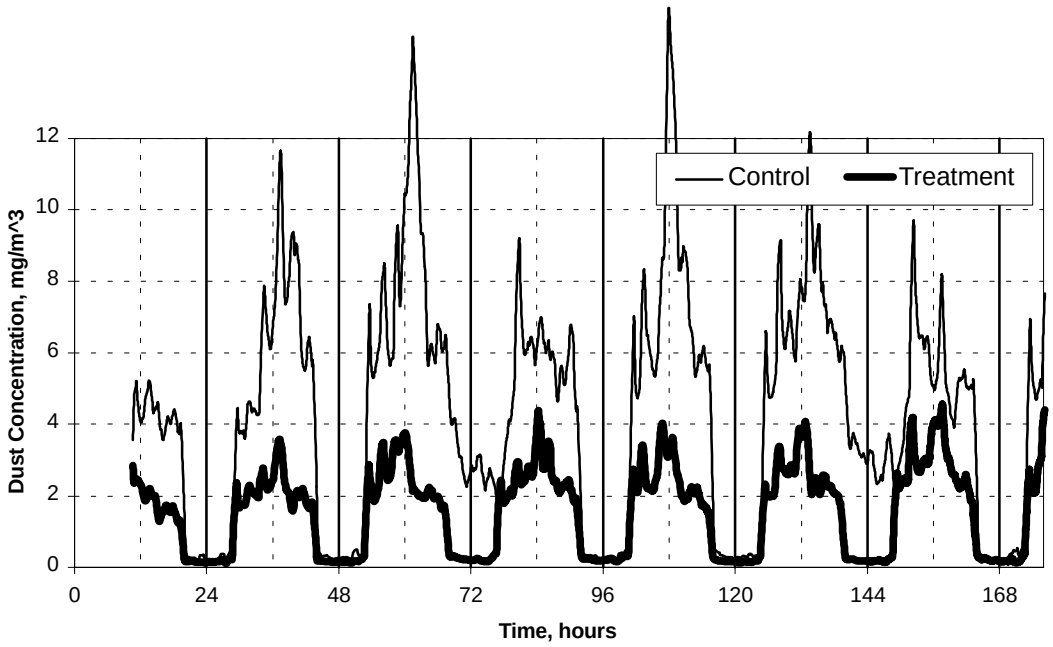

Figure 3. Dust concentration for treatment vs. control rooms by cumulative hours for a typical week. Note the light timer stuck on in the control room on the evenings ending at hour 72 and hour 144.

nia, suggesting the mixing fans may not be necessary for effective operation of the ESCS in this type of bird space. Preliminary results of a related study in a full-sized broiler production house without mixer fans also suggest that the mixer fans may not be necessary. Temperature in the two rooms averaged 22.8°C and relative humidity averaged 62%; neither was significantly different ($P > 0.05$) between the control and treatment rooms during the study period, suggesting the ventilation rates were well matched.

DUST

The lights-off period between 8 P.M. and 6 A.M. typically resulted in very low activity and near zero dust concentration levels in both rooms as can be seen on the one-week dust chart (fig. 3). A malfunction of the light timer in the control room on days ending at hour 72 and 144 caused higher activity and a correspondingly higher dust concentration in that room than was normal for nighttime hours. The dust reductions in the present study are similar to those reported earlier for the ESCS in poultry areas (Gast et al., 1998; Holt et al., 1999; Richardson et al., 2003).

AMMONIA

Drifting of the ammonia sensor due to extended exposure (Xin et al., 2002) was not observed in this study – perhaps due to the frequent and fairly complete air exchanges in the relatively small rooms (due to ventilation controls) which, along with highly variable bird activity during the day, resulted in large swings in dust concentration (fig. 3). An indication of the 24-h air exchange in the rooms was the approximately 5°C daily diurnal variation in temperature typically caused by normal outside temperature variations.

AIRBORNE BACTERIA

Reductions in airborne bacteria (fig. 7) were similar to an earlier ESCS study (Richardson et al., 2003), but lower in this study than the ESCS studies of Gast et al. (1998) and Holt et al. (1999) – perhaps due to the presence of litter and birds on the floor compared to caged birds in the earlier studies. Although the impaction air sampler used to collect airborne bacteria gave consistent results, some limitations were noted. Although the sampler seemed to have better collection

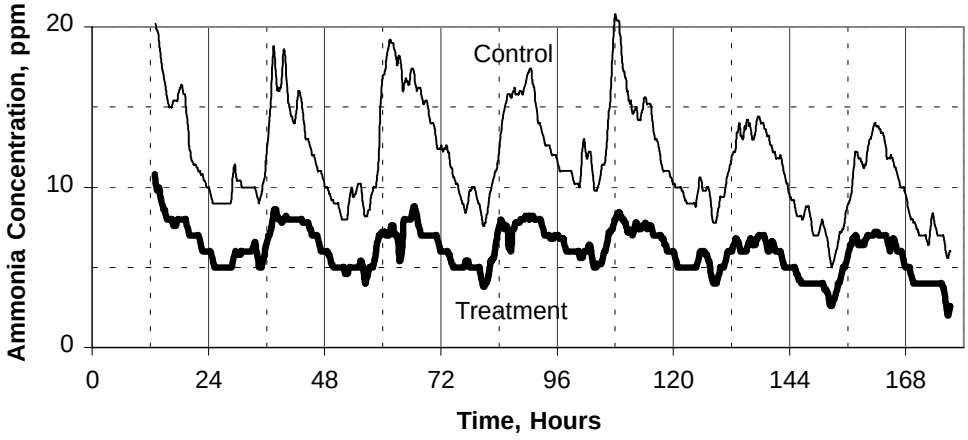

Figure 4. Ammonia concentration for treatment vs. control rooms by cumulative hours for a typical week.

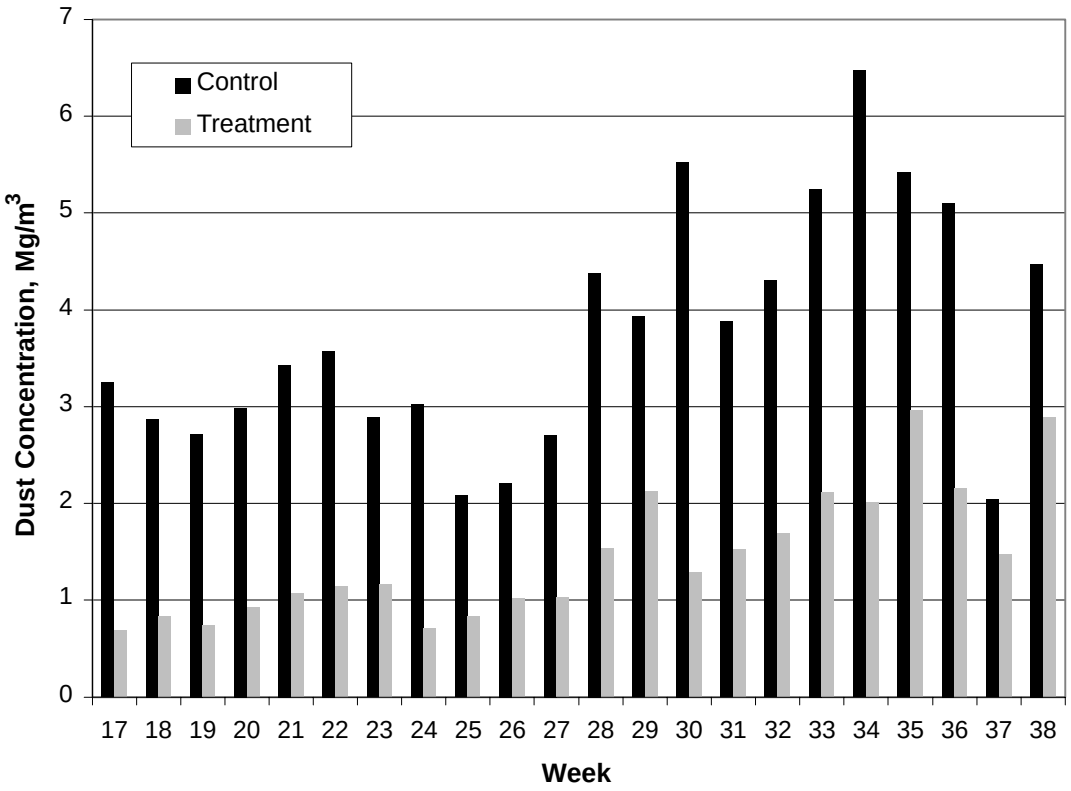

Figure 5. Average weekly dust concentrations in the control and treatment rooms from weeks 17 to 38 (bird age). The average dust concentrations in the treatment room (1.45 mg/m^3 ± SE = 0.14) were significantly different (P < 0.0001) than those of the control room (3.75 mg/m^3 ± SE = 0.25).

efficiency than settling-type agar plates used by the authors in similar studies, the cost of the sampler (approximately $5,000) made it impractical to sample in both rooms simultaneously, and required sequential measurements. A sampling time limit of 20 min to avoid excessive agar plate drying limited the ability to smooth out short-term variations in measurements due to variations in bird activity by sampling for longer periods – such as 1 to 2 h. Difficulties in sampling pathogenic airborne bacteria with commonly available equipment have led to the development at the Southeast Poultry Research Laboratory (USDA-ARS) of a

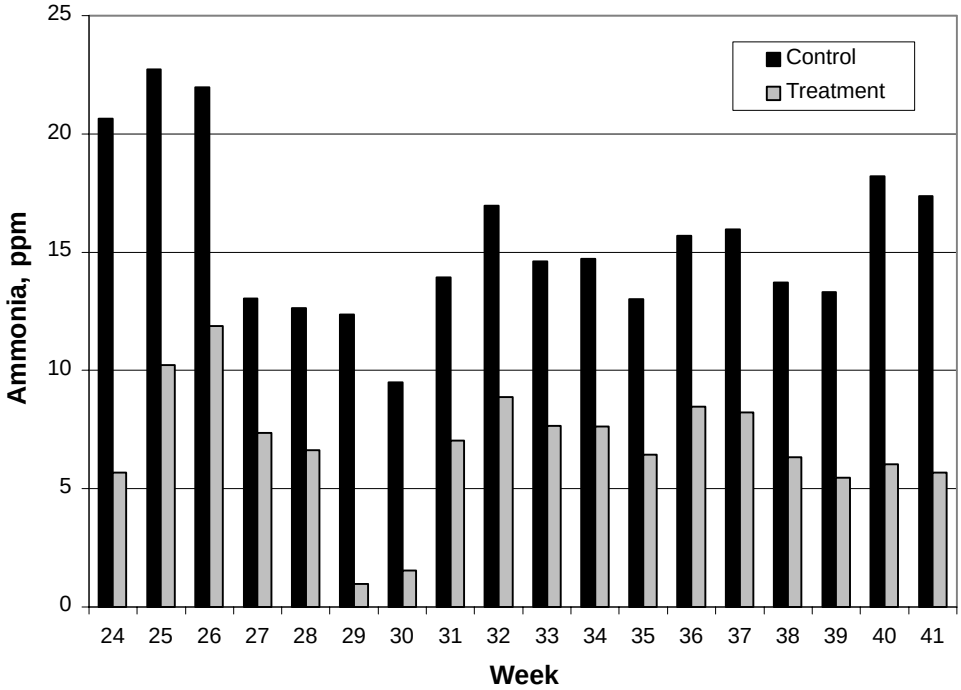

Figure 6. Average airborne ammonia levels in the control and treatment rooms from weeks 24 to 41 (bird age). The control room average ammonia level (15.6 ppm ± SE = 0.83) was significantly lower (P < 0.0001) than that of the treatment room (6.8 ppm ± 0.61).

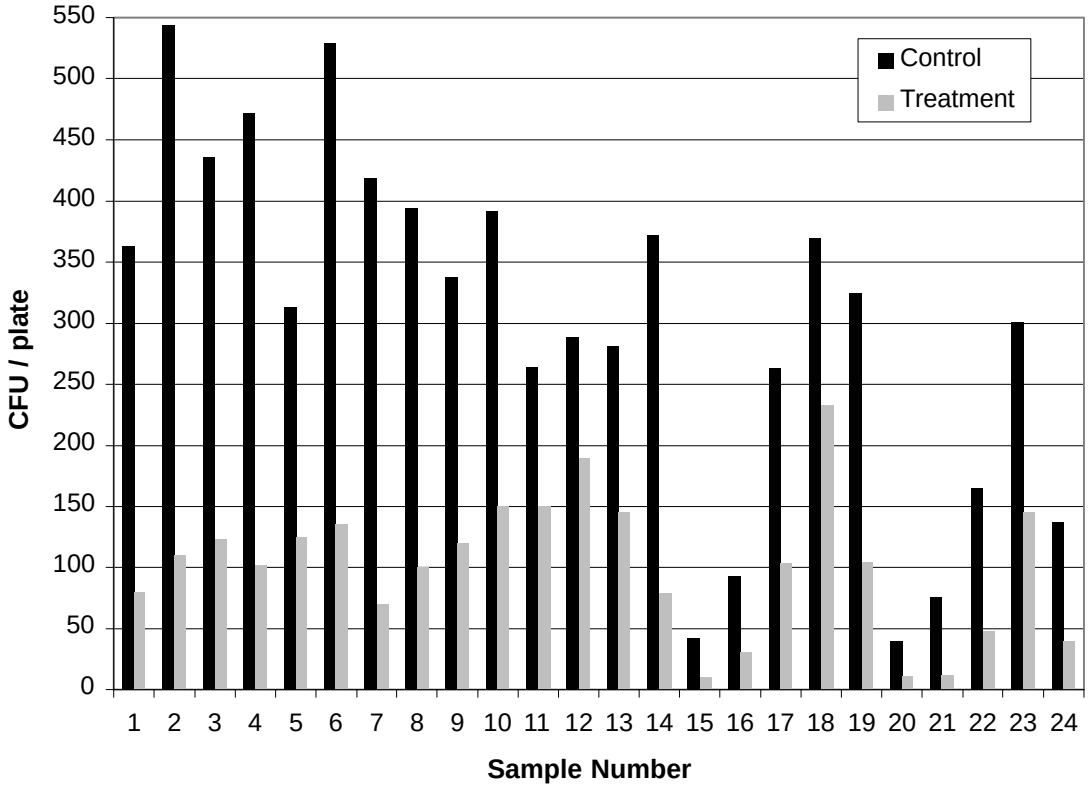

Figure 7. Weekly average gram-negative bacteria for control vs. treatment. Difference between the control that averaged 301 CFU (± SE = 29.6) and the treatment that averaged 96 CFU (± SE = 12) were significant (P < 0.0001).

low-cost and highly efficient electrostatic sampling device which will be described in a later report.

Conclusions

The ESCS was shown to be a reliable and easily maintained system for reducing airborne dust, ammonia, and bacteria in a small broiler breeder house, and the reductions seen were consistent with earlier ESCS studies in poultry hatching cabinets, controlled environment cabinets, and layer rooms. It is expected that similar results would be obtained in other enclosed spaces such as animal houses, including full sized production houses, if the ESCS is scaled up. All of the applications have potential for improving human health as well as animal health.

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