«Research Note»

Using Anhydrous Aluminum Chloride with Calcium Carbonate to Reduce Ammonia Volatilization and Increase Nitrogen Content from Poultry Litter

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This study evaluated the effects of a blend of anhydrous aluminum chloride and calcium carbonate on poultry litter properties, such as pH, NH₃ emissions, and nitrogen (N) content, over a 4-week period. The chemical treatment agents used in this study were added to the poultry litter, with rice hulls at a rate of 40 g aluminum chloride + 60 g calcium carbonate/kg litter and mixed into the upper 1 cm of litter; untreated poultry litter acted as the control. When a combination of anhydrous AlCl₃ and CaCO₃ was used as an additive, NH₃ emissions were significantly reduced ($P < 0.05$) by 55.3%, 56.4%, 40.1%, and 35.8% after 1, 2, 3, and 4 weeks, respectively, unlike that in the control groups. Additionally, the litter pH was observed to reduce (from 6.87 to 8.23). Over time, total N and NH₄-N contents significantly increased ($P < 0.05$) in litter samples with the added combination of anhydrous AlCl₃ and CaCO₃, unlike that observed in the control litter. However, no significant differences ($P > 0.05$) were observed between the control and treated litters for total N at 4 weeks or NH₄-N at 2 and 4 weeks. In conclusion, we have shown that adding a combination of chemicals to litter may be a beneficial strategy to decrease NH₃ and N loss from poultry litter.

Key words: anhydrous AlCl₃ combined with CaCO₃, N content, NH₃ emissions, pH, Poultry litter

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Introduction

High concentrations of ammonia (NH₃) inside poultry housing have a negative environmental impact on poultry and humans who spend considerable time there. Ammonia volatilization has long been recognized as an environmental problem causing acidification (Gay and Knowlton, 2005). Exposure to high NH₃ levels for long periods is eventually detrimental to poultry production (Rylander and Carvalheiro, 2006). Ammonia is the predominant gas generated from poultry houses through the interaction of poultry wastes with a combination of skin debris, feathers, and fecal matter (Ritz *et al.*, 2004). For example, poultry are raised on wet litter

combining wood shavings, rice hulls, and waste in fan-ventilated environments with high stocking rates, and air velocity from high ventilation rates fills the area with harmful gases, such as NH₃ and other contaminants. Factors that affect NH₃ volatilization can be determined by assessing several important characteristics of poultry litter, including pH, temperature, and moisture (Elliott and Collins, 1982).

Poultry litter is the most valuable resource of major plant nutrients and organic matter, which can be used to increase crop productivity and soil quality due to its high nitrogen (N) content (Sims and Wolf, 1994). However, the N content of poultry litter is susceptible to NH₃ volatilization, which can reduce fertilizer quality (Kim *et al.*, 2005). Thus, there is increased emphasis on implementing effective control technologies that would reduce NH₃ emissions from confined poultry operations by capturing and recovering N. Based on this criterion, a novel approach to NH₃ removal from poultry house was developed; i.e., the use of alum and aluminum chloride, which can also be used to have positive economic and environmental effects. As a result, alum is commonly used as a litter additive that can suppress the production of

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NH₃ and is available in both a dry and liquid form. Previous studies have shown that adding alum or liquid alum to poultry litter reduced NH₃ emissions by over 75% under commercial and laboratory conditions (Choi and Moore, 2008a; Moore *et al.*, 2000). In addition, the reduced atmospheric ammonia resulted in improved poultry production and produced benefits to cost-effective best management practices (Moore *et al.*, 2000). The studies in the literature that have measured the relative contribution of NH₃ loss aluminum chloride (AlCl₃·6H₂O) as an additive to poultry litter were performed by Choi and Moore (2008a). They suggested that the addition of aluminum chloride may present a potential strategy to decrease NH₃ release (by 48% and 92% for experiments 1 and 2, respectively) and increase N content in poultry litter under lab conditions. Since then, Choi and Moore (2008b) and Choi *et al.* (2011) conducted a study in which liquid aluminum chloride was added to poultry litter and rice hulls, and ammonia emissions were tested. The results of these studies indicated that liquid aluminum chloride was effective in decreasing ammonia levels (from 35% to 76%). However, at high concentrations (300 g of liquid AlCl₃/kg of litter) this treatment caused some obvious limping problems in the birds. Thus, one common strategy for treating poultry litter is the use of a mixture of aluminum chloride and CaCO₃. The use of a blend of additives provides the potential economic advantage of cost savings because using aluminum chloride alone (a single additive) would require higher costs. Unfortunately, the efficacy of a mixture of litter additives on NH₃ emissions and N content in poultry litter has not been tested. The general objective of this study was to assess the effects of anhydrous aluminum chloride with CaCO₃ on poultry litter properties, including pH, NH₃ emissions, and N content over a 4-week period.

Materials and Methods

Chemicals

Anhydrous aluminum chloride (white-yellow colored powder) was purchased from Junsei Chemical Co. (Tokyo, Japan). Calcium carbonate was purchased from Yoo Jin Technology Co. (Seoul, South Korea).

Bird Management

The experimental procedures were conducted according to the guidelines for animal studies at Heungsa farm (Sanchung, South Korea) over a 4-week period. A total of 6,000 broiler chicks (Arbor Acres, 1 d old) were obtained from a commercial hatchery and divided into 2 groups (3 replicate pens of 1,000 birds per group). One broiler house with a capacity for 6,000 birds was sealed off with plastic sheeting from the floor to the ceiling to prevent gas exchange. On the broiler farm, 3 pens were chosen for the treatment groups and the remaining 3 pens were the control groups. The facilities were environmentally controlled and had a clean concrete floor (approximately 0.09 m²/bird). All birds were raised on rice hulls with poultry litter in environmentally controlled houses, and incandescent lighting, temperature, and ventilation were continually monitored from 1 d to 28 d. Before starting this experiment, 2 flocks of broiler chicks were

reared in a broiler house under simulated commercial conditions without any litter additives (Coufal *et al.*, 2006), and bedding materials are spread approximately 8 cm deep onto the litter surface. During the experimental period, commercial mash diets and drinking water were provided *ad libitum*. Chicks were fed starter diets for the first 3 weeks (days 1 to 21) and were fed finish diets for the fourth week (days 22 to 28). The experiment was conducted for 28 d.

Chemical Treatments and Samples

The chemical treatment (40 g AlCl₃+60 g CaCO₃) was added to rice hulls with poultry litter and applied by top dressing onto the rice hull surface. Normal litter was used as a control. To prepare samples, litter samples from each pen were collected weekly from 4 random locations, and 100 g from each litter sample was weighed and mixed in clean plastic bags. Samples were kept frozen until analysis.

NH₃ Gas Measurements and Chemical Analysis

Ammonia measurements were conducted as described by Choi and Moore (2008b). Ammonia emissions from poultry litter with rice hulls were measured weekly within each pen at 4 random locations using a multigas analyzer (Yes Plus LGA, Critical Environment Technologies Canada Inc., Delta, Canada). Samples of poultry litter were analyzed for pH, ammonium (NH₄), and total N content on a dry-matter basis. For litter pH, 20 g of litter was taken from each sample, weighed in a 250-mL polycarbonate centrifuge tube, and then extracted with 200 mL deionized water for 2 h using a mechanical shaker (Moore *et al.*, 1995). The samples were centrifuged at 6,000 rpm for 15 min and were measured immediately in an unfiltered state. To determine NH₄ levels, samples were filtered using 0.45-μm filter, acidified to pH 2.0 with HCl (Moore *et al.*, 1995), and analyzed using the salicylate-nitroprussic technique, according to the USEPA method (1979). Two grams of litter subsamples were also used to measure total N. Total N was determined by the Kjeldahl distillation method (AOAC, 1990).

Statistical Analysis

All data were analyzed using the SAS statistical software (SAS, 1990). Significant differences between means were analyzed using Student's *t*-test ($P < 0.05$).

Results and Discussion

pH and NH₃ Emissions

Litter pH and NH₃ emission data as a function of time are presented in Fig. 1. Significantly lower pH and NH₃ emissions were observed ($P < 0.05$) for anhydrous AlCl₃ plus CaCO₃ treated litter, as compared with control litter over the 4-week period (Fig. 1A and 1B). During the first week, the pH in the control litter was 8.27; after 2 weeks, the pH in the control litter ranged from 8.64 to 8.58. Unlike the control group, the pH of treated litter was 6.87, 7.55, and 8.16 at 1, 2, and 3 weeks, respectively, but was 8.23 at 4 weeks. NH₃ emissions were approximately 25.78 ppm in anhydrous AlCl₃ plus CaCO₃ treated litter until 2 weeks and then increased to 36.22 and 38.00 ppm at 3 and 4 weeks, respectively. However, NH₃ emissions in the control litter were 45.22 and 59.11 ppm at 1 and 2 weeks, respectively, and were similar

Fig. 1. pH (A) and ammonia emissions (B) from poultry litter with and without anhydrous aluminum chloride and carbon carbonate as a function of time. * indicates significant differences at $P < 0.05$.

Fig. 2. Total N (A) and NH₄-N (B) from poultry litter with and without anhydrous aluminum chloride and carbon carbonate as a function of time. * indicates significant differences at $P < 0.05$.

until 4 weeks. When anhydrous AlCl₃ was used as an additive in a blend with 60 g CaCO₃, NH₃ emissions were reduced by 55.3%, 56.4%, 40.1%, and 35.8% at 1, 2, 3, and 4 weeks, respectively, in comparison with the control litter. This result clearly indicated that NH₃ levels can be decreased by the addition of anhydrous AlCl₃ in combination with CaCO₃, which resulted in a lower litter pH. Moreover, these results support the work of Smith *et al.* (2004) who showed that the addition of 0.75% AlCl₃ decreased NH₃ losses from swine manure by 52% over a 6-week period. Research by

Moore *et al.* (1995) indicated that NH₃ volatilization was greatly decreased by alum addition with and without CaCO₃. Another study showed that liquid AlCl₃ was effective in decreasing NH₃ fluxes in rice hulls and poultry litter, even at a concentration of 300 g AlCl₃, which reduced NH₃ by 67%–76% during the 6-week period (Choi and Moore, 2008b; Choi *et al.*, 2011). It is unclear why the addition of anhydrous AlCl₃ with CaCO₃ reduces NH₃ emissions; however, reduced NH₃ was significantly related to changes in litter pH. Al₃⁺ in an acid environment reacts with solution to

form $\text{Al}(\text{OH})_3$, releases 3 H^+ as a hydrolysis product, and then decreases litter or manure pH (Smith *et al.*, 2004). As was seen in Fig. 1, pH values for litter treated with anhydrous AlCl_3 plus CaCO_3 (ranging from 8.16 to 8.23) were slightly lower than those of control litter (ranging from 8.53 to 8.58) at 3 and 4 weeks. It has been suggested that NH_3 production in poultry litter increases substantially at pH values above 8 (Reece *et al.*, 1979). This is because the addition of CaCO_3 , which is a basic compound, may bring the litter pH up quicker, thus releasing NH_3 sooner than using AlCl_3 alone.

Nitrogen (N) Content in Poultry Litter

Changes in N content after addition of chemical additives to poultry litter are reported in Fig. 2. Over time, adding anhydrous AlCl_3 with CaCO_3 to litter caused an increase in total N content from 22.5 to 25.5 g/kg, whereas total N content in the control litter ranged from 16.1 to 22.3 g/kg (Fig. 2A). $\text{NH}_4\text{-N}$ content in the control litter ranged from 0.3 to 1.8 g/kg during the experimental period (Fig. 2B), whereas treatment with anhydrous AlCl_3 with CaCO_3 produced 1.0, 1.4, 2.2, and 2.4 g of $\text{NH}_4\text{-N}$ /kg litter at 1, 2, 3, and 4 weeks, respectively (Fig. 2B). However, there was no significant difference ($P > 0.05$) between control and treated litters for total N at 4 weeks and for $\text{NH}_4\text{-N}$ at 2 and 4 weeks. Over time, both total N and $\text{NH}_4\text{-N}$ contents were significantly increased by treatment with anhydrous AlCl_3 plus CaCO_3 , as compared with control groups ($P < 0.05$). This was consistent with other research by Choi and Moore (2008a, b). Likewise, studies conducted in the field showed that tall fescue yields from plots fertilized with alum-treated litter were greater than for the same amount of normal litter, suggesting that alum-treated litter had a higher N content (Shreve *et al.*, 1995). In general, the majority of the N found in alum-treated litter was in the ammoniacal form, which is easily available for plant uptake (Moore *et al.*, 1995). The mechanism for increases in litter total N and $\text{NH}_4\text{-N}$ may be partially explained by the acidic conditions of the litter, caused by AlCl_3 rather than CaCO_3 , which reduced gaseous losses of NH_3 and litter pH (Moore *et al.*, 1995, 2000). Sims and Luka-McCafferty (2002) evaluated several litter properties after alum application. They also reported that application of alum to litter increased total N and $\text{NH}_4\text{-N}$ contents by an average of 0.27% and 0.22%, respectively.

In conclusion, decreasing N losses, particularly NH_3 losses from poultry litter, is important in the poultry industry because of the reduction in negative environmental impact and the improvement in the fertilizer value of the litter. Consequently, the results of this study indicated that the use of anhydrous AlCl_3 and CaCO_3 as litter additives were effective at reducing NH_3 emissions and increasing N content (i.e., N availability in the litter). This is very important when examining the potential applications of anhydrous AlCl_3 plus CaCO_3 as a blend for litter in poultry houses and suggests that this blend can be applied at recommended or optimal rates to ensure the quality of poultry litter.

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