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Litter Acidification for Controlling Ammonia Levels in Poultry Houses – A Review

Abstract

Ammonia concentrations tend to be high in poultry houses (e.g., broiler and layer) due to high moisture levels in fresh manure (e.g., 75%). The poultry house ventilation rate will be reduced in winter to keep the birds warm, and thus NH_3 levels could be higher than the threshold value of 25 ppm (18 mg m^{-3}) recommended by the National Chicken Council and the United Egg Producers. Therefore, it is critical to control NH_3 levels and emissions in poultry houses. Litter additives such as poultry litter treatment (PLT), granular Al+ Clear (aluminum sulfate or alum), and Klasp™ (ferric sulfate) are common commercially available products that have shown significant mitigation efficiencies for NH_3. The results of field studies showed that the broiler house with 100 lbs. per 1000 ft^2 application of PLT had 50% lower NH_3 concentration than the house with 50 lbs. per 1000 ft^2, which was similar to the PLT mitigation efficiency on cage-free layer litter that NH_3 generations were reduced by 28%, 52%, and 79%, respectively, for 60, 120, and 180 lbs. per 1000 ft^2 application rates. Research on alum for NH_3 mitigation show that NH_3 fluxes from alum-treated litter were 70% lower than untreated litter.

Keywords. Air pollutants; emissions mitigation; waste management; litter additives.

Introduction

Ammonia (NH_3) concentrations can be high in poultry houses (e.g., broiler and layer) due to high moisture levels in fresh chicken manure (e.g., 75%) that favors and expedites the conversion of nitrogen in uric acid ($C_5H_4N_4O_3$) to NH_3 gas (Chai et al., 2010, 2018; Ritz et al., 2004; Wheeler et al., 2006). High levels of NH_3 may lead to health and welfare concerns for both animals and their caretakers if mitigation measures are not taken. In winter or during cold weather, NH_3 concentration levels in poultry houses could be higher than recommended exposure limits of 25 ppm (18 mg m^{-3}) for 8-hr average to protect animals and their caretakers (NCC, 2017; NIOSH, 2016; UEP, 2017). Ammonia emissions from poultry houses affect atmospheric air quality through the formation of fine particulate matter ($PM_{2.5}$), acidification of terrestrial ecosystems, and influence eutrophication of terrestrial and surface waters through dry and wet deposition (Chai and Zhao, 2022; Li et al., 2013). Furthermore, NH_3 emission constitutes a considerable economic loss of nitrogen from agricultural production systems (Ritz et al., 2005, 2009). Therefore, mitigating NH_3 generation is critical to protecting the health and well-being of the chickens and their caretakers, and to enhancing the environmental stewardship on broiler and layer farms (Ritz et al., 2004; Wang-Li et al., 2013; Ni et al., 2017a, 2017b).

Reviewing the State of the Science

Studies in broiler chicken houses

In poultry houses, the primary source of NH_3 is uric acid. The decomposition of uric acid is catalyzed by the enzyme uricase and influenced by the manure pH. Ammonia generation can be inhibited by lowering manure pH to decrease the conversion of NH_4^+ to NH_3 (Li et al., 2008, 2013). Litter additives or litter treatments that acidify the manure have shown significant commercial value within the poultry industry for many years. Litter additives such as sodium bisulfate (PLT), granular alum (Al+ Clear), and ferric sulfate (Klasp), are common products that have shown significant reduction efficiencies for NH_3 mitigation. Each of these products align their efficiencies with a reduction of manure pH.

Research on alum for NH_3 mitigation show that NH_3 fluxes from the alum-treated litter were 70% lower than untreated litter (Moore et al. 2000, 2004, 2005, 2007). Moore (2012) suggested that alum should be applied to poultry litter at a rate equivalent to 5-10% by weight (alum/manure). For typical broiler operations (six-week cycle), the recommendation was to use 0.1 to 0.2 lbs. alum per bird or 1-2 tons of alum per house (500 ft* 40 ft; Figure 1). The reduction in NH_3 generation is due to the acidic environment generated by alum in the litter. During this process, the reduction in litter pH allows for the conversion of ammonia to ammonium.

Figure 1. Spreading of litter additive (liquid alum) in the broiler house (photo credit: Forbes Walker, University of Tennessee Extension).

Moore (2012) also suggested applying acidifiers or litter additives between broiler flocks to further suppress NH_3 volatilization. Walker and Burns (2015) suggested the rate of 100 to 200 lbs. alum per 1,000 ft^2 for treating broiler litter and observed that alum can control NH_3 for several weeks (Figure 2). Dry alum can be applied with different spreaders such as de-caking machines, fertilizer spreaders, manure spreaders or drop spreaders. Liquid applications are typically completed by certified custom applicators. Due to the inherent danger of handling acids, applicators should use personal protective equipment (PPE) such as goggles, a dust mask, and other protective clothing to minimize exposure to the material being applied.

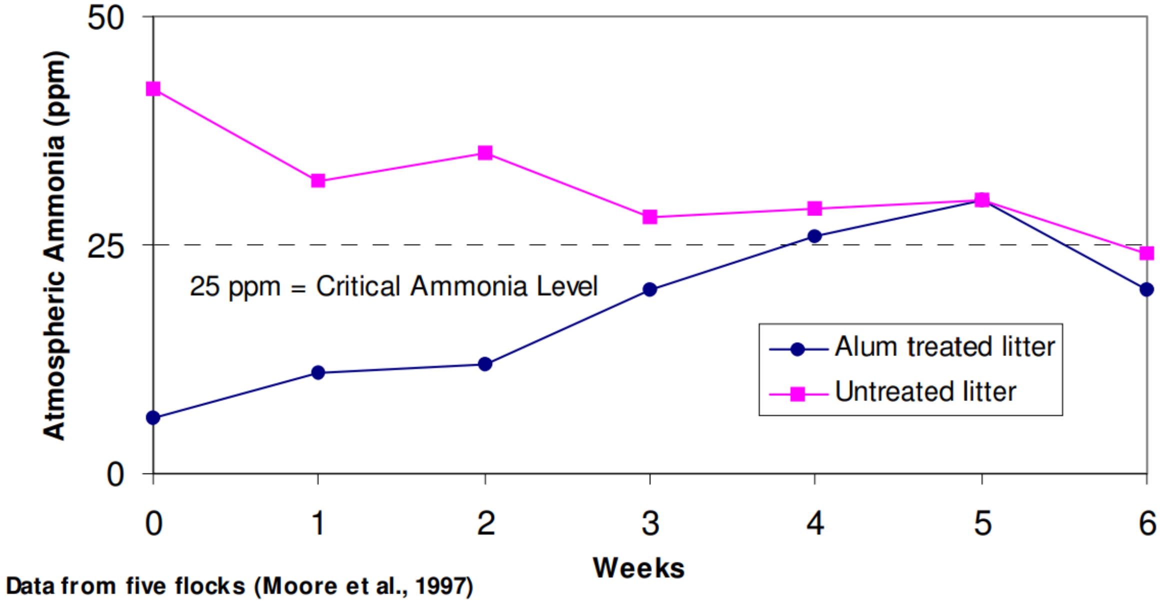

Figure 2. Effect of alum on NH_3 over time (Walker and Burns, 2015).

Sodium bisulfate (PLT) has been used for many years as a poultry litter amendment to control ammonia concentrations in poultry houses. Fairchild et al. (2006) tested sodium bisulfate in six commercial broiler houses during cold weather months at the rates of 50, 100, and 150 lbs. per 1000 ft^2. The results showed that the house with 100 lbs. per 1000 ft^2 application had 50% lower NH_3 concentration than the house with 50 lbs. per 1000 ft^2 (Figure 3). The study concluded that the duration of reduced ammonia production was positively correlated with the amount of sodium bisulfate applied to the house.

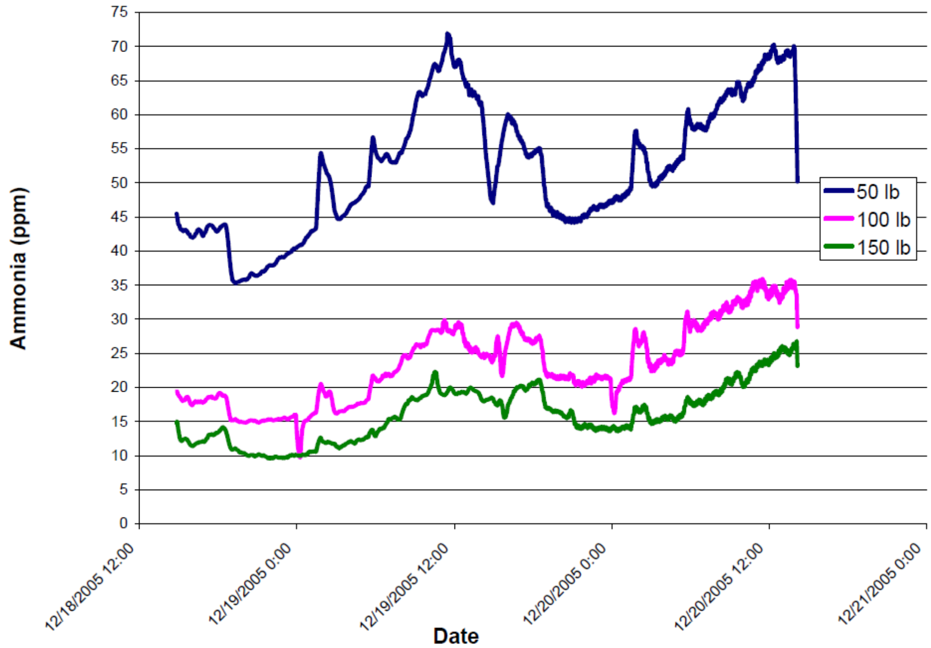

Figure 3. Effect of PLT in commercial broiler houses (Fairchild et al., 2006).

Li et al. (2013) tested the effect of sodium bisulfate within experimental dynamic chambers (six female broilers per chamber) and also found that the magnitude of NH_3 reduction increases with the application rate of sodium bisulfate. From 28 to 61 days of age for the broilers, a 75 lb/wk-1000 ft^2 application rate (i.e., applying 75 lbs. litter additive per week for each 1000 ft^2 floor) had up to 64.5% NH_3 reduction efficiency, higher than the reduction efficiency of 55% achieved by a 37.5 lb/wk-1000 ft^2 application rate (i.e., applying 37.5 lbs litter additive per week for each 1000 ft^2 floor).

Mitigating NH_3 generation from the litter of cage-free layers

Commercial litter additives/treatment (e.g., Al^+ clear, Klasp™, and PLT) are also effective in NH_3 reduction for layer manure. However, most previous studies were conducted in the lab because the majority of table egg production occurs within conventional cage systems that do not have bedded floors (Campbell et al., 2016). Li et al. (2008) conducted a systematic test within a laboratory setting utilizing containers of layer manure for mitigating NH_3 generation and found that granular Al^+Clear, Klasp™, and PLT showed no significant difference between them in the reduction of NH_3 over a

7-d period at the rate of application of 100 lb./1000 ft^2 or lower. When applied at 200 lb./1000 ft^2, Al+ Clear and Klasp™ showed greater NH_3 reduction than PLT. With the increase in the number of cage-free systems pledged by the US industry by 2025 (UEP, 2022), studies should continue to be focused on NH_3 mitigation from bedded floor systems. According to the current number of pledges, it would take more than 70% of the current US layer stock to convert to floor-reared systems to meet the cage-free (CF) demand by 2025.

Previous studies have demonstrated that daily mean NH_3 levels in CF hen houses, such as aviary housing (AH) systems, are considerably higher than in conventional cage (CC) and enriched colony (EC) housing systems (Figure 4), and they can exceed the recommended (required in some cases) NH_3 threshold concentration in wintertime (Zhao et al., 2015; Chai et al., 2017). The higher level of NH_3 in cage-free houses during winter or cold weather can also be caused by water condensation from ceilings that results in increased moisture in litter during winter (Chai et al., 2019).

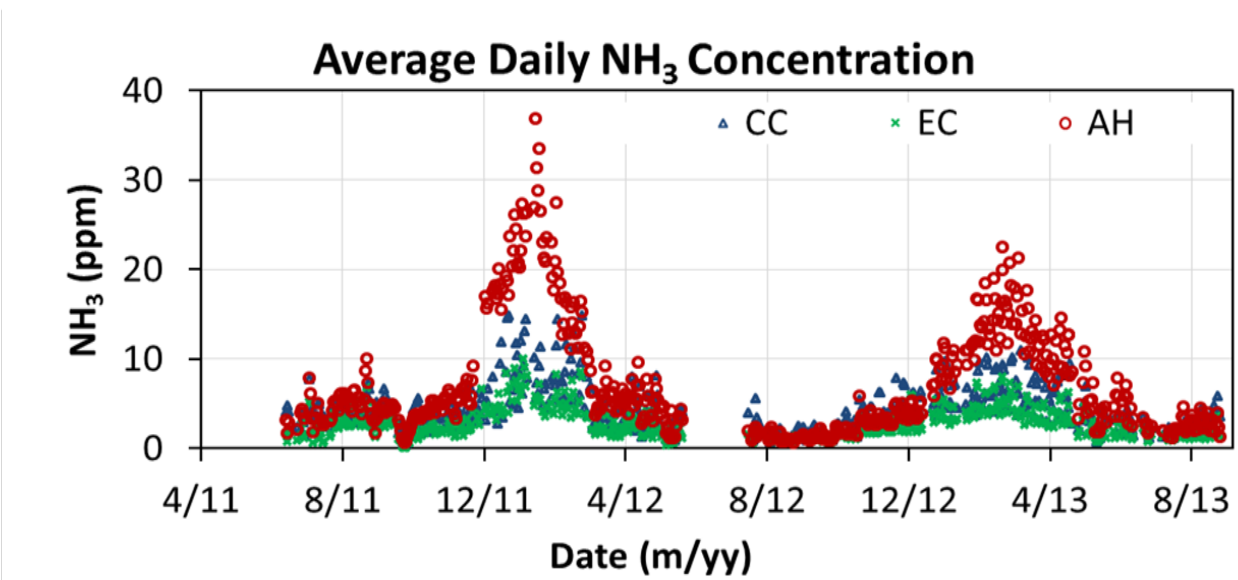

Figure 4. Daily mean NH_3 concentrations in a conventional cage (CC), enriched colony (EC), and aviary housing (AH) systems (Zhao et al., 2015).

Currently, very few studies have been conducted in commercial cage-free houses (Chai et al., 2019). Chai et al. (2018) tested three application rates of sodium bisulfate (PLT) (i.e., 60, 120, and 180 lb. per 1000 ft^2) in dynamic chambers (Figure 5 and Figure 6) on NH_3 emissions from litter samples collected from commercial cage-free houses. The results showed that NH_3 generation was reduced by 28%, 52%, and 79%, respectively, for 60, 120, and 180 lbs. per 1000 ft^2 application rates (Figure 7) and confirmed that higher usage rates of sodium bisulfate can reduce litter pH. Figure 7 shows the daily cumulative emissions of NH_3 from different experimental chambers. The experiment was carried out with four identical dynamic chambers, each measuring 34 inches long, 18 inches wide, and 26 inches high. One chamber served as the control (without litter additive), and the other three were used for the various treatments. The litter inside each chamber was tilled automatically with a rake driven by a stepper motor to mimic the daily activity of birds on the litter. Air temperature and relative humidity (RH) in all chambers were controlled to simulate CF house conditions (72^{o}F and 60% RH).

Figure 5. NH_3 mitigation test with dynamic emission chambers.

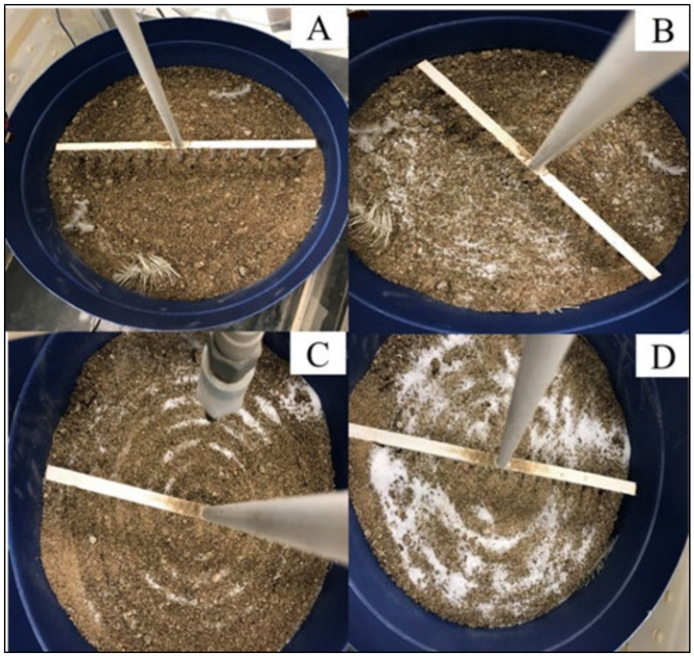

Figure 6. Topical application or absence of PLT on litter in control and treatment DECs: A = control (no LA), B = Low-LA, C = Med-LA, and D = High-LA with PLT application rates of 0, 0.3, 0.6, and 0.9 kg m-2 (0, 60, 120, and 180 lbs. per 1000 ft^2).

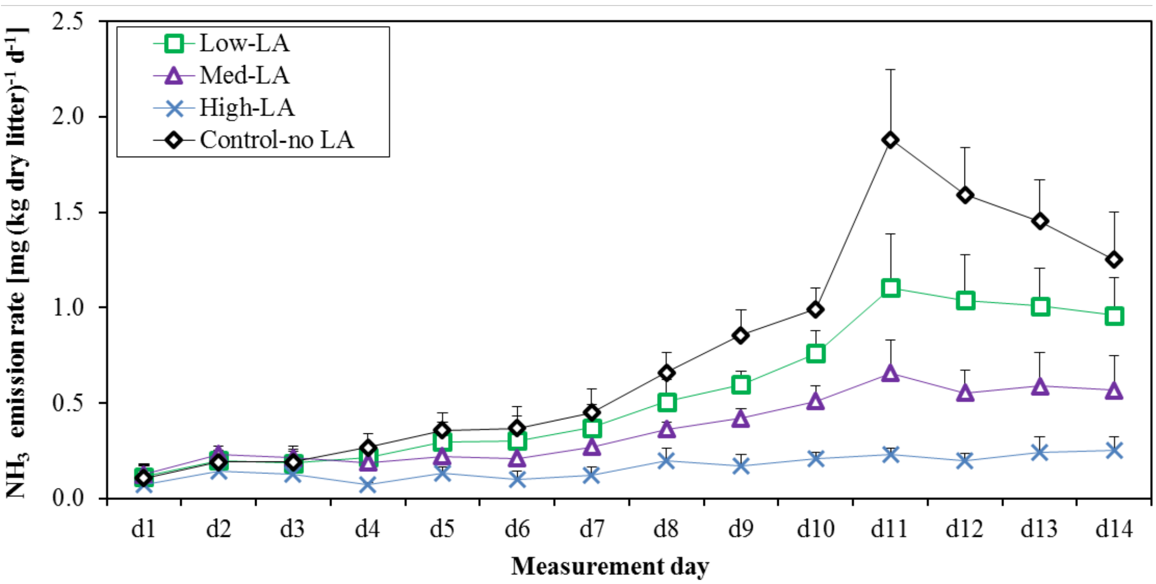

Figure 7. Daily NH_3 emission rates from treatment and control chambers (mean □SE, n = 4). Control-no LA represents no LA application, and Low-LA, Med-LA, and High-LA represent low, medium, and high application rates of 0, 0.3, 0.6, and 0.9 kg m-2 (0, 60, 120, and 180 lbs. per 1000 ft2), respectively.

Conclusions

Ammonia concentrations can be high in poultry houses (e.g., broiler and layer) due to the high moisture levels in the fresh chicken manure (e.g., 75%). In winter, poultry house NH_3 concentrations can be higher than the threshold values of 25 ppm (18 mg m^{-3}) recommended by the National Chicken Council and the United Egg Producers. Therefore, it is critical to control NH_3 concentrations to meet the bird and human welfare recommendations. Litter additives such as PLT, Al^+ Clear, and Klasp™ are common products that have shown impressive reduction efficiencies for NH_3 mitigation in commercial broiler housing. And yet, further NH_3 mitigation studies should be conducted in cage-free layer houses that also employ bedded flooring systems.

Literature Cited

Campbell, D.L., M.M. Makagon, J.C. Swanson, and J.M. Siegford. 2016. Litter use by laying hens in a commercial aviary: Dust bathing and piling. *Poultry Science* 95(1):164-175.

Chai, L., and Y. Zhao (eds). 2022. *Housing Environment and Farm Animals' Well-Being*. MPDI Books-Animals. ISBN 978-3-0365-4585-1. 212 pp. https://www.mdpi.com/books/pdfview/book/5695

Chai L., J.-Q. Ni, Y. Chen, C. A. Diehl, A. J. Heber and T.-T. Lim. 2010. Assessment of long-term gas sampling design at two commercial manure-belt layer barns. *Journal of Air and Waste Management Association* 60(6):702-710.

Chai, L., Y. Zhao, H. Xin, T. Wang, A. Atilgan, M. Soupir, and K. Liu. 2017. Reduction of particulate matter and ammonia by spraying acidic electrolyzed water onto litter of aviary hen houses: A lab-scale study. *Transactions of the ASABE* 60(2):497-506. https://doi.org/10.13031/trans.12081

Chai, L., H. Xin, Y. Wang, J. Oliveira, K. Wang, and Y. Zhao. 2019. Mitigating particulate matter emissions of a commercial cage-free aviary hen house. *Transactions of the ASABE* 62(4):877-886.

Chai, L., H. Xin, Y. Zhao, T. Wang, M. Soupir, and K. Liu. 2018. Mitigating ammonia and PM generations of cage-free henhouse litter with solid additive and liquid spray. *Transactions of the ASABE* 61(1):287-294.

Fairchild, B.D., J.W. Worley, M. Czarick, and C.W. Ritz. 2006. Effects of heavy application of litter amendment on broiler house ammonia concentration, paper 064187. *2006 ASAE Annual Meeting*. American Society of Agricultural and Biological Engineers.

Li, H., C. Lin, S. Collier, W. Brown, and S. White-Hansen. 2013. Assessment of frequent litter amendment application on ammonia emission from broilers operations. *Journal of Air and Waste Management Association* 63(4):442-452.

Li, H., H. Xin, Y. Liang, and R.T. Burns. 2008. Reduction of ammonia emissions from stored laying hen manure through topical application of zeolite, Al+ Clear, Ferix-3, or poultry litter treatment. *Journal of Applied Poultry Research* 17(4):421-431. https://doi.org/10.3382/japr.2007-00076

Li, Q.F., L. Wang-Li, K. Wang, L. Chai, E.L. Cortus, I. Kilic, B.W. Bogan, J.Q. Ni, and A.J. Heber, A.J. 2013. The national air emissions monitoring study's southeast layer site: Part II. Particulate matter. *Transactions of the ASABE* 56(3):1173-1184.

Moore, P.A., S. Watkins, D.C. Carmen, and P.B. DeLaune. 2004. Treating poultry litter with alum. *University of Arkansas Cooperative Extension Fact Sheet (FSA8003-PD-1 - 04N).*

Moore, P.A., and D.R. Edwards. 2005. Long-term effects of poultry litter, alum-treated litter, and ammonium nitrate on aluminum availability in soils. *Journal of Environmental Quality* 34:21 04-2111.

Moore, P.A., and D.R. Edwards. 2007. Long-term effects of poultry litter, alum-treated litter, and ammonium nitrate on phosphorus availability in soils. *Journal of Environmental Quality* 36:(1):63-174.

Moore, P.A., T. Daniel, and D.R. Edwards. 2000. Reducing phosphorus runoff and inhibiting ammonia loss from poultry manure with aluminum sulfate. J*ournal of Environmental Quality* 29(1):37-49.

Moore, P. 2012. *Treating Poultry Litter with Aluminum Sulfate (Alum)*. USDA ARS. https://www.ars.usda.gov/research/publications/publication/?seqNo115=283454

National Chicken Council. 2017. *Welfare Guidelines and Audit Checklist for Broilers*. https://www.nationalchickencouncil.org/wp-content/uploads/2017/07/NCC-Welfare-Guidelines-Broilers.pdf

Ni, J.-Q, S. Liu, C.A. Diehl, T.-T. Lim, B.W. Bogan, L. Chen, L. Chai, K. Wang, and A.J. Heber. 2017a. Emission baselines and characteristics of ammonia, hydrogen sulfide, carbon dioxide, and particulate matter from two manure-belt layer hen houses. *Atmospheric Environment* 156:113-124.

Ni, J.-Q, S. Liu, C.A. Diehl, T.-T. Lim, B.W. Bogan, L. Chen, L. Chai, K. Wang, and A.J. Heber. 2017b. Emission factors and characteristics of ammonia, hydrogen sulfide, carbon dioxide, and particulate matter at two high-rise layer hen houses. *Atmospheric Environment* 154:260-273.

NIOSH. 2016. Pocket guide to chemical hazards (NPG). Washington, DC: *National Institute for Occupational Safety and Health*. https://www.cdc.gov/niosh/npg/

Oliveira, J., H. Xin, L. Chai, S. Millman. 2019. Effects of managing litter floor access and including experienced hens in aviary housing: floor eggs, litter condition, air quality, and hen welfare. *Poultry Science* 98(4):1664–1677.

Ritz, C.W., and W.C. Merka. 2009. Maximizing poultry manure use through nutrient management planning. B-1245. *University of Georgia Cooperative Extension.* https://hdl.handle.net/10724/12463

Ritz, C.W., B.D. Fairchild, and M.P. Lacy. 2004. Implications of ammonia production and emissions from commercial poultry facilities: A review. *Journal of Applied Poultry Research* 13(4):684-692.

Ritz, C.W., P.F. Vendrell, and A. Tasistro. 2005. Poultry litter sampling. *University of Georgia Cooperative Extension Service B-1270*.

United Egg Producers (UEP). 2022. Retailers, Restaurants Continue Cage-free Commitments. https://unitedegg.com/retailers-restaurants-continue-cage-free-commitments/

United Egg Producers (UEP). 2017. *Animal Husbandry Guidelines for U.S. Egg-Laying Flocks*. https://uepcertified.com/wp-content/uploads/2021/08/CF-UEP-Guidelines_17-3.pdf

Wang-Li, L., Q.-F. Li, L. Chai, E. L. Cortus, K. Wang, I. Kilic, B. W. Bogan, J.-Q. Ni, and A.J. Heber. 2013. The National Air Emission Monitoring Study's Southeast Layer Site: Part III. Ammonia concentrations and emissions. *Transactions of the ASABE* 56(3):1185-1197.

Walker, F., and R. Burns. 2015. Treating broiler litter with alum. https://extension.tennessee.edu/publications/Documents/Info%20318.pdf

Wheeler, E.F., K.D. Casey, R.S. Gates, H. Xin, J.L. Zajaczkowski, P.A. Topper, Y. Liang, and A.J. Pescatore. 2006. Ammonia emissions from twelve US broiler chicken houses. *Transactions of the ASABE* 49(5):1495-1512.

Zhao, Y., T.A. Shepherd, H. Li, and H. Xin. 2015. Environmental assessment of three egg production systems: Part I. Monitoring system and indoor air quality. *Poultry Science* 94(3):518-533.