

# Evaluation of Ferric Sulfate as a Ammonia Control Product in Commercial Broiler Production

Casey W. Ritz<sup>1\*</sup>, Lowry A. Harper<sup>1</sup>, Brian D. Fairchild<sup>1</sup>, and Michael Czarick, III<sup>2</sup>, Jan Pavlicek<sup>3</sup>

<sup>1</sup>Department of Poultry Science, <sup>2</sup>Department of Biological and Agricultural Engineering, The University of Georgia, Athens, GA 30602; <sup>3</sup>Kemiron Inc. \*Corresponding author email: critz@uga.edu.

## ABSTRACT

Ammonia (NH<sub>3</sub>) concentration in poultry houses is a production issue of concern. Birds housed in environments with NH<sub>3</sub> present do not perform as well as birds not exposed to NH<sub>3</sub>. Ventilation has been the key means of removing and controlling NH<sub>3</sub> from poultry houses but poultry producers also use litter and manure treatment products that lower pH, bind nitrogen (N) and dry the litter. Acid-based litter treatments, though effective for short-term NH<sub>3</sub> reduction, are not a viable long-term solution to ammonia reduction due to the amount of product required to chemically bind NH<sub>3</sub>, problems of reapplication when birds are present, and the corrosiveness of the material. Consequently, new types of litter treatment are needed along with other mechanisms to reduce in-house NH<sub>3</sub> concentrations and subsequent house emissions. The purpose of this study was to evaluate the effectiveness of a new litter amendment containing ferric sulfate compared to a commonly used alum-based litter amendment. The ferric sulfate amendment was, on average, superior to the aluminum sulfate amendment in reducing NH<sub>3</sub> emissions and concentrations in the houses during the first 10 to 12 days after bird placement. No differences were noted in mortality, body weight or feed efficiency. The ferric sulfate product is applicator-friendly with noticeably reduced dust upon product application and significantly improved retention of N in the litter over the aluminum sulfate, suggesting that there was an enhancement effect on nitrification of NH<sub>4</sub> to the more stable NO<sub>3</sub> form.

## INTRODUCTION

In-house air quality is a major concern in poultry production. Growers spend much of their time and investment in maintaining good air quality to maximize poultry growth and performance. Previous work has correlated negative bird performance with poor indoor air quality due to NH<sub>3</sub> and dusts (Kling and Quarles, 1974; Charles and Payne, 1966; Anderson et al., 1964; Quarles and King, 1974) and has implicated NH<sub>3</sub> as a component of poultry welfare (Kristensen and Wathes, 2000). Birds exposed to NH<sub>3</sub> levels of 25 ppm or greater have shown negative impacts of reduced growth rate and feed conversion (Miles et al., 2004; Reece et al., 1979; Caveny and Quarles, 1978) as well as increased susceptibility to respiratory infections (Kling and Quarles, 1972; Anderson et al., 1964) and eye lesions (Bullis et al., 1950).

Ammonia is a colorless, alkaline, water-soluble gas that is produced by microbiological deamination or reduction of nitrogenous substances. Microbial decomposition of uric acid in the litter is the primary source of NH<sub>3</sub> generation (Bacharach, 1957; Schefferle, 1965). Litter type, management, humidity, pH, and temperature all affect NH<sub>3</sub> generation and concentration (Madelin and Wathes, 1989). Ammonia volatilization is a complex physical and chemical process (Freney et al., 1983; Harper, 2005) and emissions are generally related to four factors: NH<sub>4</sub><sup>+</sup> concentration of the medium, temperature of the medium, pH (hydrogen ion concentration where [H<sup>+</sup>] = 1 x 10<sup>-pH</sup> of the solution) of the medium and turbulent transport of the NH<sub>3</sub> from the medium. There is a trend within the poultry industry for tighter house design and less frequent litter removal. These two factors have the potential to dramatically increase the NH<sub>3</sub> concentration within poultry houses.

In addition to the bird production and welfare impacts, there is growing public concern over outdoor air quality and the amount of pollutants being released by both livestock and poultry production facilities. Of greatest interest are the emissions of NH<sub>3</sub> and particulate matter. Environmental air and water quality potentially can be impacted by animal production emissions in the form of atmospheric nitrogen deposition. Since these emissions originate from within the production facilities, strategies to reduce the generation of dust, NH<sub>3</sub>, and odors within poultry houses will have a corresponding impact on the level of house emissions. Emission control technologies either within the poultry house or outside will help to alleviate air quality concerns directed at the poultry industry.

Nuisance complaints are a growing burden on the poultry industry and best management practices need to be refined to reduce ammonia and particulate matter emissions from poultry operations. Therefore, a number of techniques to reduce NH<sub>3</sub> production are needed. One technique used in the poultry industry reduces the pH of the litter, keeping the dissociation of ammonium (NH<sub>4</sub><sup>+</sup> ⇌ NH<sub>3</sub>) in the NH<sub>4</sub><sup>+</sup> form. The application of litter amendments to reduce the pH of the litter is the mechanism used to accomplish the pH reduction. Acidifier litter treatments, though effective for short-term NH<sub>3</sub> reduction, are not thought to be a viable long-term solution due to the amounts required to chemically bind litter nitrogen (N), problems of reapplication when birds are present, and the corrosiveness of the materials.

Litter phosphorous (P) is of concern when land-applied to acreage that is susceptible to surface water runoff and edge of field erosion. Products that can bind P and reduce the soluble content of land-applied poultry litter will benefit the industry as they continue to need to address water quality impacts from poultry operations.

The purpose of this study is to evaluate the efficacy of a granular ferric sulfate product on reducing gaseous NH<sub>3</sub> volatilization from active broiler litter within commercial poultry housing.

## MATERIALS AND METHODS

A four-house broiler farm in Northeast Georgia was selected with houses managed as identically as possible for ventilation, temperature and humidity. The houses were 36 x 400 ft and stocked at a rate of 15,700 birds per house. Between flocks, the houses were opened for drying, the litter was 'decaked' by tilling the surface, and top-

dressed with pine shavings. One day prior to introduction of the flock, aluminum sulfate (Al+Clear<sup>®</sup>, General Chemical, Inc.)<sup>3</sup> and ferric sulfate (Ferix-3<sup>®</sup>, Kemiron, Inc.)<sup>3, 4</sup> at a rate of 100 lbs per 1000 ft<sup>2</sup> were applied to each of two houses.

Since alum is a commonly-used litter amendment in the broiler industry, in this study we used alum as the *Control* and the Ferix-3 as the *Treatment*. Both Treatment and Control were applied at the same time and at the same rate of 100 lbs per 1000 ft<sup>2</sup>. Litter samples were taken prior to application and on day-of-study (DOS) 4, 6, 8, 13, 20, 27, and 36. Analyses of the litter samples (Ward Laboratories, Kearney, NB) included organic N (ON), NH<sub>4</sub><sup>+</sup>, nitrate N (NO<sub>3</sub>), total N (N), calcium (Ca), copper (Cu), iron (Fe), magnesium, (Mg), manganese (Mn), P, potassium, (K), sodium (Na), sulfur (S), and zinc (Zn). Other analyses included percent moisture, pH, dry matter content, and soluble salts.

House environmental data collection included air temperature, fan flow rate, and aerial NH<sub>3</sub> concentration. Ammonia concentrations were measured using two techniques: 1. Dosimeter passive absorption tubes (Gastec, Inc.) were attached at one-meter height in all four houses at locations 1/4, 1/2, and 3/4 distance from the air-intake end of the house. They were installed during the prescribed data-collection days (DOS) 2, 4, 6, 8, 13, 20, 27, and 36 and remained in the houses for 6 to 12 hours. 2. A gas-washing technique (Fig. 1) was used to obtain NH<sub>3</sub> concentrations by drawing unfiltered air through gas-washing bottles containing 80 mL to 180 mL of 0.2 N H<sub>2</sub>SO<sub>4</sub> at a known flow rate (2 L min<sup>-1</sup>). At the end of the sample period the gas washing bottles were removed, capped, and taken to a laboratory for extraction into 90 mL glass storage bottles which were refrigerated until analysis (Ward Laboratories, Kearney, NB) by a colorimetric technique similar to that of Weier et al. (1980). The resulting aerial concentrations were converted from a weight-per-volume basis (µg m<sup>-3</sup>) to a volume-basis (ppm) through the use of the gas-law equation. For additional description of this measurement technique, see Harper et al. (2000). The average seasonal accuracy for the technique was 0.020 ppm NH<sub>3</sub>-N. All house NH<sub>3</sub> concentrations were normalized with respect to the fan-flow rate of House #1 by linear ratio of the individual house fan-flow periods [Ammonia has been shown to have an emissions rate linearly related to turbulence, Harper (2000)].

Additional data obtained from the host organization (Fieldale Farms Inc. of Balwin, Georgia) included fan-flow rates, house temperature, feed conversion efficiency, and carcass quality.

## RESULTS AND DISCUSSION

### *Application:*

Application of the Control amendment was considerably dustier than during the application of the Treatment amendment. The reduced dust and its irritation to the applicator was noticeably reduced, although there was no means of measuring the difference except by observation.

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<sup>3</sup>Trade names are included for the benefit of the reader and do not imply endorsement by the authors or the University of Georgia.

<sup>4</sup>Note: Ferix-3<sup>®</sup> is a dry, granulated form of ferric sulfate that contains about 20% iron. The dry form is non-corrosive which allows it to be able to be economically transported and stored. Its uses include organics, arsenic, heavy metals, and phosphorous removal in soil and other remediation applications.

### *Ammonia in Houses:*

Ammonia concentrations were measured using two techniques -- dosimeter tubes (Figs. 2A and 2B) and gas-washing equipment (Fig. 3A). Houses 2 and 3 were the houses instrumented with gas-washing techniques to establish interior and exterior  $\text{NH}_3$  concentration accurately ( $\forall < 20$  ppb for this study). All four houses were instrumented (interior only) with dosimeter tubes (accuracy estimated at a few ppm) for comparison with the gas-washing concentrations and to estimate comparison within the amendments. Both measurement techniques showed that  $\text{NH}_3$  concentrations were low after application for both litter amendments (lowest in the Treatment Houses) and increased as the flock increased in size. Comparing  $\text{NH}_3$  concentrations in Houses 1 and 4 using the dosimeter measurements (Fig. 2B) indicated that the Treatment House amendment was more effective controlling  $\text{NH}_3$  than that in the Control House whereas there was little difference between the Treatment and Control in Houses 2 and 3. The dosimeter tubes showed there was no difference between Houses 2 and 3 (Fig. 2B), we think due to litter moisture (Fig. 2C). The averages of both Treatment and Control houses suggested that the Treatment was more effective for the first 15 days (Fig. 2A) following with no difference to the end of the study. Houses 2 and 3 measurements only (using more-accurate gas washing  $\text{NH}_3$  techniques) showed also that the Treatment House was more effective at controlling  $\text{NH}_3$  during the first 7 days (Fig. 3A). After 7 days, the Treatment House was less effective than the Control House because the litter moisture in the Treatment House was much higher (Fig. 3D).

After the first few days, the house temperatures were gradually decreased daily from a set temperature of  $31^\circ\text{C}$  (by reducing heat input and increasing ventilation) to a final set temperature of  $24^\circ\text{C}$  (about DOS 23). After DOS 10, ambient temperatures increased considerably and ventilation rates were ramped up to reduce interior heat buildup and  $\text{NH}_3$  concentrations (Fig. 3D).

### *Litter Analyses:*

Litter analyses showed that the Treatment amendment significantly retained more  $\text{NO}_3\text{-N}$  in the litter (Figs. 4A through D) than the Control amendment. Organic N and total N were retained significantly (one Standard Error) larger in the Treatment houses until the last two weeks of the study where the absolute amounts were numerically but not significantly larger. Ammonium N was not significantly different between the amendments throughout the study period. These results suggest that housing and management characteristics removed  $\text{NH}_3$  from the litter about the same for both amendments but the Treatment amendment retained N in the litter in all other forms by reducing mineralization of organic N, ureic acid, and other forms of N. It also suggests that nitrification of  $\text{NH}_4$  to  $\text{NO}_3$  may be a form of N retention by the Treatment amendment.

Another form of  $\text{NH}_3$  control by the amendments is due to increase of the hydrogen ion concentration (pH) in the litter. This mechanism may not be substantial in the difference noted in this study since there was no significant difference in litter pH between the two amendments.

Iron was higher, as anticipated because of the amendment application, in the Treatment houses but calcium, magnesium, manganese, sulfur, and zinc were also higher

in the Treatment houses (Figs. 4A-E). There was no difference in copper, phosphorous, potassium, sodium, or soluble salts between treatments (Figs. 5A-E).

#### *Animal Performance:*

There was no significant difference in mortality between treatments. Feed conversion efficiencies were identical for the two treatments (2.023 lb feed per lb weight gain) although the weight gain in the Control was slightly (significant) higher than in the Treatment houses (6.39 vs 6.29, respectively). The results of this study suggest there are not differences on broiler performance between the two different litter amendments.

### **CONCLUSIONS**

The Treatment amendment was, on average, superior to the Control amendment in reducing NH<sub>3</sub> emissions and concentrations in the houses during the first 10 to 12 days after the chicks were placed in the houses. Although this period is critical in the development of the broilers, the reduction did not show any difference in survivability, feed conversion, or carcass weight. The Treatment did show significant retention of N in the litter over the Control and also suggested that there was an enhancement effect on nitrification of NH<sub>4</sub> to the more stable NO<sub>3</sub> form. The Treatment amendment showed variable retention of elements in the litter with respect to the Control amendment. The application of ferric sulfate as a poultry litter amendment for ammonia control is a viable option when compared to aluminum sulfate.

**RECOMMENDATIONS:** Due to the confounding effect of variable moisture in the litter of the houses, we recommend that further studies be conducted using either larger numbers of gas washing techniques or open-path laser spectrometry in all four houses. It is our conclusion that the Treatment amendment is superior overall in reducing NH<sub>3</sub> concentrations during the beginning critical period and in the retention/conversion of N in the litter.

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Fig. 1. Gas washing technique. Fig. A is the pump and control system for the gas washing bottle (B).

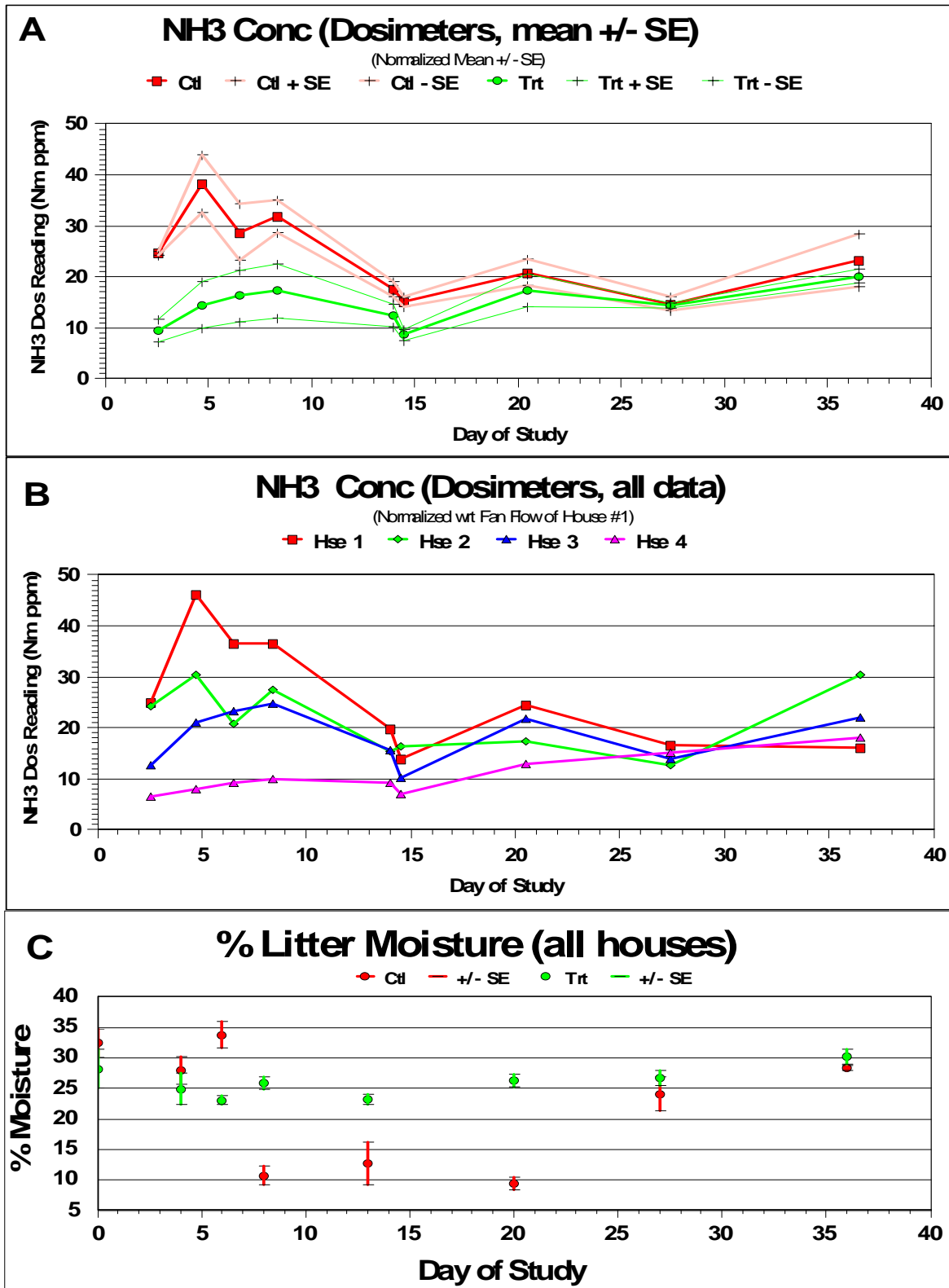


Fig. 2. Ammonia concentrations estimated using dosimeter tubes and litter moisture content in the Control (Houses #1 and 2) and Treatment (#3 and 4) houses. Averages are the means of Control and Treatment houses.

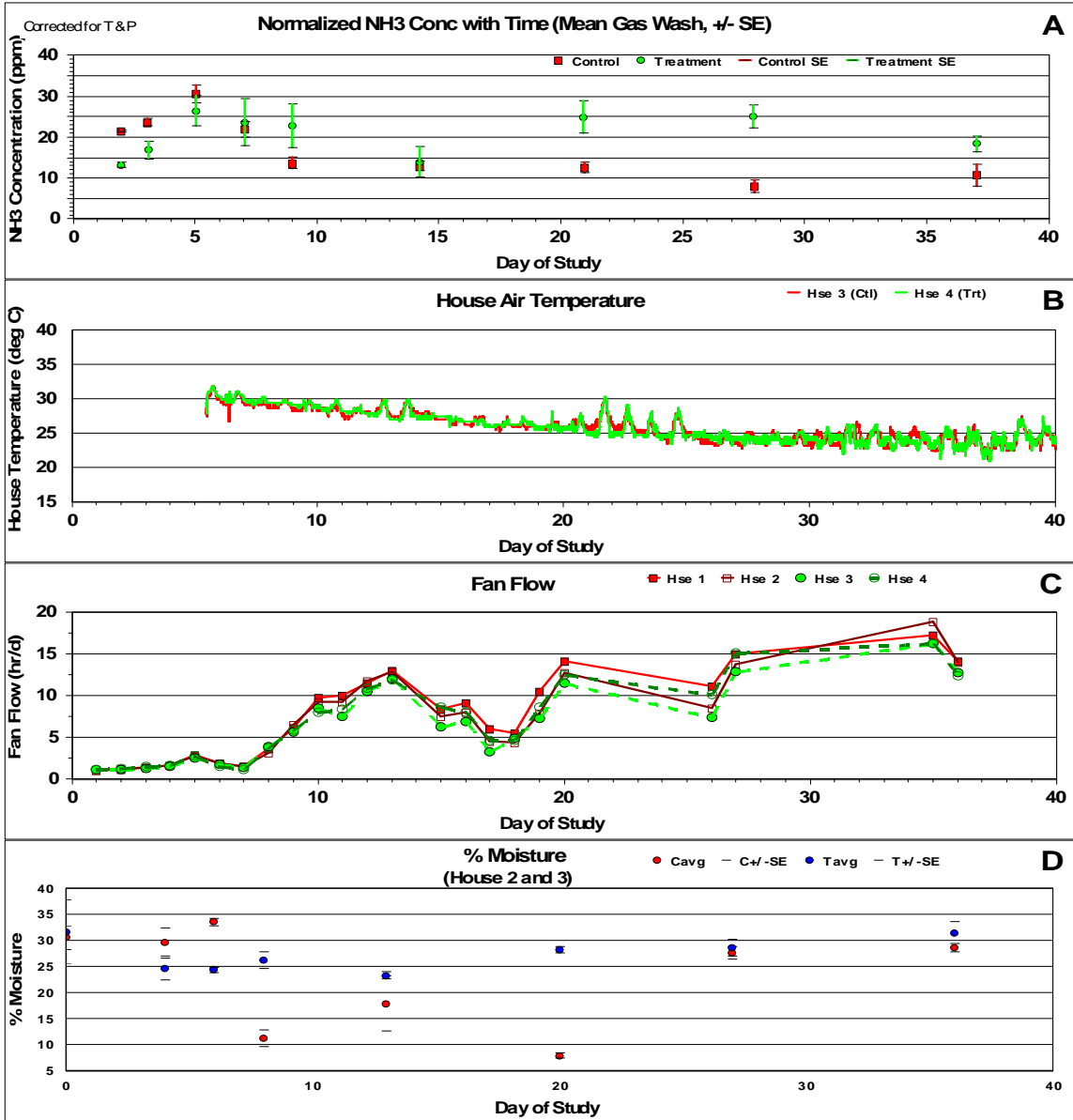


Fig. 3. NH<sub>3</sub> concentrations normalized with respect to ventilation rates in Control and Treatment houses compared to house air temperature, percent litter moisture, and fan-flow periods per day.

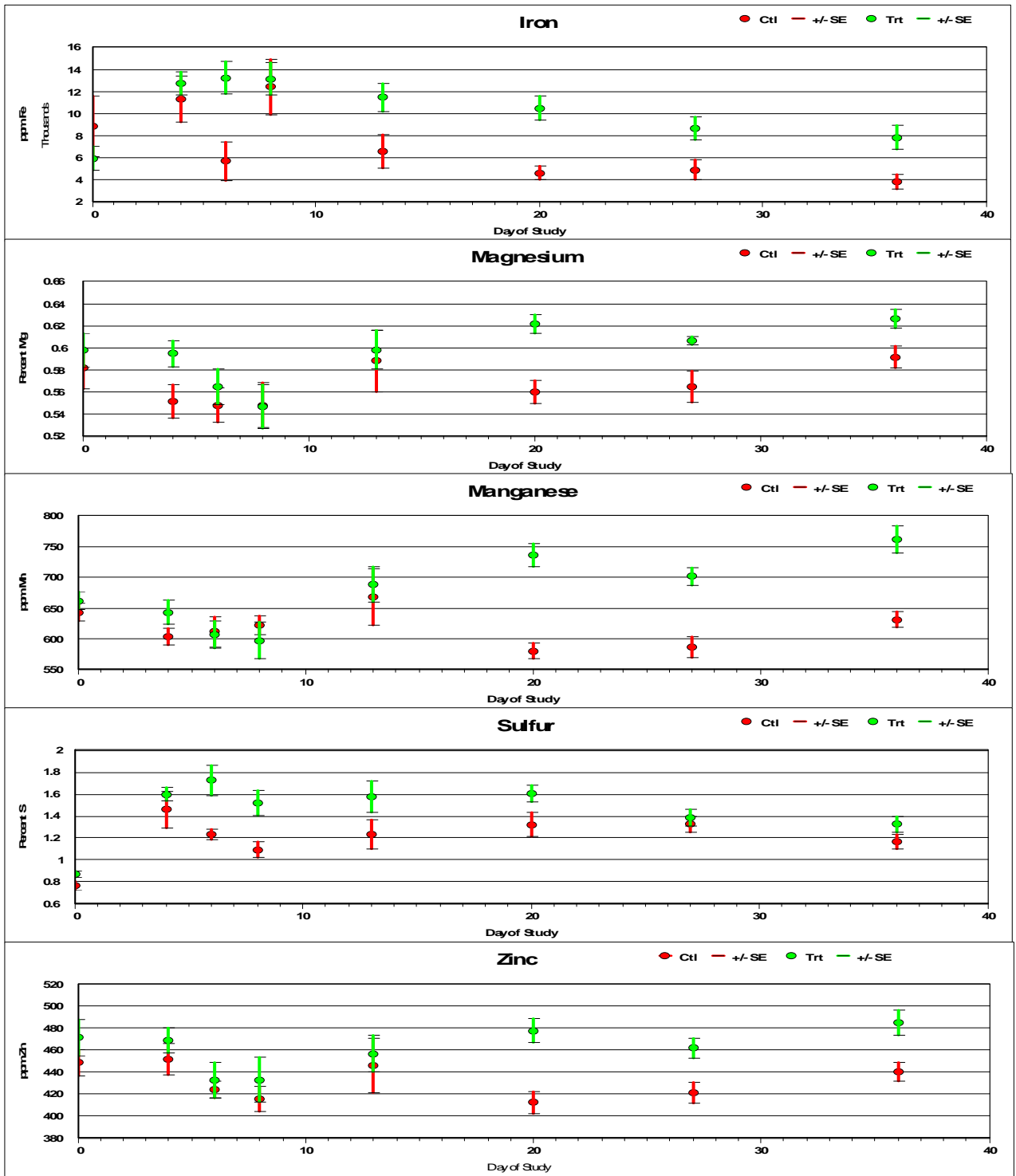


Fig 4. Litter analysis of Control and Treatment amendment treated litter during a study of the amendment effects on  $\text{NH}_3$  release.

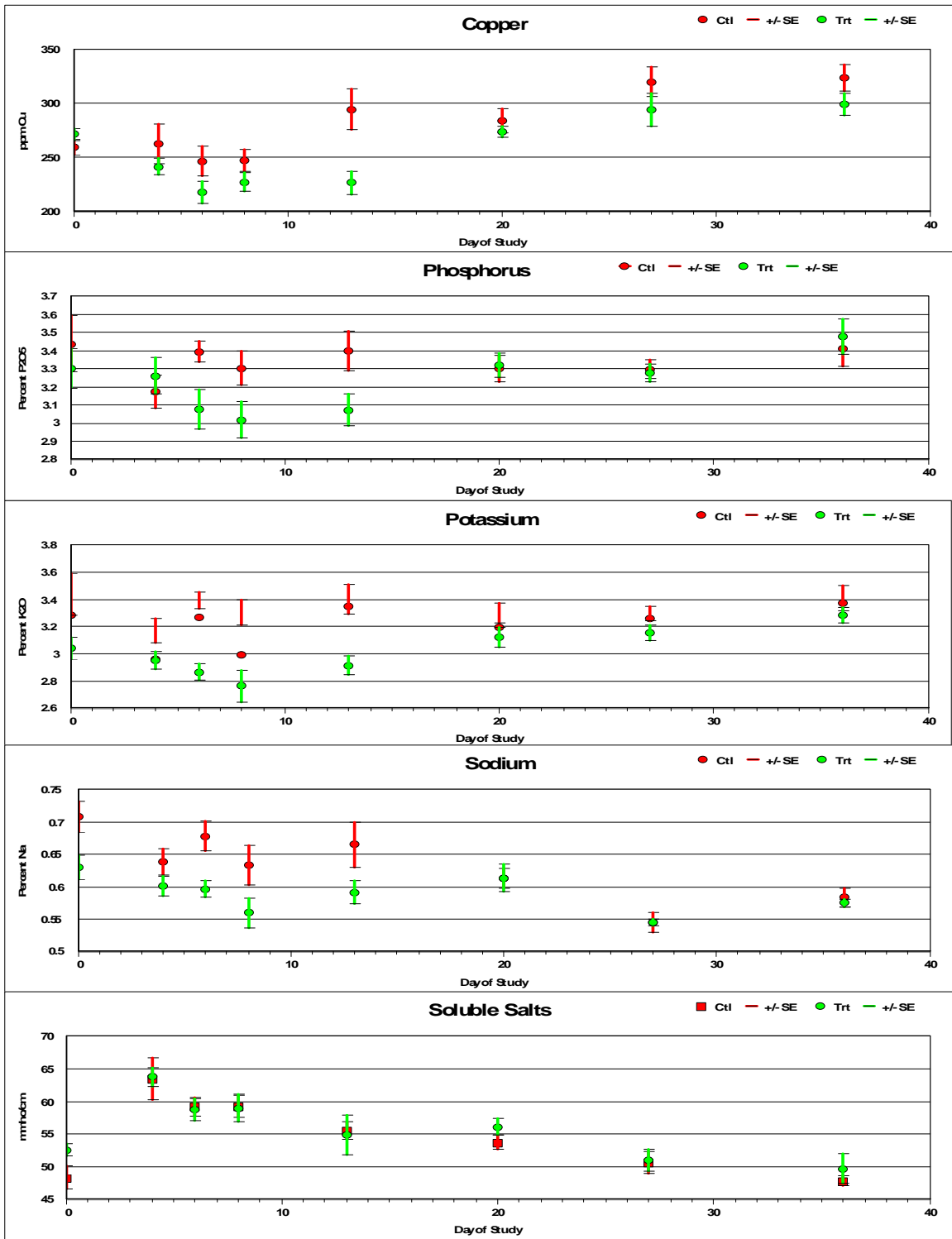


Fig 5. Litter analysis of Control and Treatment amendment treated litter during a study of the amendment effects on  $\text{NH}_3$  release.