

# FINAL REPORT

## Integrated Nutrient Management for High Yielding Corn in a Poultry-Grain Production System

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# Integrated Nutrient Management for High Yielding Corn in a Poultry-Grain Production System

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## Project Objectives

Evaluate the combined potential of ACT poultry litter, subsurface placement of poultry litter with Nitrpyrin, and sensor-guided variable rate N application to increase N use efficiency (NUE) and attain high irrigated corn grain yields.

## Summary

We completed laboratory soil mineralization and ammonia volatilization incubation studies. In addition, we completed a one year field study comparing inorganic, surface applied fertilizer nitrogen to surface applied standard litter and injected, ACT poultry litter treated with nitrpyrin. Due to the compressed time period required under the revised proposal (shortened from three years to one year) we have not yet received all results from the analytical laboratory on some of the field and incubation samples. Nonetheless, we were able to draw some distinct conclusions.

Overall, the project was successful, our results indicate that irrigation, nitrpyrin, ACT, and litter injection can increase nitrogen use efficiency in grain systems utilizing poultry litter. However, we must urge caution in interpretation of the data presented within this report. Due to financial and time restraints imposed by FPPC only a proof of concept study could be completed. These constraints did not allow for a complete experimental design that would allow full interpretation of treatment effects. Rather, we revised our proposed study, according to FPPC instructions, to ascertain whether the combination of advanced technologies could increase NUE. Therefore, as an example, we can see that Instinct combined with litter injection did increase NUE compared to fertilizer only or surface applied poultry litter without Instinct, but we cannot determine whether it was the Instinct, Injection, or a combination of both that provided the benefit. However, if we consider the results of the laboratory study, which showed a distinct advantage with the use of Instinct, we can conclude that it was probably at least a combination of effects that yielded the benefit in the field.

## Field Study Results

The most striking and fascinating result of this study was the benefit seen from the ACT Litter + Injection + Instinct in the field study. In nutrient response trials such as this it is expected that eventually the yield lines will converge. In other words, even if we gain efficiency through one treatment (higher yield at a given N rate) we would expect that as N rate goes up all treatments will reach a sufficient rate and yields will converge. This did not occur in our field study. The combination of ACT + Instinct + injection resulted in a higher overall yield potential than the other two treatments (Figure 1). This means that before side dress (V6) the ACT treatment provided some benefit allowing a higher yield potential to be realized than

with surface applied standard broiler litter or the fertilizer control. Because of the limitations of this study we cannot determine whether injection, nitrapyrin, or the ACT litter were responsible for this benefit. We will seek additional funding to sort out this information.

## Laboratory Study results

### Soil Nitrate Mineralization Over Time

Unlike the field study, the laboratory study consisted of a complete factorial randomized complete block design. Therefore, we will be working to publish this data in peer-reviewed journals this year. The findings were fascinating and helped to explain our findings from the field study. We investigated the effects of nitrification inhibitor (Instinct), initial soil moisture content (targeting 40% and 75% of field capacity), N source (ACT PL, normal PL, and UAN) on soil N cycling. Over a sixteen week period we measured inorganic N as  $\text{NO}_3\text{-N}$  and  $\text{NH}_4\text{-N}$  in the soils.

Statistical analysis of the soil  $\text{NO}_3\text{-N}$  concentrations revealed that the data should be evaluated across time as the sample week had a significant interaction with many combinations of the main effects. Table 1 shows the statistical significance of the main effects and their interactions using the MIXED procedure (SAS 9.3). Effects where  $P < 0.005$  were deemed significance and are highlighted in yellow.

*Table 1. Type 3 Tests of Fixed Effects for all soil nitrate concentrations in laboratory incubation study. Effects where  $P < 0.05$  were deemed significant.*

Effect	Num DF	Den DF	F Value	Pr > F
n_source	3	237	34.59	<.0001
inhibitor	1	237	24.65	<.0001
target_FC	1	237	26.84	<.0001
week	4	237	96.10	<.0001
n_source*inhibitor	3	237	0.38	0.7684
n_source*target_FC	3	237	6.62	0.0003
inhibitor*target_FC	1	237	1.08	0.3000
n_source*week	12	237	14.20	<.0001
inhibitor*week	4	237	18.76	<.0001
target_FC*week	4	237	3.88	0.0045
n_source*target_FC*week	12	237	4.76	<.0001
n_source*inhibitor*week	12	237	0.31	0.9881
inhibitor*target_FC*week	4	237	0.86	0.4886
n_sour*inhibi*target	3	237	0.77	0.5115
n_so*inhi*targe*week	12	237	0.94	0.5122

A second model was run, again using PROC MIXED, looking at the effects by week. This second run showed more clearly the effect of the treatments. Table 2 shows the results from this run. The effects highlighted in yellow were deemed significant at the  $P < 0.001$  level. We can see that in the first two

samplings (weeks 2 and 4) the main effect of inhibitor was significant and was almost significant in week 8. From this we can conclude that the Inhibitors were very effective for four weeks and maintained some efficacy up to almost eight weeks. In fact the combined effect of inhibitor and N source was significant at week 8, this demonstrates that for some of the N sources Instinct maintained its effectiveness into the eight week. This was unexpected since this was a very aggressive incubation with high N rates and moist soils. More impressive was that this study was conducted at 25 C (77 F). Instinct efficacy is known to decline with increasing temperature and has been found to be most effective when soils are cool. While we expected Instinct to be effective, we did not expect this level of effectiveness under these conditions. This shows great promise for poultry litter applied in cooler months, which is more common in the field. Figure 1 shows the mean soil NO<sub>3</sub>-N concentration across all sample dates for each level of nitrification inhibitor (with or without Instinct). We can see that there was more NO<sub>3</sub>-N in the soil in the cups without Instinct regardless of moisture or N source up until week 10.

The main effect of soil moisture content was significant for all sample dates and the main effect of N source was significant at weeks eight through 16. However, when there are interactions we cannot simply look at the main effects. There was an interaction between N source and soil moisture in weeks two and four. Therefore, we have to look at the combined effect of these two treatment factors over that time period. First, looking at the main effect of soil moisture, we can see that in general the wetter soil, where the target moisture content was 75% of field capacity, generated more nitrate regardless of other treatments over the course of the study (Figure 3). The trend is so clear that it is surprising that there is an interaction with N source. Figure 5 shows the mean soil NO<sub>3</sub>-N concentration over time as a function of N source. We can see that initially there was a large spike in the control soil where no N was applied. This is puzzling and raises concerns about laboratory error, but does not necessarily effect overall research conclusions. Nonetheless, we hope that when total N results are returned from the lab we can perhaps determine if this effect is real. We also see that in the first four weeks the NO<sub>3</sub>-N concentrations followed a general trend of normal PL>ACT PL > UAN, but the differences seen in the first four weeks were not deemed significant. This means that there is no difference NO<sub>3</sub>-N mineralization in the first four weeks between any of the four treatments. However after week four the control soil returns to expected concentrations and very little difference is seen between the N sources. This difference is significant from week eight through 16. This is expected since we applied all N sources at the same total plant available N rate and this data is averaged across soil moisture and the use of Instinct. However, in week eight we cannot assume that all N sources are statistically the same and significantly greater than the control because there is an interaction between N source and inhibitor. Looking closer at the mean separation we can see that all treatments with N added (UAN, ACT-PL, and PL) regardless of use of instinct are greater than the controls, this is expected. However, the interaction is caused because in one case the use of instinct was still giving an advantage, this was in the comparison of UAN with instinct, which produced statistically lower soil NO<sub>3</sub>-N concentrations than UAN without instinct (94 versus 103 mg-NO<sub>3</sub>-N/kg, respectively). The means of the combined treatments N source and inhibitor are presented in Figure. After week eight this interaction no longer occurred and the main effects of N source and target soil moisture content were the only significant differences. In general, there were no significant differences between N sources, but all soils treated

with PL or UAN, regardless of Instinct use, yielded greater soil  $\text{NO}_3\text{-N}$  concentrations than the control in weeks 12 and 16. Similarly, in weeks 12 and 16 regardless of inhibitor or N source the wet soils always had higher soil  $\text{NO}_3\text{-N}$  concentration than the drier soils in weeks 16 and 12. As stated previously, while it is tempting to look just at the main effects of soil moisture (Figure 3) and inhibitor (Figure 2) in the first four weeks, because there was significant interaction during that time period we have to look at the combined effects. Figure 6 shows that these trends are complicated and the interaction might be a function of the anomalous behaviour of the control soils in week four. In fact, in week two when the Tukey adjustment is made the interaction is not significant and in week four the differences are minimal and a function of the high concentrations detected in the control soils.

### Total Inorganic N Mineralization Over Time

In addition to measuring soil  $\text{NO}_3\text{-N}$  concentrations we also measured soil ammonium N ( $\text{NH}_4\text{-N}$ ). As would be expected  $\text{NH}_4\text{-N}$  concentrations were lower than  $\text{NO}_3\text{-N}$  concentrations, quite variable, had numerous interactions, and produced few clear trends. Generally,  $\text{NH}_4\text{-N}$  declined with time, although there was an anomalous bump around week eight that deserves further attention through analysis of additional data. We did look at pH as well (data not presented) and we would expect pH to respond to the generation of  $\text{NH}_4\text{-N}$ , but this was not the case it declined with time steadily as nitrification progressed. The sum of the  $\text{NH}_4\text{-N}$  and  $\text{NO}_3\text{-N}$  concentrations represents the total inorganic N in the soil system and presents more useful data.

At the week two sampling there were no statistical differences between the total inorganic N concentrations. This was expected since we attempted to apply the same amount of plant available or inorganic N. By week four statistical differences began to emerge. The main effect of inhibitor and target soil moisture content and the combined effect of N source and target soil moisture content were deemed significant. Looking at the combined effect of N source and soil moisture for week four (Figure 7) we see that generally this is a function of the high inorganic N concentrations resulting from the high moisture content combined with either standard poultry litter or no N added. As discussed previously this seems to be some sort of laboratory anomaly. After week four these trends disappear and seem more reasonable. The significance of the main effect of Instinct use is more believable. Clearly in Figure 8 the inclusion of Instinct decrease total inorganic N across all N sources and soil moisture regimes. After week four the effect of inhibitor is masked in the total inorganic N data. However, in weeks 8 – 16 both the main effect of N source and soil moisture are deemed significant. First, looking at the main effect of N source in weeks 8 – 16 we see that all N sources resulted in significantly greater inorganic N concentrations than the control soils, regardless of moisture or inhibitor. Furthermore, there were no statistical differences between any of the N sources (Figure 9). Next, looking at the main effect of soil moisture content on total inorganic N concentrations we see that in weeks 8 through 12, regardless of other treatment factors, the wet soil always has statistically greater concentrations than the drier soil (Figure 10).

## Laboratory and Field Study Figures and Tables

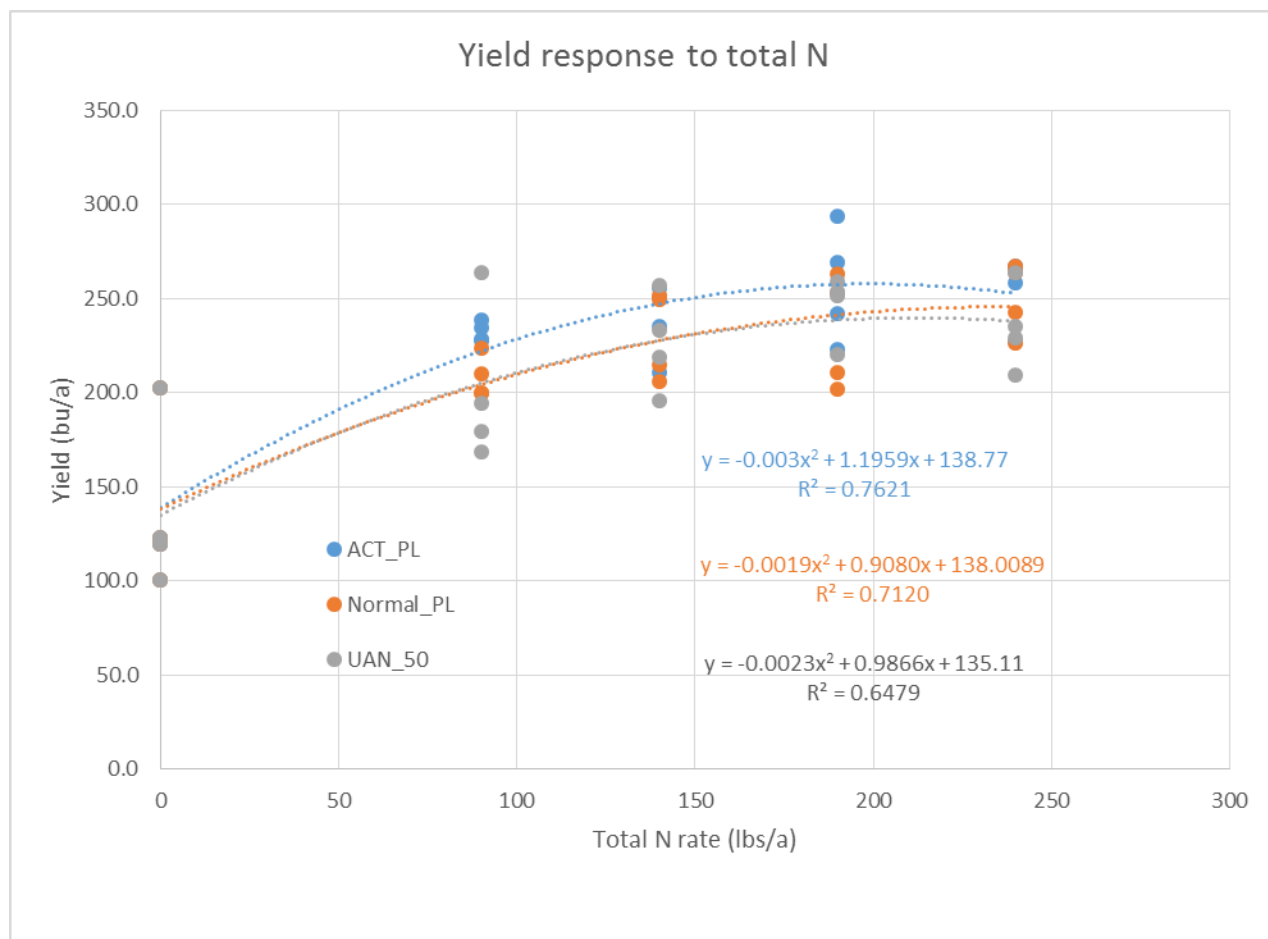
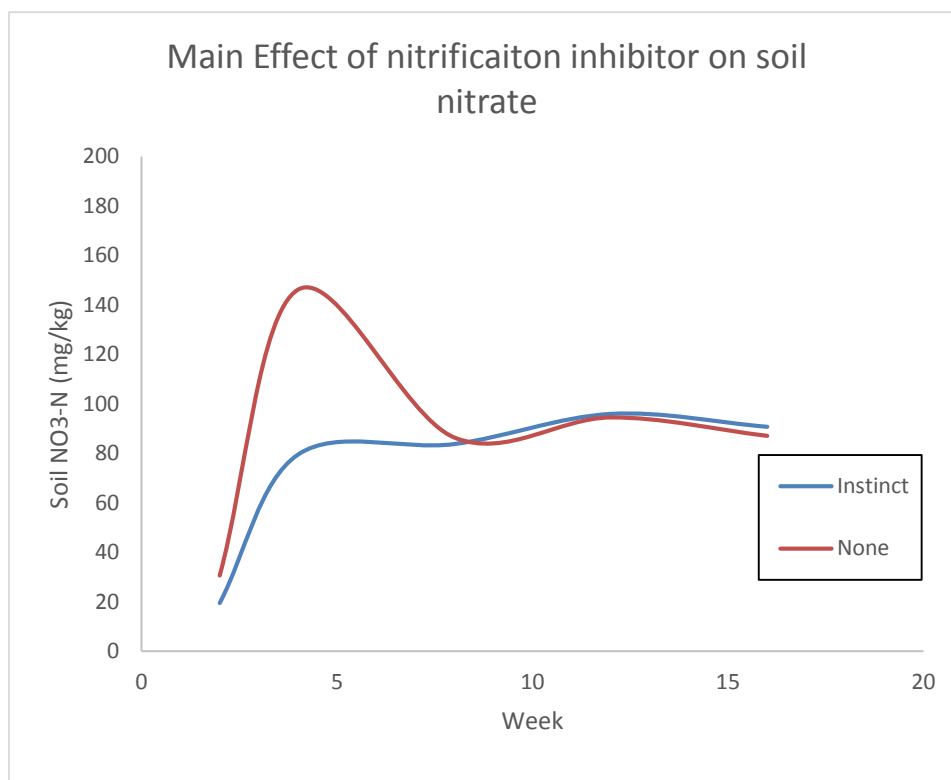


Figure 1. Yield response to total nitrogen rate by pre-plant nitrogen treatment. Note: outliers have been identified in the dataset. Nitrogen application data files from side-dress equipment and yield files are being evaluated to identify if this is background noise or experimental error. However, in general it appears that better responsiveness to side-dress nitrogen was achieved through the combination of ACT litter, nitrapyrin, and manure injection. Nonetheless, further data analysis is required to confirm this conclusion.



*Figure 2. Main effect of nitrification inhibitor on soil nitrate over time was significant ( $P<0.01$ ) in weeks 2 and 4.*



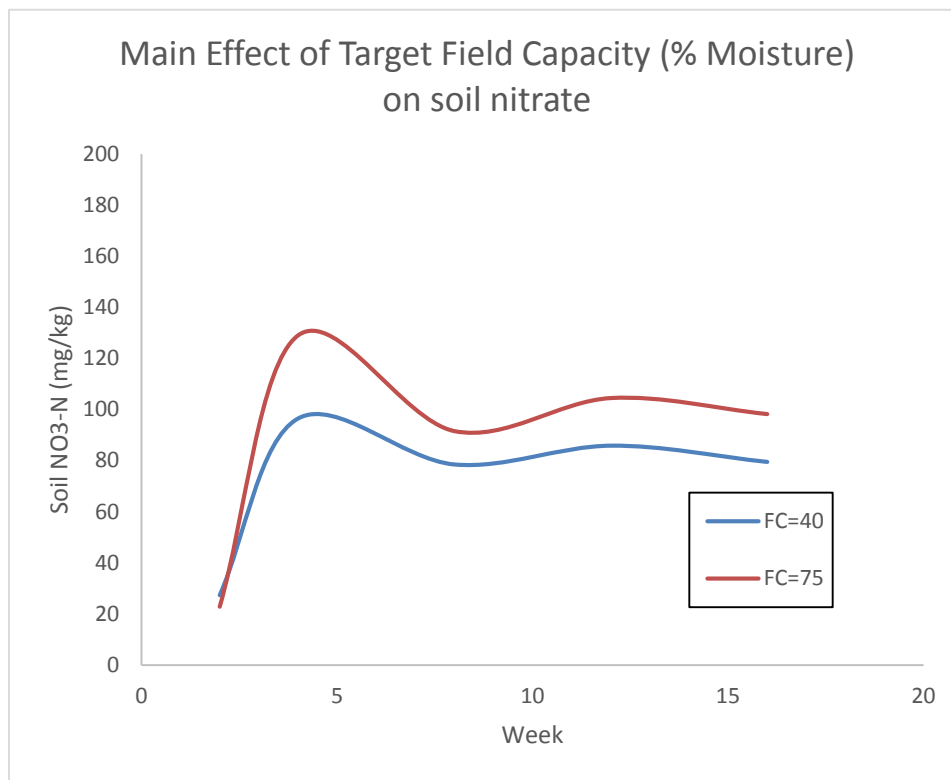


Figure 3. Main effect of target field capacity on soil nitrate over time.

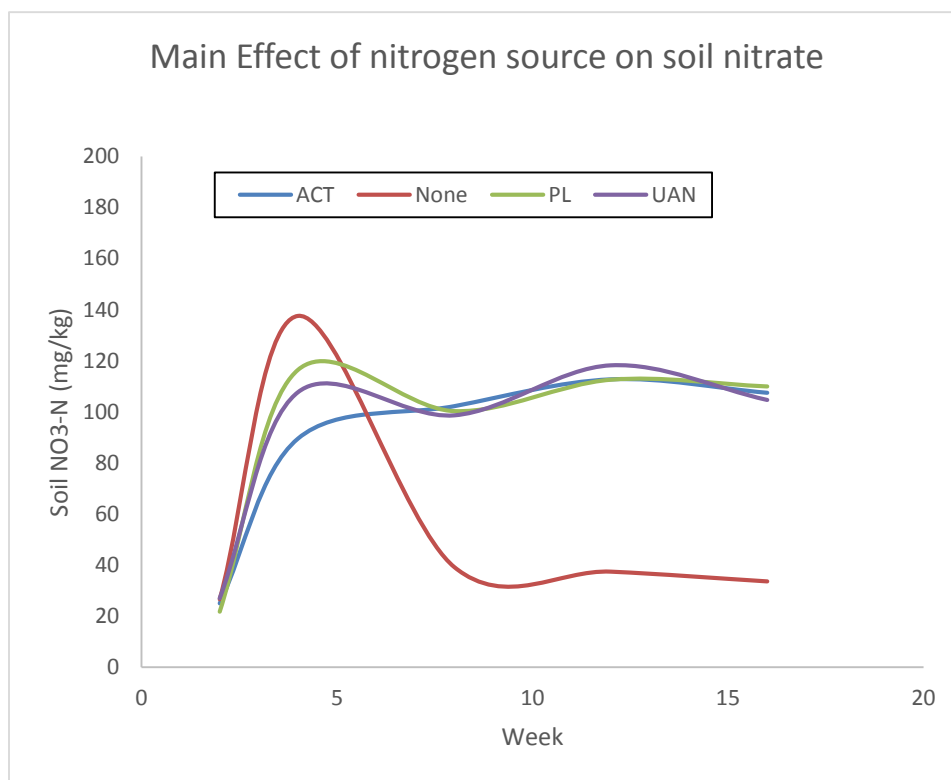
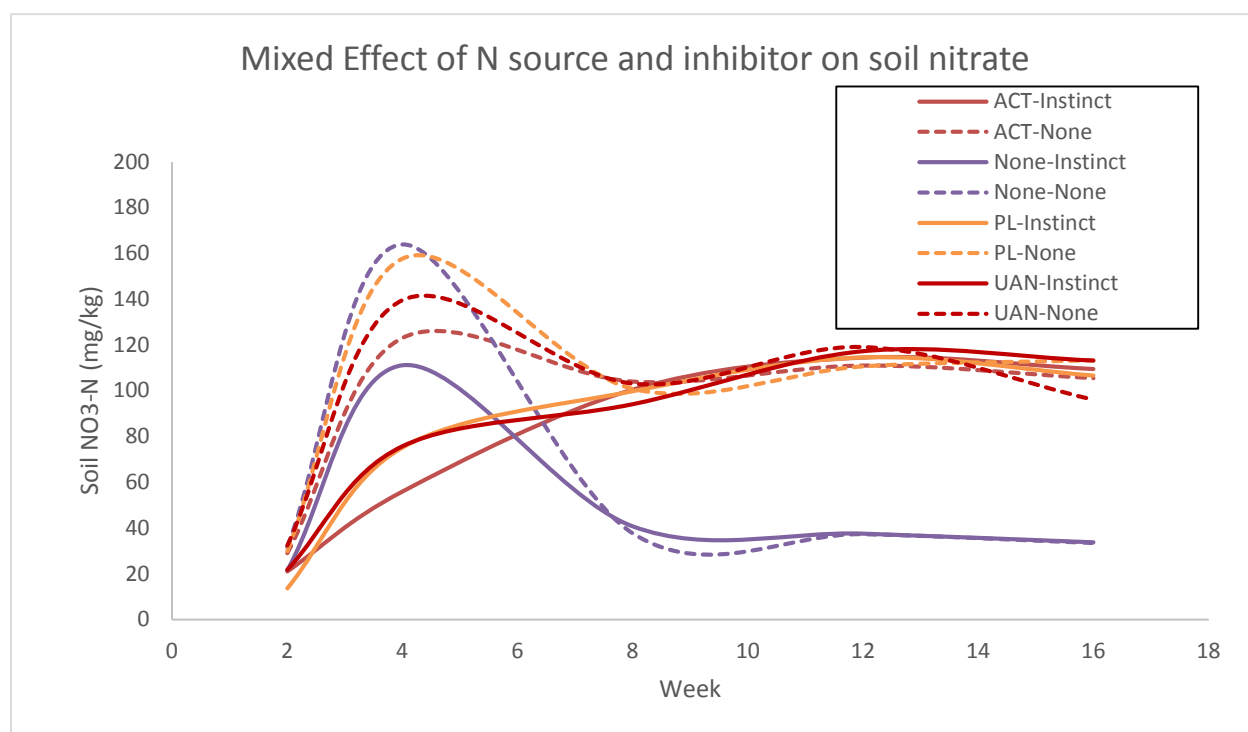


Figure 4. Main effect of nitrogen source on soil nitrate concentrations over time.



*Figure 5. Combined effect of N source and inhibitor on soil nitrate concentrations over time.*

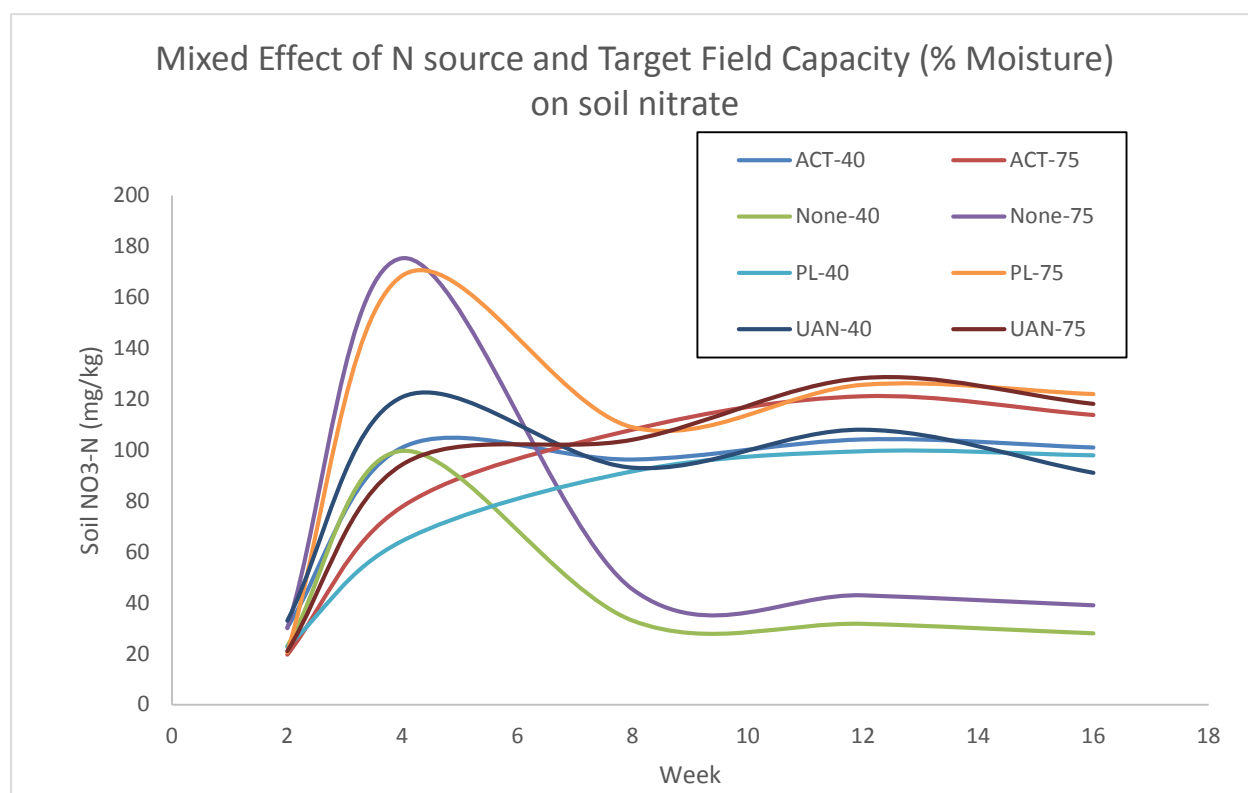


Figure 6. Combined effect of N source and soil moisture content on soil nitrate concentrations over time.

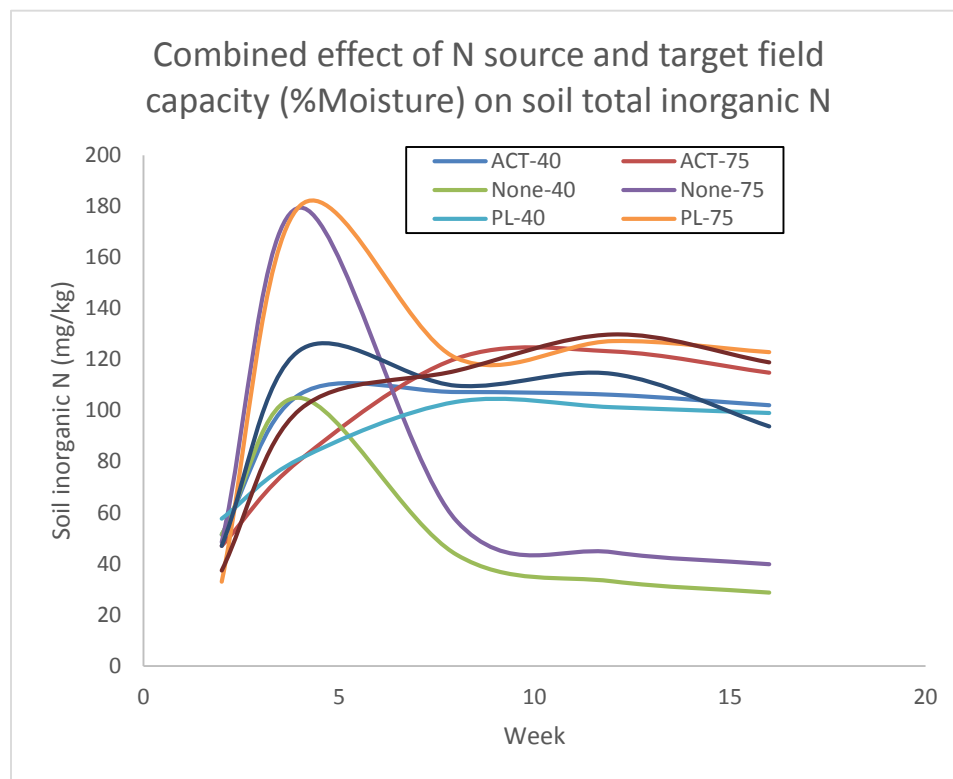
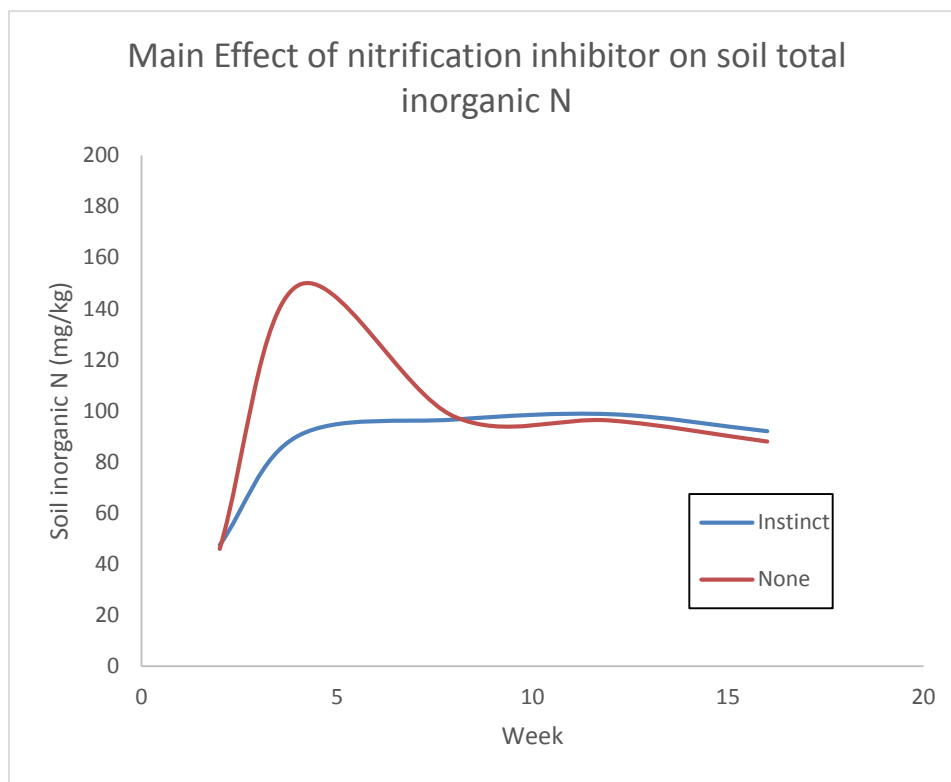
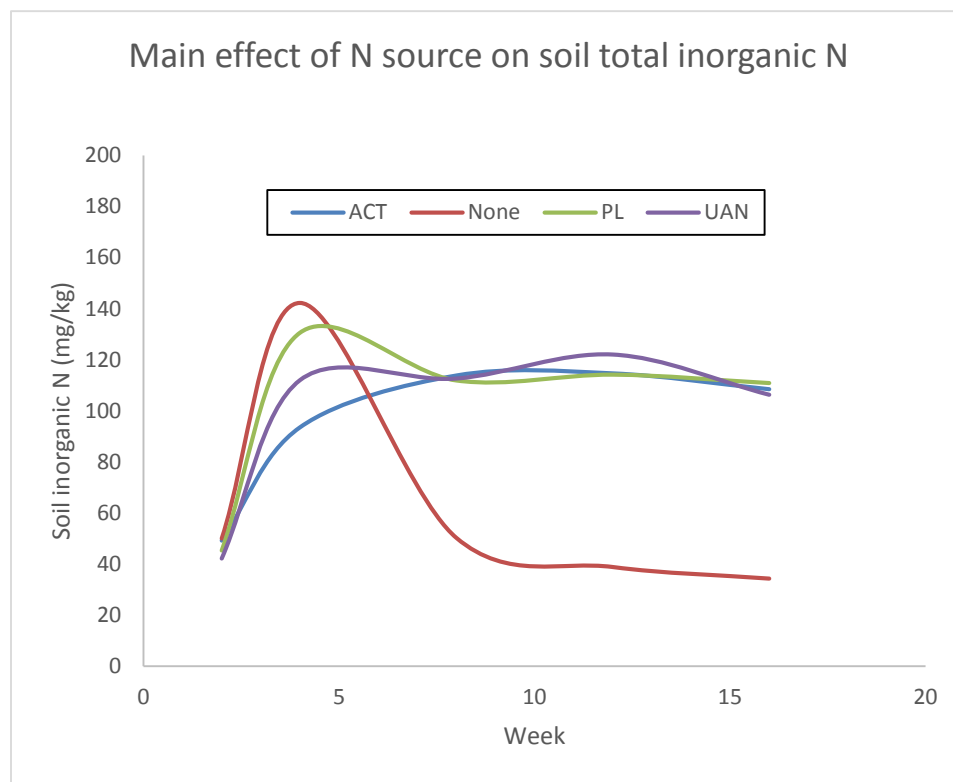


Figure 7. Combined effect of target soil moisture content and N source on soil total inorganic N concentration over time.



*Figure 8. The main effect of nitrification inhibitor on total soil inorganic N concentrations over time.*



*Figure 9. Main effect of N source on soil total inorganic N concentrations over time.*

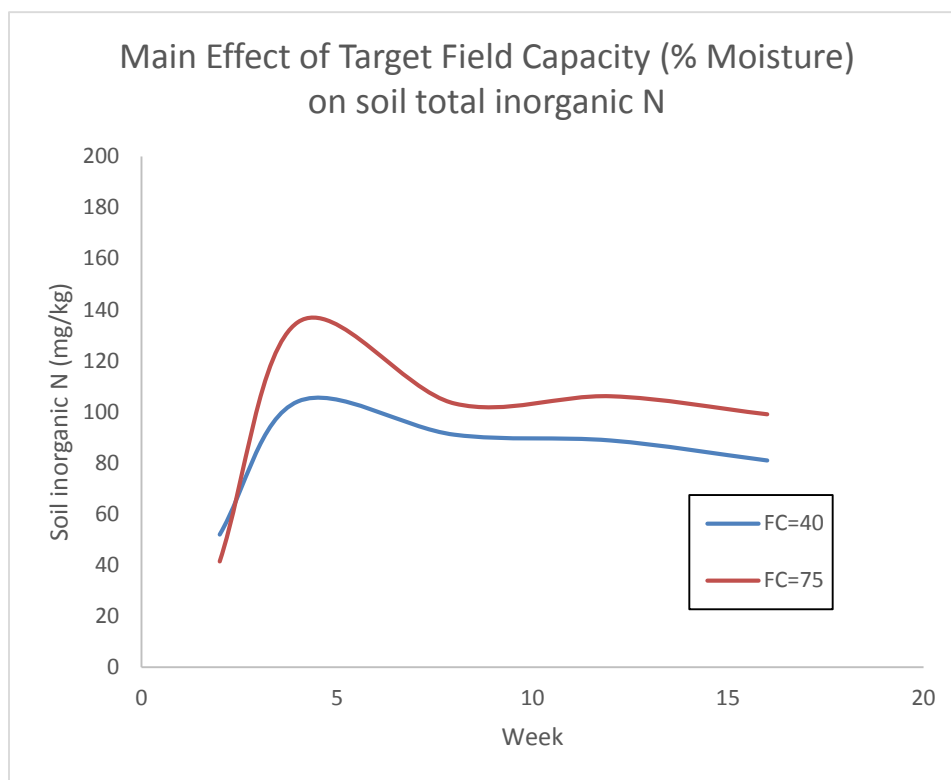


Figure 10. Main effect of soil moisture content on total soil inorganic N concentrations across time.



Table 2. Type 3 tests of fixed effects on soil NO<sub>3</sub>-N concentrations.

Effect	Num DF	Den DF	Week 2		Week 4		Week 8		Week 12		Week 16	
			F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
n_source	3	45	1.41	0.2534	2.07	0.1179	460.78	<.0001	338.11	<.0001	120.12	<.0001
inhibitor	1	45	30.66	<.0001	23.03	<.0001	3.37	0.0728	0.48	0.4926	1.19	0.2808
target_FC	1	45	4.81	0.0336	5.49	0.0236	83.91	<.0001	78.71	<.0001	30.89	<.0001
n_source*inhibitor	3	45	0.74	0.5347	0.19	0.8994	3.16	0.0338	0.42	0.7377	2.17	0.1043
n_source*target_FC	3	45	4.78	0.0056	5.88	0.0018	0.99	0.4055	2.16	0.1056	1.39	0.2569
inhibitor*target_FC	1	45	0.32	0.5731	1.04	0.3126	0.81	0.3715	0.01	0.9055	0.34	0.5621
n_source*inhibitor*target_FC	3	45	2.77	0.0522	0.96	0.4211	0.63	0.6013	2.01	0.1265	0.14	0.9337

## **Litter Amendment to Control Ammonia Emissions Results**

### **Impact of Frequent Litter Amendment Application on Nutrient Composition and Properties Changes of Stored Broiler Litter**

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#### **Introduction**

Ammonia (NH<sub>3</sub>) not only is detrimental to animal health and production, but also contributes to acid deposition and eutrophication. The subsequent impacts of acid deposition can be significant, including adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation. Eutrophication can lead to severe reductions in water quality with subsequent impacts including decreased biodiversity, changes in species composition and dominance, and toxicity effects. NH<sub>3</sub> also contributes to the formation of secondary particulate aerosols, an important air pollutant due to its adverse impacts on human health. NH<sub>3</sub> Emissions from the poultry houses in the Chesapeake Bay region are being considered on their impact to water quality; air emission regulations are expected especially as air quality standards become more stringent.

Litter amendment has been widely used in broiler and turkey operations, mostly at the early age for improving production performance. Mid-flock litter amendment application will further improving litter quality and maximize the potential of litter amendment on NH<sub>3</sub> reduction. A field study with three flocks with multiple mid-flock PLT applications showed >50% NH<sub>3</sub> emission reduction after 6-wk of age in a broiler facility.

Litter amendments can reduce the breakdown of uric acid and NH<sub>3</sub> formation, thus increasing the N value of litter/manure and reducing air and water quality concerns. Conserving NH<sub>3</sub> in poultry houses has other benefits as well including resource conservation (the original source of the NH<sub>3</sub> in litter was the fertilizer N used to grow the feed, which was produced using natural gas, a finite resource) and producing litter with higher N/P ratios which will more closely match crop uptake and thus be less likely to lead to P accumulations in soils.

By utilizing the litter amendment to control NH<sub>3</sub>-N loss, the industry can demonstrate initial efforts to reduce air emissions before regulations come into effect, thereby appeasing regulators. In addition, estimating ACT effectiveness will allow regulators to consider their inclusion as a conservation practice in models, such as the US EPA Chesapeake Bay Model, and allow producers to receive credit for both implementation and decreases in pollutant emission.

In addition, there is increasing concern about the potential for N loss from litters stored in or near agricultural fields and the effects of storage practices on N losses from litters after land application. Furthermore, questions have been raised over the impact of changes in litter moisture content during storage on nutrient composition in the stored litter and the interaction of storage conditions and litter amendment.

The purpose of this study was to determine if NH<sub>3</sub>-N, organic-N, pH, and moisture content change during different storage periods in a covered manure storage. Three profile samples from each stored litter were collected and analyzed monthly over a 7-month period. Litter pH,

moisture content, organic-N, and  $\text{NH}_3\text{-N}$  concentrations were determined on an as-is sample. Evaluating the effect of storage time will help determine how storage time affects N composition and litter properties in the two different litters.

## Materials and Methods

The litter production was performed in an experimental house at the University of Delaware. The environmental house measuring 34.6 m x 12.1 m (114 ft x 37 ft) was east-west orientated and divided into two partitions, 17.3 m x 12.1 m (57 ft x 37 ft) each. The two partitions were symmetrical and shared the same end wall and control room. Each partition had insulated drop ceilings, static-pressure controlled box air inlets along the sidewalls, two radiant tube heaters (11,722W or 40,000 British thermal units [Btu]/hr each), two gas-fired space furnaces (65,940W or 225,000 Btu/hr each), two 0.6-m (24-in) and two 0.9-m (36-in) diameter fans located at each end of the building. Independent environmental controllers (Choretronics 2; Chore-Time Brock, Milford, IN) coordinated control of air temperature, ventilation fan and heater operation, and lighting programs. The houses were equipped with foggers for cooling, as needed. East partition was equipped a little amendment delivery system, which consisted of two overhead applicators with variable speed motors. The two partitions were managed separately, but had the same setup, bird genetics, and production stage.

Each partition had an initial placement of approximately 2,400 straight-run broiler birds with new bedding. The broilers were fed for 52 – 59 days to reach a market body weight of approximately 3.85 kg (8.5 lb). Prior to the experiment, the same used litter was placed into the two partitions. Before each flock, the brooding chamber (90 m<sup>2</sup> area) of each partition received 45.4 kg (100 lb) sodium bisulfate. During the grow-out from April 2 to May 28, 2013, variable rates (122, 183, 244, 305, and 366 g/m<sup>2</sup> or 25, 37.5, 50, 62.5, and 75 lb/1000ft<sup>2</sup>) of sodium bisulfate (PLT<sup>TM</sup>) was applied weekly to the east partition at the ages of 21, 28, 35, 42, and 49-d. Production performance data for birds from each partition, including feed and water consumption, body weight, and feed efficiency, were collected. At the end of each flock, litter samples were taken from each partition for nutrient and chemical analysis. One June 3, the caked litter in both partitions was removed and collected from partition for the storage study. Four 0.12-m<sup>3</sup> trashcans were filled with litter from each partition for a total of eight cans. Lids with holes drilled in them were placed on the trashcans to allow for air exchange and prohibit disturbance by pests. The eight cans were paired together and stored at ambient temperature in a litter storage at the University of Delaware Research and Education Center for 10 months.

Litter samples (2.5 cm in diameter and the depth of the litter in the can) were collected with a core litter sample (Fig. 1) from three cans for each kind of litter bi-monthly after the initial setup. First and last sample dates were June of 2013 and April of 2014. One temperature probe (TMC-6 HD, Onset Comp.) was inserted into each litter can at the center to measure and record the core temperature with 4-channel data logger (U12-006, Onset Comp.). Ambient temperature and relative humidity of the storage were measured and recorded by a data logger (U23 Pro Temp/RH, Onset Comp.). The



**Figure 1. Poultry litter samplers used for this study**

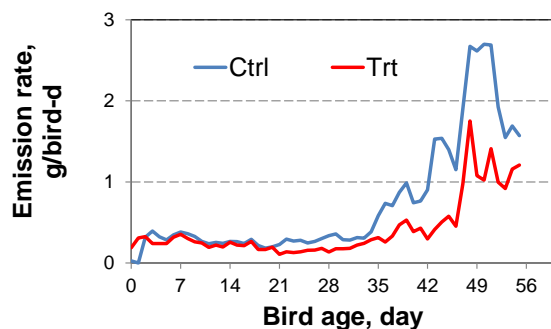
recording interval was set to 5 min. Litter samples were sent to a commercial lab (Midwest Laboratories, Inc.) for nutrient and chemical property analysis. During the 10-mo storage period, the core temperatures of litter were below 40 °C.

Analyses of variance were conducted using General Linear Model in JMP (JMP 11, SAS Institute). Tukey method was used for paired comparisons.

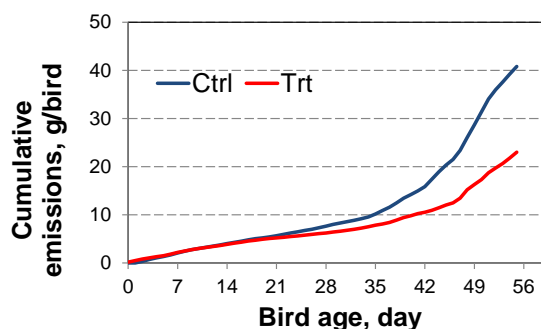
## Results

### *Effect of Litter Amendment on Ammonia Emissions from Broiler House*

Daily  $\text{NH}_3$  emission rate (ER) and cumulative emissions over the 8-wk grow-out period for the control and variable rate treatment were summarized and shown in Figures 2 and 3. The  $\text{NH}_3$  ERs of the birds with sodium bisulfate were significantly lower than the control after sodium bisulfate was applied. The daily  $\text{NH}_3$  ER was reduced dramatically right after sodium bisulfate application and then increased till the following application. Birds with sodium bisulfate had significant lower daily  $\text{NH}_3$  ERs and cumulative emissions after 30-d of age. The dynamic reduction rate of daily  $\text{NH}_3$  ERs fluctuated in the range of 21.3 and 73 % depending on the dissipation of the applied sodium bisulfate after 21-d of age. The reduction rate of cumulative  $\text{NH}_3$  emissions with sodium bisulfate rate was 46% for the 8-wk growout.



**Figure 2. Daily ammonia emission rates of broilers in two partitions without (Ctrl) and with sodium bisulfate treatment.**

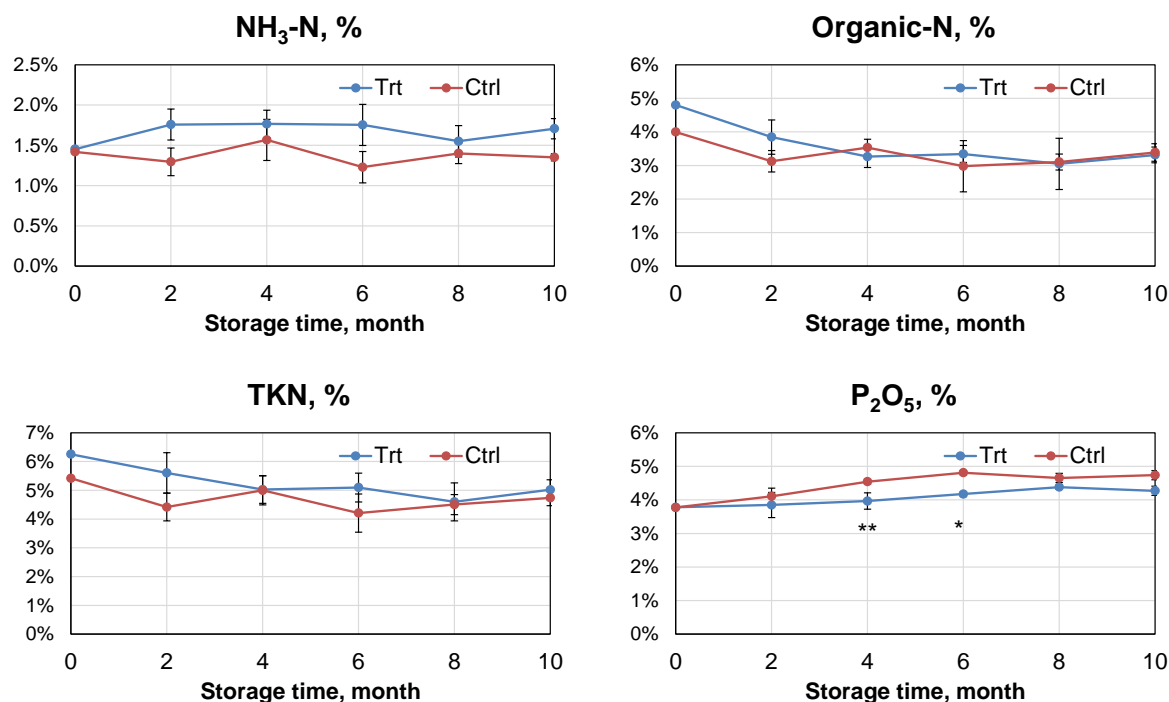


**Figure 3. Cumulative ammonia emissions of broilers in two partitions without (Ctrl) and with sodium bisulfate treatment.**

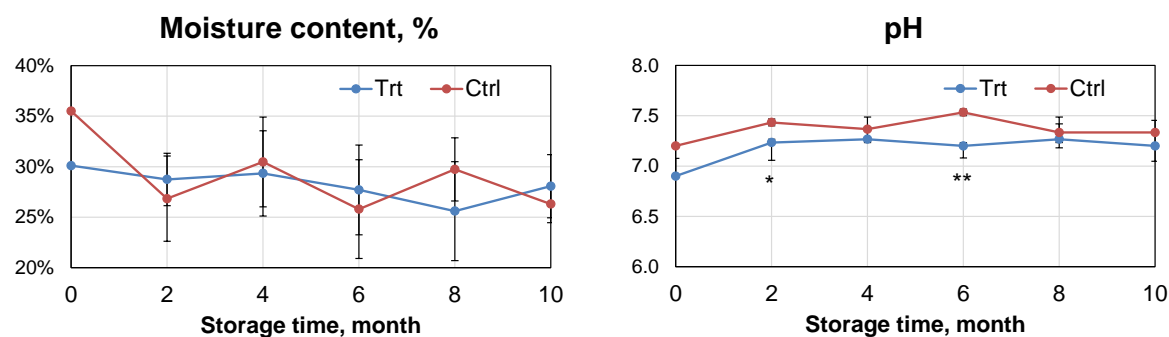
### *Litter Properties and Nutrient Composition during Storage*

At the beginning, the treated litter had higher Org-N, TKN, and  $\text{N}/\text{P}_2\text{O}_5$  ratio than the untreated litter while the  $\text{NH}_3\text{-N}$  and P levels were similar in both litter (Fig. 4). The pHs of treated litter were lower than the control throughout the 10-mo period (Fig.5). The manure properties indicate that sodium bisulfate application during the growout led to less pH, greater Org-N and TKN contents in the litter. Litter amendment reduces nitrogen loss as  $\text{NH}_3$  and increase the Org-N in litter by lowering litter pH during broiler growout. During the 10-mo storage period,  $\text{NH}_3\text{-N}$  of treated litter varied from 1.75 to 1.5 %, which was slightly higher than the control, while Org-N levels were similar in both types of litter. The Org-Ns in both litter dropped to 3.3% while the TKNs were 4.7 and 5% in the control and treated litter after 10-mo. In general,  $\text{P}_2\text{O}_5$  in control litter was higher than in treated, which was presumably due to the normal variation of litter moisture content.  $\text{P}_2\text{O}_5$  of the control litter at 4 and 6- mo were significantly higher than that in treated litter ( $P < 0.05$ ). The  $\text{N}/\text{P}_2\text{O}_5$  ratios of both litter continuously decreased over the

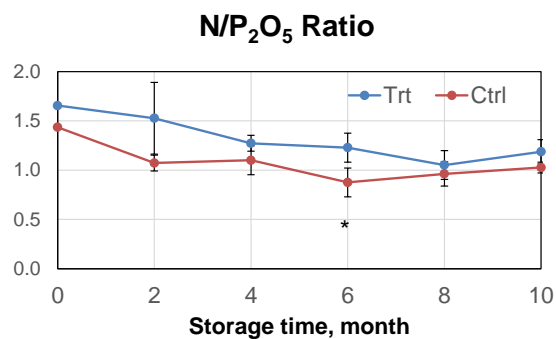
10-mo period due to N-loss to atmosphere as  $\text{NH}_3$  and other forms of gases (Fig. 6). The treated litter consistently had 15% higher N/ $\text{P}_2\text{O}_5$  than the control litter.



**Figure 4. Nutrient properties of stored litter during a 10-mo period.**



**Figure 5. Moisture content and pH of stored litter during a 10-mo period.**



**Figure 6. Nitrogen and P<sub>2</sub>O<sub>5</sub> ratio of stored litter during a 10-mo period.**

## Conclusions

A study was conducted that aimed to evaluate the impact of frequent litter amendment application on NH<sub>3</sub> emission from a broiler operation and nutrient composition and properties changes of stored litter during a 10-mo storage period. The following conclusions and observations were made.

- Frequent application of sodium bisulfate led to significant reduction in NH<sub>3</sub> emissions from broilers.
- Litter pH level of the litter was lower in the treated litter. Organic and total nitrogen contents in the treated litter were higher while less nitrogen was emitted as NH<sub>3</sub>.
- The N/P<sub>2</sub>O<sub>5</sub> ratios of both litter continuously decreased over the 10-mo period. The treated litter consistently had 15% higher N/P<sub>2</sub>O<sub>5</sub> than the control litter.

# Greenhouse Gas Emissions of Corn Fielded with Broilers Litter Treated by Ammonia Control Technology

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## Introduction

Delmarva is one of the most geographically concentrated poultry industries in the USA, producing ~600 million broiler chickens per year. The poultry litters (PL; manure and bedding) generated are valuable fertilizers, which can increase yields, and therefore overall nutrient use efficiency, compared to inorganic fertilizer alone. In recent years, concerns have also grown about the adverse human health and environmental impacts of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), ammonia (NH<sub>3</sub>) and nitrous oxide (N<sub>2</sub>O) emissions from poultry production facilities and PL applied to cropland.

Since poultry litter contain both organic and inorganic N and C resource, it provide the essential substrates required for the microbial production of CO<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub> and N<sub>2</sub>O. CO<sub>2</sub> produced from the respiration of microorganism in soil. Soil respiration rate with manure application may 1.6 times larger than CO<sub>2</sub> release from none treatment soil and N<sub>2</sub>O flux from manure treatments was 25 times larger than that from mineral fertilizers (Jones et al., 2004). Thornton et al. (1998) applied composted poultry litter and fresh poultry litter and urea as fertilizer in Bermuda grass field and measured the N<sub>2</sub>O emission at 1.64 kg N ha<sup>-1</sup>, 3.87 kg N ha<sup>-1</sup> and 2.96 kg N ha<sup>-1</sup>, respectively. Yagi et al. (1990) applied different kinds of fertilizer into paddy fields and observed a 1.8-3.5 times increase on CH<sub>4</sub> emission with organic matters than inorganic fertilizer. Few works did on the NH<sub>3</sub> emission after poultry litter application on the field.

New technologies have been introduced to help combining PL and inorganic fertilizers in high yielding corn production with minimal environmental impact in Delmarva. Ammonia control technologies (ACT) that use innovative methods to mitigate NH<sub>3</sub> loss from poultry houses, thus increasing the N value of PL and reducing air and water quality concerns. Conserving NH<sub>3</sub> in poultry houses has other benefits as well including resource conservation (the original source of the NH<sub>3</sub> in PL was the fertilizer N used to grow the feed, which was produced using natural gas, a finite resource) and producing PL with higher N:P ratios which will more closely match crop uptake and thus be less likely to lead to P accumulations in soils. And a new fertilizer application method, called “subsurfer”, was used to inject solid PL under soil surface, which both reduces N loss via NH<sub>3</sub> volatilization and the potential for P losses in surface runoff. Moreover, the subsurfer offers the unique opportunity to use nitrpyrin in combination with PL. Nitrpyrin can conserve ammonia in soil, reducing nitrification and denitrification, resulting in overall higher N use efficiency by maintaining plant available N in the root zone.

In this study, ACT poultry litter, normal poultry litter and urea nitrogen were applied in a corn field as fertilizer. Greenhouse gas ( $\text{CO}_2$ ,  $\text{CH}_4$ , and  $\text{N}_2\text{O}$ ) fluxes were measured using a static chamber to decide new poultry litter treatment and application technology can reduce the gas emission rate and decrease the environmental impacts.

## **Methods and Materials**

### *Site and corn description*

The experimental site is at the experimental farm of University of Delaware in Georgetown, Delaware, United States. This site is an irrigated corn field. The corn was planted in May, 2014 and harvested in September, 2014. The distance between each row was 30 in.

### *Poultry litter (PL) preparation*

Two kinds of poultry litter, ammonia control technology poultry litter (ACT-PL) and normal poultry litter, were used as the fertilizer in this study. The ACT technology in this study included the use of permanently installed in-house spinners that applied sodium bisulfate weekly to control  $\text{NH}_3$  emission during broiler grow-out.

An environmentally-controlled experimental house at the University of Delaware Carvel Research and Education Center (UDCREC; Georgetown, DE) was used for this project. The environmental house measuring 114 ft x 37 ft was east-west orientated and divided into two partitions, 57 ft x 37 ft each. The two partitions were symmetrical and shared the same end wall and control room. East partition was equipped a little amendment delivery system, which consisted of two overhead applicators with variable speed motors. The two partitions were managed separately, but had the same setup, bird genetics, and production stage. Each partition had an initial placement of approximately 2,400 straight-run broiler birds with new bedding. The broilers were fed for 52 – 59 days to reach a market body weight of approximately 8.5 lb. Prior to the experiment, the same used litter was placed into the two partitions. Before each flock, the brooding chamber (90 m<sup>2</sup> area) of each partition received 100 lb sodium bisulfate. During the grow-out from October 17, 2012 to March 18, 2013, 150 lb/1000ft<sup>2</sup> of sodium bisulfate (PLT™) was applied to the east partition at the age of 21. Two flocks of broilers with 8 week grow-out were raised in two separate rooms (2400 bird/room), one with ACT and the other as control. Eight tons of ACT litter and control litter from the two rooms was stored separately and used for laboratory field application.

### *Static chamber setup*

The gas emission was measured using USDA recommended static chamber. The chamber mainly included two parts, the anchor and chamber. The anchor was made using the middle part of a 5-gallon plastic bucket. The upper diameter of the anchor was 6.4 in., which is slightly smaller than the chamber. The anchor was 6 in. tall, and had some saw teeth for easily installation. All anchors were permanent installed into the sampling points one week before the measurement. The over ground part of the anchor was 1in to avoid any micro environment perturbations.



The chamber was cut from the bottom of the 5-gallon bucket. The chamber had a diameter of 10.5 in. and height of 6 in. Two holes were made at the center and edge of its top, respectively. Air sample was taken from the central hole and sent back from the edge hole after real-time

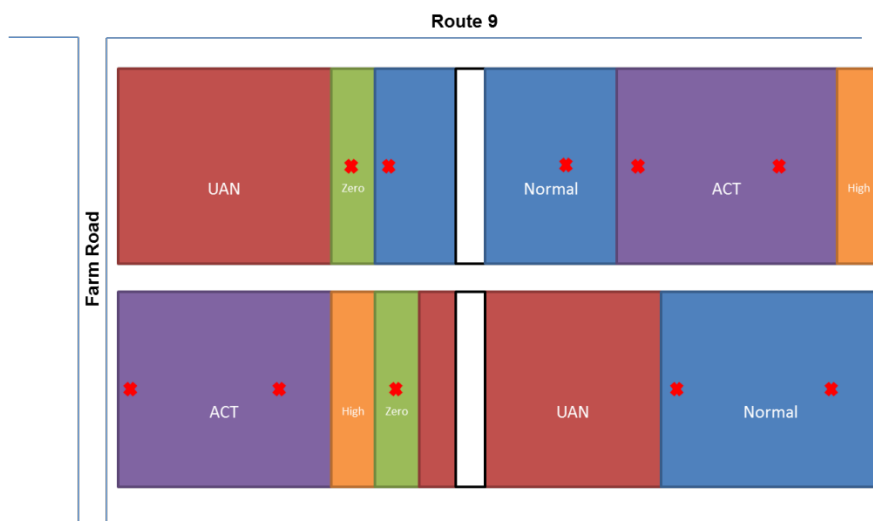
measurement. The edge hole connected with a 5.5in long tubing inside the chamber to send the air back to the bottom of the chamber. Weather-strip tape was applied inside the chamber at bottom part to increase airtightness between anchor and chamber. Outside of the chamber was covered by aluminum tape to decrease the temperature perturbations due to the solar radiation (Fig. 1).



**Figure 1. Static flux chamber used for the study**

### *Experiment design*

There were two repeated experiments in this study. Each replicate had a control plot and three treated plots (the high treatment shown in Figure 1 was not included in this study). The three main treatments were ACT litter injected with nitrapyrin, normal litter surface applied, and Urea-nitrogen (UAN) surface applied. Before the experiment, these four plots randomly distributed into each replicate. The control plot had six rows of corn and each treatment plot had thirty rows of corn. The plot map is shown in Figure 2.



**Figure 2. Plot and sampling map. (X: sampling points)**

Each plot was applied with PL 14 days before planting at a rate equivalent to 50% of the total estimated plant available nitrogen (PAN) requirement based on yield goal. Six side-dress N rates were nested in each of these plots. Each side-tress occupied five rows corn and included 0, 50, 75, and 125% of the remaining N prescribed based on yield goal, respectively. In addition, there was also a sensor-based variable rate N side-dress treatment based on the GreenSeeker active optical sensor. The overall treatment setup is shown in Table 1.

Five sampling pints were selected in each replicate which located in control plot, ACT-PL plot with 0% and 125% side-dress, normal PL with 0% and 125% side-dress. The surface greenhouse gas fluxes were measured in a 15min period using static chamber. Change in greenhouse gas concentration inside the chambers was analyzed in situ with a 1412 Infrared Photoacoustic Gas Monitoring System (Innova Air Tech Instruments, Ballerup, Denmark). Soil temperature and moisture content at each sampling point were measured using a moisture probe and temperature probe.

**Table 1. Treatments setup**

Main Plot #	Sub-plot #	Pre-plant treatment	Side-dress
1	1	ACT-PL injected w/Nitrapyrin	0-N
	2		50% Yield Goal Rate
	3		75% Yield Goal Rate
	4		100% Yield Goal Rate
	5		125% Yield Goal Rate
	6		Sensor-based
2	7	Normal PL surface applied	0-N
	8		50% Yield Goal Rate
	9		75% Yield Goal Rate
	10		100% Yield Goal Rate
	11		125% Yield Goal Rate
	12		Sensor-based
3	13	UAN surface applied	0-N
	14		50% Yield Goal Rate
	15		75% Yield Goal Rate
	16		100% Yield Goal Rate
	17		125% Yield Goal Rate
	18		Sensor-based
4	19	0 N Control	0-N

#### *Data analysis*

During the measurement, gas concentrations in the chamber were determined every 50s over 15 minutes, for a total of 19 values including time zero. Before a measurement the INNOVA took the ambient air sample until the reading became steady. For the linear increasing data ( $R^2 > 0.80$ ), the slope  $\phi$  (concentration vs. time) of the linear regression line was used to calculate the emission rate using the following equation.

$$ER = \phi \times 10^{-6} \times \frac{T_{std}}{T} \times \frac{w_m}{V_m} \times \frac{V}{S} \times t_d \quad (1)$$

Where,

ER = Gas emission rate from the field surface,  $\text{g d}^{-1} \text{m}^{-2}$

$\phi$  = slope of linear regression line, ppm<sub>v</sub> min<sup>-1</sup>  
 $T_{std}$  = standard temperature, 273.15K  
 $T$  = absolute temperature of soil surface, K  
 $w_m$  = molar weight of the gas, g mole<sup>-1</sup>  
 $V_m$  = molar volume of gas at STP, 0.022414 m<sup>3</sup> mole<sup>-1</sup>  
 $t_d$  = minutes in one day, 1440 min d<sup>-1</sup>

For the nonlinear increased data, three specific data point (0, 7.5 and 15min) were selected to determine the emission rate. The following equation (Eq. 2) modified based on Hutchinson et al. (1981) was used:

$$ER = \frac{(C_1 - C_0)^2}{t' \times (2 \times C_1 - C_2 - C_0) \times \ln[(C_1 - C_0) / (C_2 - C_1)]} \times 10^{-6} \times \frac{T_{std}}{T} \times \frac{w_m}{V_m} \times \frac{V}{S} \times t_d \quad (2)$$

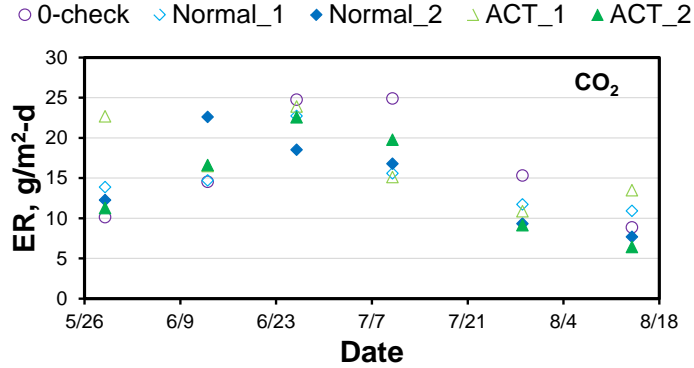
Where,

$ER$  = Gas emission rate from the field surface, g d<sup>-1</sup> m<sup>-2</sup>  
 $C_0, C_1, C_2$  = gas concentration at 0, 7.5, 15 min, ppm<sub>v</sub>  
 $t'$  = interval between sampling points, 7.5 min  
 $T_{std}$  = standard temperature, 273.15K  
 $T$  = absolute temperature of soil surface, K  
 $w_m$  = molar weight of the gas, g mole<sup>-1</sup>  
 $V_m$  = molar volume of gas at STP, 0.022414 m<sup>3</sup> mole<sup>-1</sup>  
 $t_d$  = minutes in one day, 1440 min d<sup>-1</sup>

All data were analyzed by repeated measures analysis of variance (ANOVA) using a Paleontological Statistics Software Package (PAST) (Hammer et al. 2001).

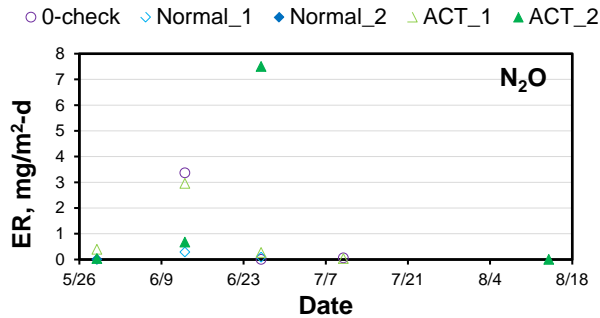
## Results and Discussion

CO<sub>2</sub> emission from soil resulted from the respiration of microorganism could vary from 0 to 56 g m<sup>-2</sup> d<sup>-1</sup> depending on soil type and time of year (Glinski & Stepniewski, 1985). CO<sub>2</sub> emission rate change during the experiment shows in Figure 2. The P-value of repeated measures ANOVA for different treatments was 0.584, which indicated no significant difference between any of two treatments. The soil temperature and water content change during the test period shows in figure 3 and figure 4. Since the test conducted between 8:00 to 14:00 in the same day, the soil temperature (P=0.085) and water content (P=0.475) did not change. The result shows neither litter treatment nor application rate had significant influence on CO<sub>2</sub> emission from the corn fields. The mean CO<sub>2</sub> emission rate was 15.4 g m<sup>-2</sup> d<sup>-1</sup>.

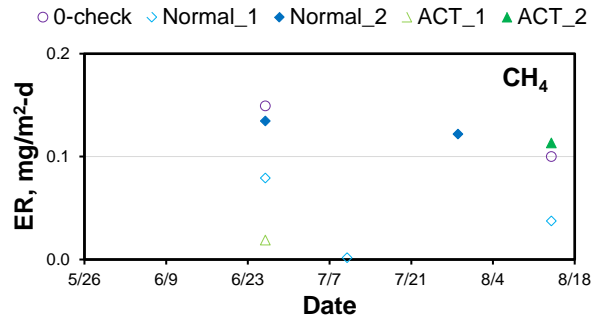


**Figure 2. CO<sub>2</sub> emission rates during experiment period**

Due to the low emission rate and higher detection limits (0.03 ppm on N<sub>2</sub>O and 5 ppm on CH<sub>4</sub>) of INNOVA, only limited numbers of emission rates were collected for N<sub>2</sub>O and CH<sub>4</sub>. Figures 3 and 4 show emission rates of N<sub>2</sub>O and CH<sub>4</sub> from corn fields. There were large variations among different treatment and no clear correlation between emission rate and litter type or litter application rate was found. The average emission rate of N<sub>2</sub>O and CH<sub>4</sub> were 1.22 and 0.08 mg m<sup>-2</sup> d<sup>-1</sup>. Gaseous emissions were converted to CO<sub>2</sub> equivalents (Mg CO<sub>2</sub> equivalents ha<sup>-1</sup> yr<sup>-1</sup>) using global warming potential of 310 and 21 for N<sub>2</sub>O and CH<sub>4</sub> respectively (IPCC, 2001). Annual flux (Mg CO<sub>2</sub> equivalents ha<sup>-1</sup> yr<sup>-1</sup>) totaled 57.6 for corn field in Delaware.



**Figure 3. N<sub>2</sub>O emission rates during experiment period**



**Figure 4. CH<sub>4</sub> emission rates during experiment period**

**Table 2. Greenhouses gas emissions from literatures**

Location	Soil condition	Gas emission rate, mg m <sup>-2</sup> d <sup>-1</sup>		Reference
		N <sub>2</sub> O	CH <sub>4</sub>	
Alabama	Fresh PL in Bermuda grass field	1.73		Harper et al., 2000
Alabama	Urea in Bermuda grass field	1.30		Harper et al., 2000

Alabama	Composted PL in Bermuda grass field	0.86		Harper et al., 2000
Alabama	No fertilizer in Bermuda grass field	<0.43		Harper et al., 2000
Georgia	Field grazed by cattle	10.37		Walker et al., 2002
Finland	Peat soil	3.66	0.36	Nykanen et al., 1995
Netherlands	Drained peat soil	3.83~16.71	-0.08~0.03	Langeveld et al., 1997
This study		1.22	0.08	

## Conclusions

A study was conducted to evaluate the impact of different broiler litter treatment on greenhouse gas emission from core fields in Delaware. The following conclusions and observations were made.

- Neither litter treatment nor application rate had significant influence on CO<sub>2</sub> emission from the corn fields. The mean CO<sub>2</sub> emission rate was 15.4 g m<sup>-2</sup> d<sup>-1</sup>.
- No clear correlation between emission rate and litter type or litter application rate was found. The average emission rate of N<sub>2</sub>O and CH<sub>4</sub> were 1.22 and 0.08 mg m<sup>-2</sup> d<sup>-1</sup>.
- Annual flux greenhouse gas flux was (Mg CO<sub>2</sub> equivalents ha<sup>-1</sup> yr<sup>-1</sup>) 57.6 for corn field in Delaware.

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