ISSN 1682-8356
ansinet.com/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

OPEN ACCESS International Journal of Poultry Science

ISSN 1682-8356
DOI: 10.3923/ijps.2020.137.141

Research Article
Lignite Coal and Biochar Reduce Ammonia Emissions from Broiler Litter

Dana M. Miles, Ardeshir Adeli and John P. Brooks

Genetics and Sustainable Agriculture Research, United States Department of Agriculture, Agricultural Research Service, United States

Abstract

Background and Objective: Ammonia volatilizes from broiler litter in the rearing facility, during storage and upon land application. The gaseous release of NH_3 to the air decreases bird productivity, decreases fertilizer value of the litter and can impair natural resources including nearby land, water and air. A chamber, acid-trap study was conducted to determine the effect of lignite coal and biochar on NH_3 volatilization from broiler litter. **Materials and Methods:** Two sizes of biochar were investigated separately and two methods of application were utilized in a total of six experiments. Lignite or biochar (at 10, 20, or 30% by weight) were mixed into or broadcast over broiler litter in 1 L containers. Air exiting each chamber was trapped in acid and the amount of NH_3 captured was determined via titration intermittently for 21 days. **Results:** Method of application was not significant whether mixed or broadcast for 10 and 20% applications but both lignite and biochar reduced NH_3 losses. At the 30% application rate, broadcasting reduced emissions most. Overall NH_3 losses were reduced 47-91% by lignite, 18-42% by bedding size biochar and 29-58% by soil size biochar. **Conclusion:** Both materials can be added to broiler litter to reduce NH_3 emissions in broiler facilities, during storage and when applying litter as fertilizer. Integrators would need to assess the effects on bird digestion of biochar or lignite before broadcasting inside broiler facilities. Beyond the benefits of healthier birds and protecting the environment, the potential benefit is that broiler growers and farmers can confidently enjoy the labor and cost savings of broadcasting versus mixing these additives with broiler litter.

Key words: Ammonia, biochar, broiler, lignite coal, litter

Received: September 20, 2019 Accepted: October 24, 2019 Published: February 15, 2020

Citation: Dana M. Miles, Ardeshir Adeli and John P. Brooks, 2020. Lignite coal and biochar reduce ammonia emissions from broiler litter. Int. J. Poult. Sci., 19: 137-141.

Corresponding Author: Dana M. Miles, 810 Hwy 12 East, Mississippi State, MS, 39762, United States Tel: 662-320-7380 Fax: 662-320-7379

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture

INTRODUCTION

Broiler litter has historically been used as fertilizer on hay and forage crops near broiler facilities in the United States. In more recent years, its popularity as a replacement for commercial fertilizer in row crops has grown not only because of being economically attractive but for improved crop yields and soil health benefits. Adeli *et al.*[1] reported that rotating cotton and corn when applying broiler litter improved soil quality parameters and nutrient cycling. Another cotton study stated that "broiler litter is more effective in improving soil physical, chemical and biological components than conventional fertilizer"[2].

Along with the beneficial aspects of using broiler litter as a comprehensive row crop fertilizer comes potential negative impacts of NH_3 losses from litter. This may be especially true for no-till crops where leaving litter on the soil surface can decrease available N due to losses of NH_3[3]. In the southeastern United States, no-till cotton occupies approximately 57% of the total cotton acreage, a significant increase from previous years[4]. One report[5] provides that 40% of Mississippi Delta cotton land is no-till. And, in upland soils of the midsouth, a vast quantity of cotton is produced with cover crops under no-till[6,7]. Broiler litter can act as a mulch to reduce soil erosion while increasing soil organic matter and protecting soil moisture[8] but can increase nutrient concentrations and create imbalances. Further, ambient conditions influence NH_3 volatilization to the air which increases with increases in temperature, pH and moisture. Outside broiler facilities, NH_3 deposition can regionally affect land, water and air resources contributing respectively to less ecosystem diversity, nutrient enrichment leading to algal blooms and atmospheric haze. Outside impacts of NH_3 emissions are not the only concern. Controlling NH_3 emissions from litter is also important within broiler facilities to produce healthier birds and maintain livability, making a solution important to both row crop agriculture, broiler growers and environmental protection.

In addition to mitigating environmental impacts and helping row crop farmers and broiler producers, our agricultural research goals include identifying and synergistically using byproducts for greater sustainability. Lignite coal and biochar were used in this study as additives to broiler litter as a first step in determining effects on NH_3 losses. Lignite, also called brown coal, is the lowest rank of coal based on low heating value and is soft and dusty compared to much older anthracite[9]. Within the classification of lignite, properties and heating values also vary such that the lowest ranked (usually the uppermost layer) lignite does not enter the power plant and it is piled onsite. This material is cheaply available for alternative uses. There are two major lignite deposits in the United States; one is located in North Dakota, South Dakota and Montana[9]. The other larger deposit runs through Texas, Louisiana, Arkansas, Tennessee, Mississippi and Alabama[9]. Lignite production for power was over 67 million short tons in 2017, comprising 8.74% of the U.S. coal production[10]. The average sales price of lignite coal was $19.51 per short ton in 2017[10].

Unlike lignite coal, biochar is produced by burning biomass in a low or no oxygen environment; it is a carbon-rich porous, black material that has important potential benefits for soils and plant growth in addition to storing carbon in a stable form for hundreds of years[11]. When used with soils, biochar contributes to climate change mitigation by storing stable carbon but the amount of spare and economical biomass that can be used for producing biochar places limits on its production[11]. The interest in the potential use of biochar has continued to escalate according to a review by Clough *et al.*[12]. Various aspects of biochar uses were reported in more than 442 manuscripts between 2011 and 2013[12]. Many reports show agronomic benefits and carbon sequestration potential but lack demonstration of long-term impacts of biochar and are limited by the specificity of the soil/biochar combination, the origination of the biochar feedstock and biochar production processes[12]. Regarding use in poultry farming, Gerlach and Schmidt[13] report benefits of reduced NH_3 concentrations in coops, regulation of litter moisture, lower foot pad dermatitis, with no adverse effects on digestive health.

The current literature using lignite to reduce N losses is scant and has been published for cattle feedlot manure. Chen *et al.*[14] investigated application of lignite as a cost-effective method for mitigating NH_3 loss from intensive cattle feedlots finding approximately 66% reduction in NH_3 loss from the pen. Kagimbo *et al.*[15] studied the effectiveness of lignite and biochar in reducing N losses from cattle feedlot manure in drum tests. They reported that biochar reduced emissions of NH_3 by 38% and lignite reduced emissions by 72%. From the literature, Chen *et al.*[14] surmised that reducing emissions from local hot spots such as feedlots will achieve local environmental benefits, which should equally apply to broiler houses or row crops using manure as fertilizer. The only report found for lignite and biochar in conjunction with broiler litter N losses was an abstract that will be presented this fall in October of 2019 at the 7th International Symposium on Soil Organic Matter in Hilton Adelaide, South Australia. Thus, the current study is at the forefront of research in this subject area.

The objective of the study was to determine the efficacy of biochar and lignite coal in reducing NH_3 volatilization from broiler litter, to determine the best rate of application and to determine the most effective method of application whether broadcast over the surface or mixed into broiler litter. These goals were met as described below.

MATERIALS AND METHODS

To determine the efficacy of biochar and lignite in reducing NH_3 losses from broiler litter, a completely randomized design was used to compare the two materials at three rates of application with three replications. In each of two sets of three complete experiments, two sizes of biochar were separately compared to lignite. In one of those sets, two methods of application (broadcasting on top of the litter vs. mixing into the litter) were also compared. Three experiments compared lignite and bedding size biochar (2-6 mm); three experiments compared lignite and soil size biochar (0-2 mm). Tests for application method were completed in the latter three.

The tests were carried out in a chamber, acid-trap system, which was described previously[16]. Briefly, four manifolds provided water-scrubbed air to 1 L containers (twelve per manifold). The air flow rate was approximately 110 mL min^{-1}. Broiler litter (100 g) was weighed into each container followed by broadcasting or mixing in lignite coal or biochar at 10, 20, or 30% by weight. A total of six experiments were completed where the air passed through the containers exited into a series of two 30 mL flasks containing a boric acid solution. Ammonia was captured in the solution and quantified by titration with HCl every 24 h for 7 days and then intermittently for a total duration of 21 days. The cumulative emissions were calculated for each treatment and reported as NH_3 (mg of N). Lignite was obtained from a local power plant (Red Hills Mine, Ackerman, MS) and was screened with a no.10 sieve to 2 mm or less for all experiments. Biochar was obtained from a commercial supplier (Black Diamond Charwood, Newtown, CT), with a nominal "bedding size" (2-6 mm) given by the manufacturer, suggesting this size would be appropriate inside broiler rearing facilities for maintaining lower levels of noxious gases. Similarly, the "soil size" designation was suggested for cropping system applications. Black Diamond patented their production process in about 2013 using European hardwoods or pine as the original biomass stock for producing the biochar. This study was conducted with the first samples arriving in the U.S. from the Baltic region facility.

Broiler litter was obtained from a commercial broiler house in Mississippi where the original bedding was pine shavings. The litter had been reused for more than 30 flocks with decaking and windrowing between flocks. For the 6 experiments, litter was collected in the non-brood half of the house, approximately mid-way from the fan end and away from feeders and waterers which are known to have variable characteristics[17]. Usually on the morning of starting an experiment, eight to ten samples were taken from the house to fill an 18 L container. At the lab, the litter was thoroughly mixed in a large tub before it was weighed into the chamber, acid-trap containers. Moisture content (loss in weight) and pH (ratio material:DI water 1:5) was determined for all materials at the beginning of each experiment. The broiler litter was also analyzed for N and C via combustion (Max CN analyzer, Elementar Americas, Inc., Mt. Laurel, NJ, U.S.).

The data were statistically analyzed using the mixed procedures of SAS[18] via paired t-tests. Significant differences were declared at $p \leq 0.05$.

RESULTS AND DISCUSSION

The NH_3 emission results for broiler litter alone and with the lignite and biochar treatments are given in Fig. 1 and 2.

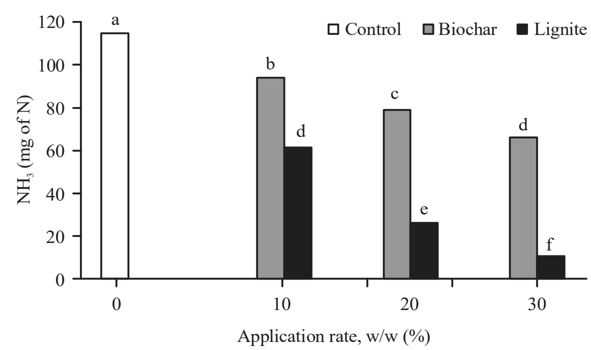

Fig. 1: Ammonia emissions from broiler litter only (Control) and broiler litter with bedding size biochar (2-6 mm) or lignite coal (0-2 mm) broadcast over the surface at 10, 20 or 30% by weight

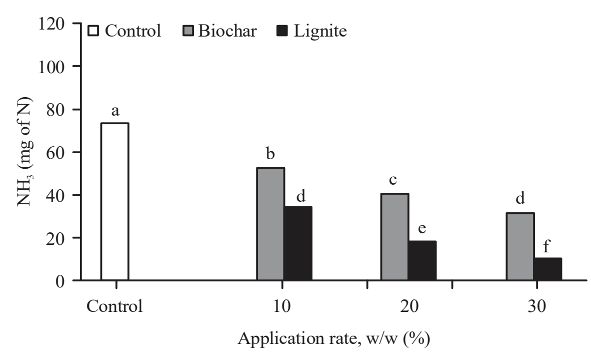

Fig. 2: Ammonia emissions from broiler litter only (Control) and broiler litter with soil size biochar (0-2 mm) or lignite coal (0-2 mm) broadcast over the surface at 10, 20 or 30% by weight

The characteristics of the materials are given here. The average N and C content of the broiler litter at the beginning of the experiments was 2.96% N and 27.51% C. These values are comparable those in a recent report quantifying more than 1000 litter samples from U.S. broiler houses[17]. In the center of houses at chick placement for that report, N content was 2.47% and C was 28.81%, while values increased to 2.81% N and 29.09% C by mid-flock[17]. And, at market age, litter in the center of the houses contained 2.45% N and 26.93% C on average. Further characterization of the materials in the current study indicated that the original litter moisture content was approximately 23-25% with an average pH of 7.9. Compared to the results of Miles *et al.*[17], center house litter moisture was 21.9-33.8% with pH ranging from 8.04-8.39. Biochar moisture content was about 5% for both sizes. However, the pH of the 0-2mm biochar ranged from 8.2-8.5 but the pH of the 2-6mm biochar ranged from 5.9-8.4. Lignite moisture content was approximately 14% with a pH of 5.7. Properties reported for the lignite used in a previous study by Chen *et al.*[14] included pH = 3.69, a cation exchange capacity of 96.75 cmol(+) kg^{-1}, a labile carbon content of 20.1% and a water content of 65%. Comparatively that lignite was much wetter and acidic than that used in the current study. Kagimbo *et al.*[15] stated that the initial characteristics of the materials (fresh manure, lignite and biochar) were determined but those values were not reported.

Investigating the method of application, whether mixing the additive with the broiler litter or broadcasting it over the surface of the litter, indicated that at the 10 or 20% application rates, method was not significant (p = 0.98 and 0.58, respectively). However, the method appeared significant at the 30% application rate (p = 0.0024) and broadcasting yielded lower NH_3 emissions. Thus, only the results for broadcasting lignite or biochar over broiler litter are given in Fig. 1 and 2.

The results from evaluating the broiler litter NH_3 volatilization when using bedding size biochar and lignite are featured in Fig. 1. Broiler litter alone emitted approximately 115 mg NH_3. Compared to that the bedding size biochar emitted 18% less at the lowest application rate, 31% less at the middle rate and 42% less at the highest application rate, whereas lignite decreased NH_3 emissions by 47, 77 and 91%, when applied at the lowest, middle and highest application rates, respectively. Except for the lowest lignite rate and the highest biochar rate appearing similar to each other, each treatment rate was significantly different from the others in the amount of NH_3 reduced.

The soil size biochar and lignite experiments gave analogous results (Fig. 2). For those experiments, the broiler litter emitted approximately 74 mg NH_3. Again, each treatment decreased NH_3 emissions from the broiler litter. The soil size biochar at 10, 20 and 30% w/w decreased NH_3 by 29, 44 and 58%, respectively. Those reductions where lignite was broadcast over the litter were 53, 75 and 86%, respectively. Also, each treatment was significantly different from the other treatments except that the 30% w/w soil size biochar and 10% w/w lignite treatments did not appear different.

Based on the effectiveness reported in the literature using lignite and/or biochar to control NH_3 losses of manures[13-15], the results presented here are reasonable and expected. These additives could be especially beneficial in no-till cropping systems by reducing NH_3 volatilization from the soil surface and increasing available N[19]. Chen *et al.*[14] reported that lignite is acidic, has a high humic acid content, high cation exchange capacity and contains up to 20% labile carbon, all of which may suppress NH_3 volatilization from manure. They reported reduced NH_3 losses of approximately 66% from feedlot pens. Converting their area based application rate to our system, their rate would be equivalent to 42% by weight, or 12% higher than our highest rate. In the cattle feedlot manure drum tests by Kagimbo *et al.*[15], the rates of biochar and lignite were equivalent to 15% in our system. In their findings of 38% and 72% reduction in NH_3 losses using biochar and lignite, respectively, they experienced a greater reduction using lignite as our results also indicated. Gerlach and Schmidt's article[13] on biochar in poultry suggests applying 5-10% by volume onto litter. They also discuss use of biochar in feed as beneficial to animals but there are no long term studies and there are only two references cited in that article. Global poultry production would require extensive studies using lignite or biochar addition to litter to prove its safety and benefits to broilers.

CONCLUSION

Both lignite coal and biochar reduced NH_3 emissions from broiler litter at all application rates. Higher application rates yielded higher reduction of emissions. Overall NH_3 losses were reduced 47-91% by lignite, 18-42% by bedding size biochar and 29-58% by soil size biochar. Broadcasting the additives over the litter surface was more effective at reducing emissions than mixing the additive with the litter. This is the most important finding of the study indicating a potential labor and cost savings for application of the materials in the broiler house or in row crops. These specific applications need further study, however. The literature states that biochar characteristics vary with type of original biomass as well as the production process. Biochar sources with known and reliable characteristics will be important to their continued use in agriculture. Further, long term studies of biochar and lignite in row crops are needed. For use with broiler litter in houses, how consumption of the additives affect bird health must be known, in addition to economic benefits of NH_3 reduction inside and outside houses.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Rhonda Cornelius for setting up and executing the experiments, Mary Hardy for chemical analysis of the materials and Nicole Barksdale for obtaining the lignite and assisting in the laboratory.

REFERENCES

1. Adeli, A., H. Tewolde, K.R. Sistani and D.E. Rowe, 2009. Broiler litter fertilization and cropping system impacts on soil properties. Agron. J., 110: 1304-1310.
2. Adeli, A., H. Tewolde, K. Sistani and D. Rowe, 2010. Comparison of broiler litter and commercial fertilizer at equivalent n rates on soil properties. Commun. Soil Sci. Plant Anal., 41: 2432-2447.
3. Eghball, B. and J.F. Power, 1999. Phosphorus- and nitrogen-based manure and compost applications corn production and soil phosphorus. Soil Sci. Soc. Am. J., 63: 895-901.
4. National Cotton Council of America, 2003. Conservation tillage study. http://www.cotton.org/tech/biotech/contill-study.cfm.
5. Martin, S.W. and F. Cooke, 2004. Cotton tillage characteristics in the Mississippi delta. Proceedings of the Beltwide Cotton Conference, January 5-9, 2004. Mississippi State University, pp: 668-671.
6. Meyer, L.D., S.M. Dabney, C.E. Murphree, W.C. Harmon and E.H. Grissinger, 1999. Crop production systems to control erosion and reduce runoff from upland silty soils. Trans. Am. Soc. Agric. Eng., 42: 1645-1652.
7. Boquet, D.J., R.L. Hutchinson and G.A. Breitenbeck, 2004. Long term tillage, cover crop and nitrogen rate effects on cotton: Yield and fiber properties. Agron. J., 96: 1436-1442.
8. Nyakatawa, E.Z., K.C. Reddy and K.R Sistani, 2001. Tillage, cover cropping and poultry litter effects on selected soil chemical properties. Soil Till. Res., 58: 69-79.
9. Schweinfurth, S.P., 2003. Coal-A complex natural resource: An overview of factors affecting coal quality and use in the United states with a contribution on coal quality and public health. U.S. Geological Survey Circular. https://pubs.usgs.gov/circ/c1143/c1143.pdf.
10. U.S. Energy Information Administration, 2018. Annual coal report 2017. https://www.eia.gov/coal/annual/archive/05842017.pdf
11. Shackley, S., G. Ruysschaert, K. Zwart and B. Glaser, 2016. Biochar in European Soils and Agriculture. 1st Edn., Taylor and Francis, UK., Pages: 302.
12. Clough, T.J., L.M. Condron, C. Kammann and C. Muller, 2013. A review of biochar and soil nitrogen dynamics. Agronomy, 3: 275-293.
13. Gerlach, H. and H.P. Schmidt, 2014. Biochar in poultry farming. Biochar J.
14. Chen, D., J. Sun, M. Bai, K.B. Dassanayake, O.T. Denmead and J. Hill, 2015. A new cost-effective method to mitigate ammonia loss from intensive cattle feedlots: Application of lignite. Sci. Rep. 10.1038/srep16689
15. Kagimbo, F.M., A. Weatherley and H. Suter, 2012. The effectiveness of lignite coal and biochar in reducing nitrogen (N) losses from cattle feedlot manure. Conference proceedings of the third RUFORUM biennial meeting, September 24-28, 2012. Entebbe, Uganda 671-676.
16. Miles, D.M., P.R. Owens, P.A. Moore and D.E. Rowe, 2008. Instrumentation for evaluating differences in ammonia volatilization from broiler litter and cake. J. Applied Poult. Res., 17: 340-347.
17. Miles, D.M., D.E. Rowe and J.P. Brooks, 2017. Implications of intensive spatial sampling of broiler litter: Characteristics and gaseous emissions. Int. J. Poult. Sci., 16: 60-68.
18. SAS., 2003. SAS System for Microsoft Windows, Version 9.1 (TSM1). SAS Institute Inc., Cary, NC., USA.
19. Adelia, A., M.W. Shankle, H. Tewolde, K.R. Sistani and D.E. Rowe, 2008. Nutrient dynamics from broiler litter applied to no-till cotton in an upland soil. Agron. J., 100: 564-570.