

Ozone Application for Mitigating Ammonia Emission from Poultry Manure: Field and Laboratory Evaluations

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Species: Poultry (Broiler and Layer)
Use Area: Animal Housing
Technology Category: Ozonation
Air Mitigated Pollutants: Ammonia

Description:

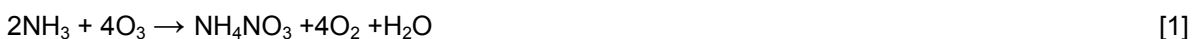
Ammonia, as a harmful gas in broiler chicken housing, is known to significantly compromise poultry welfare (Dawkins et al., 2004). Reduction of ammonia level inside poultry houses is not only important to gain compliance with current air quality regulations and laws, but also to increase birds' live performance. Among various mitigation technologies for animal house ammonia control, house ozonation is the most controversial technique. Reported results in the literature with regard to ozonation application for air emission control are somewhat contradictory (Keener et al., 1999; Yokoyama and Masten, 2000; Elenbaas-Thomas et al., 2005). Work by Keener et al. (1999) indicates that ozone (O₃) treatment at concentrations levels between 0 and 0.15 ppm removed 58% of ammonia and 60% of dust mass in a swine building, whereas Elenbaas-Thomas et al. (2005) reported that room ozonation in a swine building at a maximum O₃ concentration of 0.1 ppm did not result in any statistically significant reduction in dust mass concentrations, odor concentrations, sulfur compound concentrations, and bacteria counts. Moreover, significantly higher ammonia concentrations were observed in the ozone treated room as compared with the room without ozone treatment in the study reported by Elenbaas-Thomas and collaborators. Schwean et al. (2001) also evaluated the effect of adding ozone (target level of 0.05 ppm) to rooms housing broilers. The authors concluded that the application of this gas in a commercial broiler unit is unacceptable at the dosage studied due to increments in mortality and reduced body gain and feed intake. However, a significant improvement in the mortality corrected gain to feed ratio was noted in the O₃-treated birds (0.553 vs 0.535). This study was conducted in only three rooms of five replicate pens, each containing 110 birds. Housing of this type plus other factors can affect mortality, especially in small sample sizes as used in this study. The ammonia levels were measured only at specific days (15, 20, 28, 32, and 38 d), and the addition of O₃ caused a near-significant reduction in ammonia levels at 38 d (12.7 vs 25.7 ppm) and total aerobic populations at 19 d (142 vs 225 colonies/plate).

The controversy over application of ozonation technique also comes from ozone's health effect. Although as a powerful oxidizing agent ozone at high concentration level may have potential to remove ammonia through chemical reaction, ground-level ozone has been defined as a criteria pollutant by the US Environmental Protection Agency under Clean Air Act (EPA, 1996) due to its harmful effects on the respiratory systems of human beings and animals. The current health standards/limits for ozone exposure are 0.1 ppm for an 8-hour, time-weighted average exposure by the Occupational Safety & Health Administration (OSHA, 1998), 0.05 ppm for continuous exposure by the Food and Drug Administration (FDA, 1998), and 0.08 ppm maximum 8-hour outdoor concentration by EPA (1996). According to EPA's report (1998), it may take ozone concentrations 5-10 times higher than these standards before ozone could decontaminate the air. Ozone is not effective at removing air contaminants under the public health standard limits (EPA, 1998).

This reported study aimed to evaluate the effectiveness of in-house ozonation under safety limits for mitigating ammonia emission from poultry manure on the farm scale as well as in the laboratory controlled condition. In addition, bird performance under continuous exposure to ozone was also evaluated.

Mitigation Mechanism:

The fundamental mechanism used by the ozonation technique for ammonia mitigation is built upon an assumption that due to its strong oxidizing property, ozone may remove ammonia from the air through chemical reaction. This chemical reaction is described by the following equation (Wikipedia, 2008):



Contrary to the claim of this removal mechanism, some scientists reported that the reaction process of ozone with many indoor chemical contaminants may take months or years (Salls, 1927; Shaughnessy et al., 1994; Esswein and Boeniger, 1994; Boeniger, 1995). Hoigne also reported that direct oxidation of NH₃ by ozone in the aqueous phase is

very slow. Based upon comprehensive review of the sound science, only peer-reviewed scientifically supported findings and conclusions, EPA (1998) has claimed that ozone does not react at all with indoor air contaminant chemicals for all practical purposes.

While the reaction in equation 1 may only hold at the ozone level that exceeds current public health standard limits, this reaction will produce another criteria pollutant, ammonium nitrate, which is also known as a secondary aerosol. The concentration of ozone used depends on the characteristics of the air to be treated, and as a matter of fact, there are large differences between commercial and research houses. The half-life of ozone is 2.5 to 7 minutes, but in a cool, sterile environment, its half-life can be extended to 60 minutes (Keener et al., 1999).

Applicability:

The room ozonation technique aimed to mitigate in-house ammonia concentration in poultry production systems. Our field and laboratory studies indicate that this technique is not effective at removing ammonia inside broiler houses. Due to ozone's potential adverse impact on the health of workers and birds, and its effectiveness, the application of this technique is subject to debate. It is important to observe closely the effects of this technology, since ozonation is already in use in several broiler chicken farms in the Southeast region of the United States.

Limitations:

Results (figures 1 - 4) from a field evaluation (on a commercial broiler farm) and a laboratory study indicate the following limitations of using this technique:

- In-house ozonation at the threshold limits for public health standards is not effective at mitigating ammonia concentration inside the broiler houses
- Ozone treatment had positive effects on broiler performance in two broiler flocks and adverse impact in two flocks
- Ozone treatment may cause higher level of fine / ultra fine particles / aerosols.

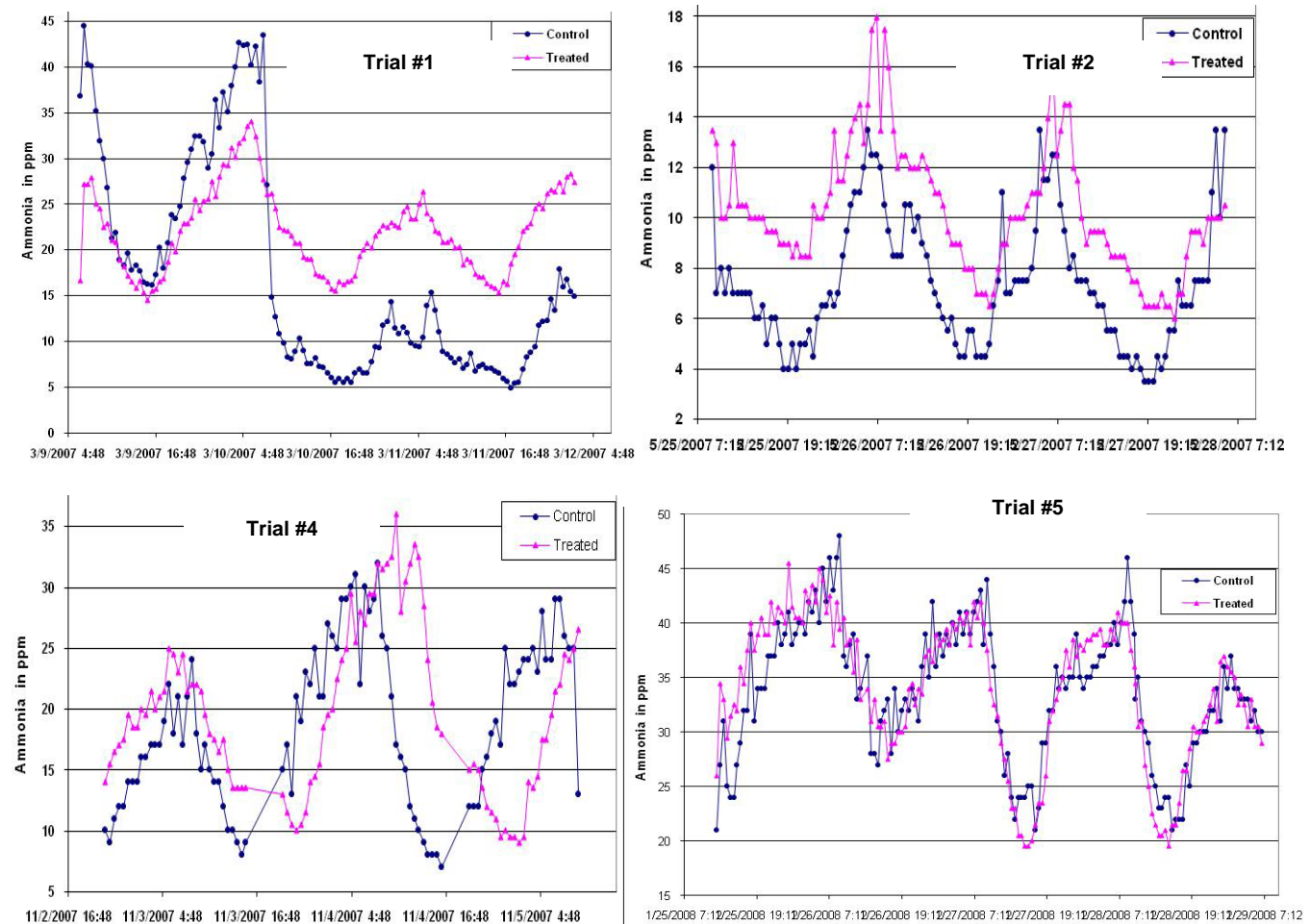


Figure 1. An example of comparison of in-house ammonia concentration between control and treated houses (Field experiments were conducted through five-flock growing cycles. Data analysis for trial 3 is ongoing and will be included in the future report by Wang et al. 2008)

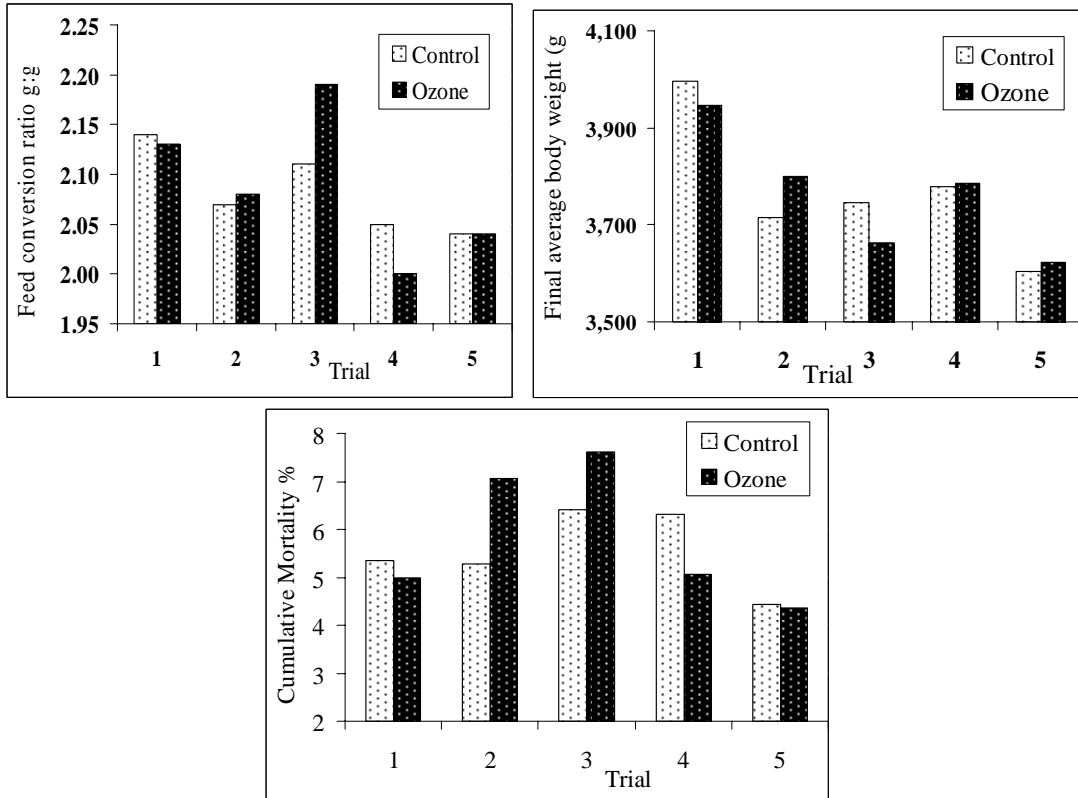


Figure 2. Broiler chicken performance comparison between control and treated (Ozone) houses through five flocks. (Each bar corresponds to the average of flocks of approximately 40,000 broilers. In feed conversion the lower the value the better the efficiency of broilers to transform feed in body weight. The age of flocks at processing vary between 58 and 63 days)

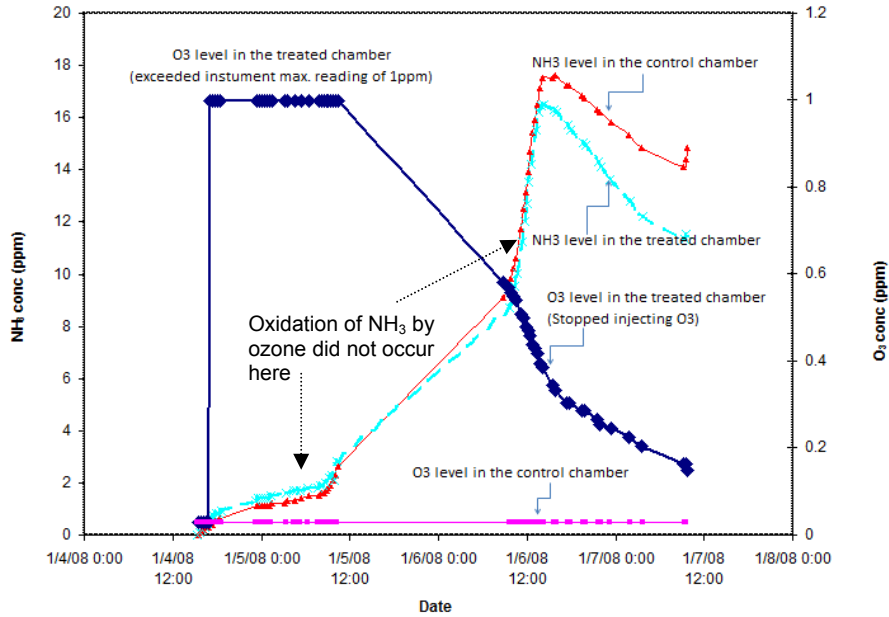


Figure 3 comparisons of ammonia and ozone concentrations in the treated and control chambers (laboratory study) (More details will be reported by Li et al., 2008)

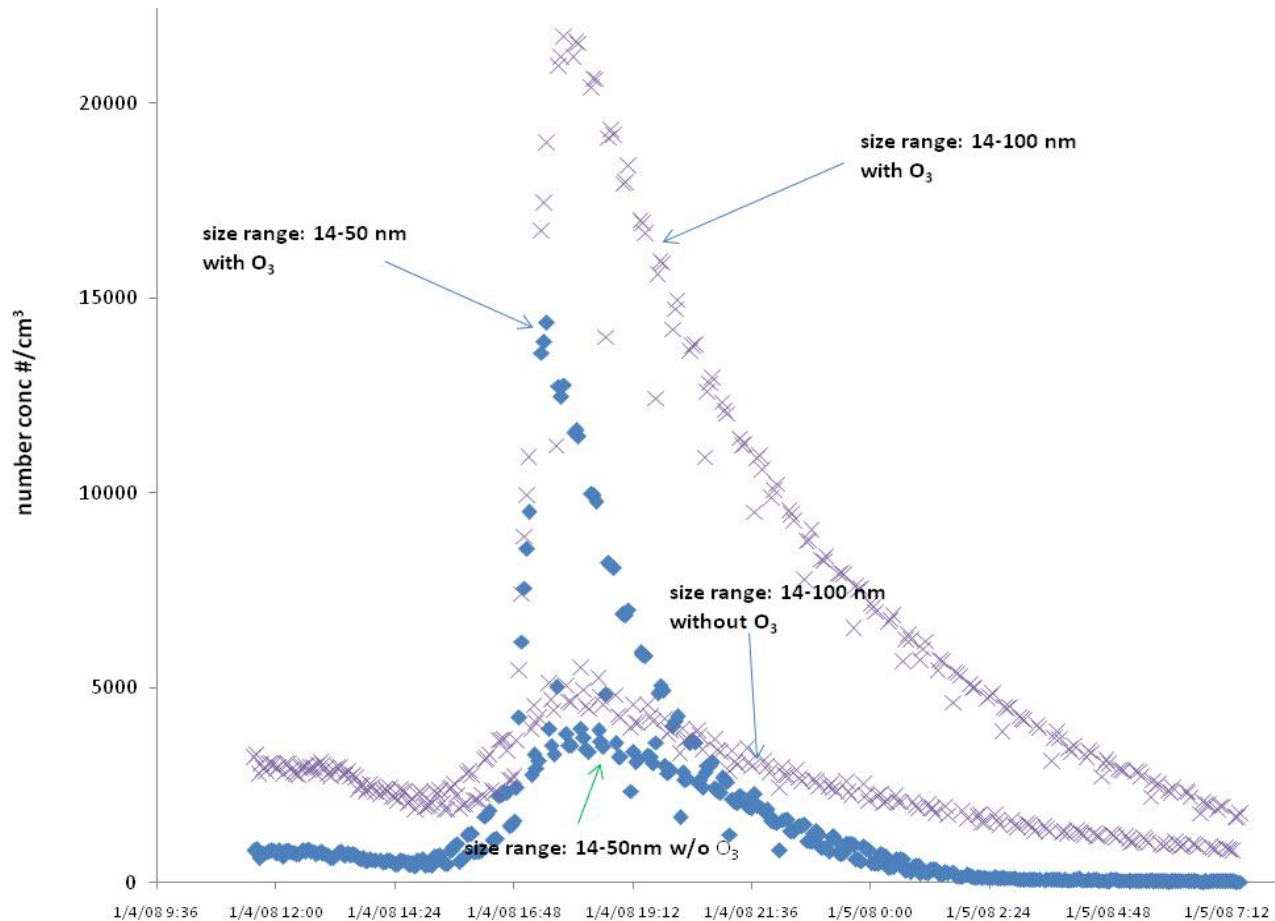


Figure 4. Comparison of aerosol number concentrations in the treated and control chambers (laboratory study)(More details will be reported by Li et al., 2008)

Cost:

The economic analysis for this reported project is very preliminary. Since no significant reduction in ammonia concentration was observed, the economic analysis was based only upon feed conversion ratios. The results of this analysis (table 1) indicate that after 5 flocks the ozonation treatment resulted in an economical loss of \$345. Taking in consideration that installation costs are close to \$20,000 for two houses, it is very unlikely that the use of ozonation is economically feasible to be used in the poultry industry.

Table 1. Analysis of economic impact of ozonation application

Flock	Age (days)	Average broiler live weight (lbs)		Total pounds of live weight produced ¹		Adjusted FC @ 7.5 lbs (g:g) ²		Farm condemnations ³ (%)		Grower payment ⁴ (\$)	
		Control	Ozone	Control	Ozone	Control	Ozone	Control	Ozone	Control	Ozone
1	62	8.81	8.81	340,720	337,533	1.90	1.91	0.27	0.24	17,160.51	17,173.08
2	62	8.19	8.19	319,520	320,848	1.94	1.92	0.17	0.21	16,905.52	16,489.53
3	64	8.26	8.26	302,860	299,440	1.97	2.08	0.25	0.24	15,708.78	14,337.94
4	58	8.33	8.33	327,900	331,071	1.90	1.84	0.41	0.45	16,164.42	17,632.58
5	59	7.95	7.95	331,100	333,100	1.96	1.95	0.38	0.34	19,955.93	19,917.54
Total	61	8.31	8.31	1,622,100	1,621,992	1.93	1.94	0.30	0.30	85,895.16	85,550.67

*Variance in grower payment in five (5) flocks: \$344.49

¹Every flock includes the chickens produced in two houses per treatment. In average each flock had 40,000 broilers at placement.

²Feed conversion standardized at 7.5 lbs body weight, taking in consideration feed consumption and average daily gain.

³Broilers with some type of defect at the market age that exclude them from processing.

⁴Net profit obtained per flock of two houses (40,000 broilers), before cost of labor, gas, electricity, taxes, and house and equipment depreciation. This includes cost of feed, day-old chickens, vaccines, bonuses due to improvements in performance compare to pair farms processing in the same week, and any additional water additives or therapeutic treatments when chickens suffered of disease.

Implementation:

In this reported study, ozonation technique was tested on a commercial broiler farm with four (42ft by 500 ft) identical tunnel ventilated houses with 21,500 broilers per house. This field evaluation consisted of five field trials utilizing the direct introduction of O₃ into the atmosphere of two commercial broiler houses paired with two control houses located on the same farm and placed at the same time over a period of five consecutive grow-out periods. Except for the ozonation, all flocks were managed in the same manner (feed, number of chicken, ventilation system setting). Flocks were grown out for periods of 58 to 63 days. Individual body weights were collected at 42 and 56 days of age from 200 birds sampled in groups of 40 from 5 representative areas from each house. Average flock weights for each house/flock were collected at the processing plant. Feed intake, mortality, and weight of mortality and morbidity were recorded for each house and feed conversion calculated based on the number of birds placed. Carcass condemnations, average carcass dressing percentage, were collected by house and flock from the grower's settlement sheets. In-house ammonia and CO₂ concentrations were continuously measured for a minimum of 48 hours per week for five grow-out periods using one portable multi-gas unit (PMU) (Gates, et al., 1995) per house. Ozone concentrations were monitored with GasAlert Extreme[®] (BW Technologies) data loggers as well as spot checked with colorimetric sampling tubes.

The laboratory study was designed to exam reaction of ozone and NH₃ under well-controlled condition. Seven experimental trials were carried out in the UNC 270 m³ dual Teflon film outdoor aerosol smog chamber located at Pittsboro, NC. The chamber was divided into two separated rooms, of which one served as treated room and the other one served as control room. The same amount of layer manure (6 x 800 g) was placed in each room with emission area of 6 x (15cm x 10.5cm). Ozone was introduced into the treated room at various concentrations. Ozone concentrations in both rooms were monitored using a UV photometric ozone analyzer (TEI Model 49PS). Ammonia concentrations in both rooms were monitored using a chemiluminescence ammonia analyzer (TEI 17C). The particle size distribution (13 to 690 nm) was measured at 10 minute interval using a Scanning Mobility Particle Sizer (SMPS 3936 TSI, MN) composed of a Differential Mobility Analyzer (TSI long DMA, 3081, MN) and a Condensation Particle Counter (TSI CPC, 3022, MN).

Technology Summary:

House ozonation is a controversial technique that has been used in the literature for broiler house cleaning and in-house air contaminant control. Field evaluation in this reported study suggests that ozonation cannot effectively remove ammonia from air inside the broiler houses. Moreover, it caused a negative effect on feed conversion in two of the five flocks evaluated and in the average of five flocks. The laboratory study on this technique indicates that ozone does not react with NH₃ in days even at ozone concentration above 1 ppm, which was more than 10 times higher than the health safety limit set by OSHA. The laboratory tests also show significantly higher level of fine/ultra fine particles / aerosols in the ozone treated environment as compared with the environment without ozone treatment. The direct application of ozonation technique for ammonia mitigation in the animal facilities is not recommended.

Additional Resources:

<http://www.epa.gov/iedweb00/pubs/ozonegen.html>

Acknowledgments:

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