Evaluation of surface-applied char on the reduction of ammonia volatilization from broiler litter

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Primary Audience: Broiler Producers, Production Managers, Nutritionists, Researchers

SUMMARY

Biomasses such as peanut hulls or tree clippings have the potential for use in the production of chars, which can in turn be used as tools for environmental improvements. The purpose of this study was to evaluate the effectiveness of chars on reducing NH_3 volatilization from poultry litter when used as a surface-applied treatment. The chars used were produced from 3 biomasses: peanut hulls, pine chips, and coconut husks. Peanut hull char (pH 9.2) was produced by pyrolyzing peanut hulls at 400°C for 30 min. The pine chip and coconut husk chars were acidified with sulfuric acid at a final concentration of 53% and had a pH of 2.0. Application rates were 0, 0.24, 0.37 + 0.37, and 0.73 kg/m^2 to the floor of pens containing broilers at a commercial density (0.07 m^2/bird). The addition of peanut hull char did not reduce NH_3 concentrations in the air compared with untreated pine shavings bedding material. However, the use of acidified chars resulted in significant linear reductions in NH_3 concentrations. The reduction in NH_3 by the acidified chars was likely due to a combination of litter pH reduction and NH_3 immobilization by the H_2SO_4 on the char. Bird performance was not adversely affected by any of the char treatments.

Key words: ammonia, broiler, char, litter amendment

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DESCRIPTION OF PROBLEM

The generation of NH_3 in animal and poultry production facilities is inherent with manure deposition. Controlling NH_3 generation is the challenge of all who aim to improve animal performance in confinement facilities. For the poultry industry, litter quality exerts a significant influence on broiler performance as a result of NH_3 volatilization [1]. A great deal of interest is currently being expressed in NH_3 and particulate matter emissions from animal and poultry operations [2]. Although considerable research is directed at defining the problem and scope of emissions, it is equally important that viable control alternatives to reduce NH_3 generation be examined. Available technologies that can reduce NH_3 emissions from poultry houses, such as scrubbers, are not practical or economically feasible for commercial poultry operations. Ventilation within facilities will reduce the effects of NH_3 inside the chicken house, but the expelled air may contain dust and NH_3 that, together with odor emissions, can lead to adverse effects on

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the environment, neighbor complaints, and legal action against the industry. This research was conducted with the primary interest in NH_3 control in broiler production in the context of overall environmental protection.

Broilers excrete excess feed N as uric acid, which is converted into NH_3 by a series of biochemical reactions that are affected by the moisture, temperature, and pH of the litter. The optimal litter pH for the growth of bacteria involved in the conversion of uric acid to NH_3 is approximately 8.5 [3–5]. Moreover, at pH >8.0, NH_3 is present in the gaseous phase. Typically, the pH of poultry litter is in the 7.5 to 8.5 range. Thus, reducing litter pH through the use of acidifying litter amendments is one way to suppress NH_3 release [6, 7].

High NH_3 concentrations in the air inside broiler houses have an immediate detrimental effect on the health of both birds and workers. Maintaining a low concentration of NH_3 is one of the most important factors influencing chick performance during brooding. Broilers exposed continuously to 50 ppm of NH_3 during brooding (2 wk) had an 8% reduction in BW by the seventh week of age [8]. Bird performance is reduced when aerial NH_3 levels exceed 25 ppm [9–13], as demonstrated by slow growth rates and decreased feed conversion efficiency. High levels of NH_3 are linked to increased susceptibility to respiratory infections [14–16] and have been identified as a major concern in animal welfare audits [17]. Reducing the NH_3 concentration within the house can be the difference between a below-average and a high-performing flock.

The impact of NH_3 on poultry worker health is also of concern. Well recognized as a human toxin, the current Occupational Safety and Health Administration permissible exposure limit for NH_3 is a time-weighted average of 50 ppm (odor threshold 5 to 50 ppm), although the American Conference of Industrial Hygienists and the National Institute for Occupational Safety and Health recommend a lower time-weighted average of 25 ppm [18]. In Iowa, Donham et al. [19] found that exposure to a concentration of 12 ppm of NH_3 during a work shift was associated with significant pulmonary function decrements in farm workers.

Because litter management strategies increasingly reuse the litter for multiple flocks, NH_3 generation has also increased, leading to potentially high levels of NH_3 in poultry houses and greater NH_3 atmospheric emissions. This dual challenge for the industry indicates a continued need for products and technologies that assist in the management of NH_3.

Current Litter Amendment Strategies

Control of NH_3 levels in chicken houses has been accomplished largely through ventilation. However, seasonal variation in NH_3 concentrations can occur as growers reduce ventilation rates during the winter months to cut heating expenses. Litter amendments have been developed to help control NH_3 release from litter and are being used extensively by the poultry industry. These amendments are applied before chick arrival and are a critical part of maintaining proper air quality during the brooding period, when ventilation rates are at their lowest.

Strategies for the use of litter amendment products depend on the management objectives for individual growers and poultry companies alike. Determining litter management priorities will help determine the best product for a given use. Malone [20] described the importance of identifying bird management scenarios when selecting litter amendment products for use in poultry houses. Litter accumulation and moisture, bird type, brooding temperature program, and disease challenge are among the variables that potentially influence amendment selection, efficacy, and return on investment.

Litter amendment products fall into 3 categories: acidifying agents that inhibit NH_3 volatilization through litter pH reduction; clay-based products that absorb odors and reduce NH_3 release by absorbing moisture; and inhibitors of microbial growth, uricase, and urease production, and the subsequent breakdown of uric acid.

Several acidifying agents have been developed and studied for effectiveness in reducing NH_3 volatilization. These products function similarly by protonating volatile NH_3 into nonvolatile ammonium (NH_4^+) [21, 22]. Clay-based products, some containing zeolite, have the ability to absorb moisture and odors. By drying poultry litter, clay-based products can reduce NH_3 emissions. Nakaue and Koelliker [23] found reductions of 15% for both moisture and NH_3 with the addition of clinoptilolite zeolite to poultry litter. Volatilization of NH_3 can also be reduced by using microbial and urease inhibitors, which prevent or slow the growth of microorganisms that convert uric acid into NH_3 [24–26].

Although litter amendments can be effective in controlling NH_3 emissions, their overall use has met with varying levels of success. The ability of amendment products to control NH_3 loss into the environment is temporary [25]. Most products have a limited long-term impact on aerial NH_3 concentrations, especially during the later stages of production, because they are typically depleted by the time the birds are 14 to 21 d of age. Many products require moisture to become activated to reduce NH_3 concentrations. Phosphoric acid has been shown to be effective in controlling NH_3 [5], but its use results in high levels of soluble and total P in litter [21]. As nutrient management of poultry litter becomes increasingly important, the addition of P to the litter is not the best solution.

Chars can be manipulated to make them valuable environmental tools, such as to promote adsorption of NH_3 on their surfaces [27]. It stands to reason that properly modified chars could also be used in animal and poultry production facilities to improve air quality if a system could be devised that would allow for NH_3 capture within their matrix.

Production of Char

Chars can potentially be used as base materials to alleviate NH_3 emissions in poultry production environments. The agricultural, forestry, and industrial manufacturing industries in the United States produce an abundant quantity of biodegradable, biomass materials that can potentially serve as a source for char production. Biomass materials such as peanut hulls or tree clippings are available in Georgia in large amounts and could be used as raw materials for producing chars [28].

Chars can be produced by pyrolysis wherein the raw material is heated to temperatures in the range of 370 to 870°C in the absence of O_2 [29]. During the pyrolysis of wood, for instance, H_2O and virtually all volatile wood gases are driven off the material, leaving a porous space that, combined with the original vascular structure of the wood, produces a potentially highly adsorptive and lightweight material [30]. Acidification after pyrolysis can enhance the capability of chars to adsorb cationic species by lowering pH and introducing acidic functional groups on their surface [31]. The purpose of this project was to explore the potential of chars derived from agricultural wastes to reduce NH_3 volatilization from broiler litter in production facilities.

MATERIALS AND METHODS

The chars used were made from 3 source biomasses: peanut hulls, pine chips, and coconut husks or coir. The last 2 types of chars were obtained in their finished form after they had been acidified with sulfuric acid at a final concentration of 53% (wt/wt), whereas the peanut hulls from South Georgia were pyrolyzed at 400°C for 30 min to produce the peanut hull char, which was ground and screened using a comminuting mill with a 3.0-mm mesh. The pH of the peanut hull char was 9.2, whereas the pH of the acidified chars was 2.0. A total of 1,980 Cobb × Cobb 500 [32] male broiler chicks were randomly distributed within 36 floor pens (3.72 m^2/pen) at a commercial density of 0.07 m^2/bird. Pine shavings-based broiler litter from a previous flock was chosen as bedding material to enhance NH_3 generation. Prior to bird placement, the chars were surface applied at 0, 0.24, 0.37 + 0.37, and 0.73 kg/m^2 (50, 75 + 75, and 150 lb/1,000 ft^2), which are application rates comparable with those of commercially available acidifying litter amendments used by the poultry industry. The treatment, consisting of 0.73 kg/m^2 split into two 0.37 kg/m^2 applications, was included to determine if splitting the application of the amendment into one application at the start of the flock and another halfway through the grow-out period would improve its efficacy. The treatments were arranged in a complete randomized block design with 3 replications. The birds were fed standard broiler starter crumble (0 to 14 d) and pelleted grower (15 to 35 d) diets. Feed and water were provided ad libitum. The animal care protocol used for this study was ap-

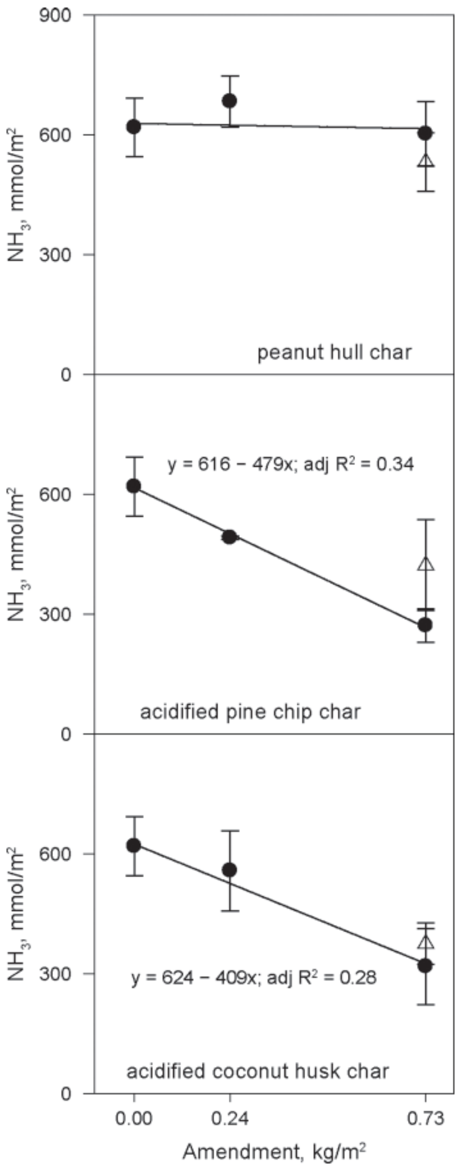

Figure 1. Effect of 3 char amendments applied at 3 rates on the total amount of NH_3 emitted from broiler litter. The open triangle corresponds to the application of 0.73 + 0.73 kg/m^2 of amendment.

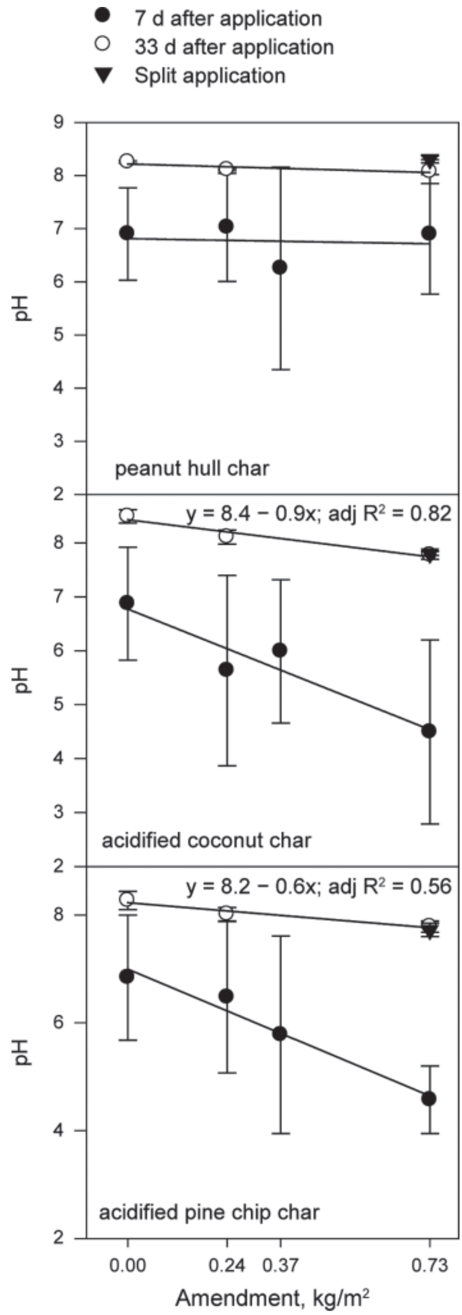

Figure 2. Effect of 3 char amendments applied at 3 rates on litter pH ($P < 0.05$).

proved by the University of Georgia Animal Use and Care Guidelines.

Body weight and feed consumption were recorded weekly on a per-pen basis for each of the treatments until the birds reached 35 d of age. Mortality was monitored daily. At 35 d of age, 10 birds from each pen were killed and processed to assess carcass quality. The birds were stunned with 24 V, 60 Hz alternating current for 20 s by a commercial stunner [33] and then killed by manual exsanguination. The birds were then scalded at 58°C for 110 s and feather picked for 35 s [34]. Exterior and interior evaluations of the carcasses were performed.

Ammonia volatilization was measured every 3 d by using a static-chamber acid-trap system following the procedure described by Tasistro et al. [35], wherein the NH_3 released during a 24-h period into the air in an inverted container placed on the litter was trapped in a vial containing 25 mL of 0.1 *N* H_2SO_4. Ammonia was subsequently measured colorimetrically as ammonium (NH_4^+-N) by the salicylate-hypochlorite method [36]. The milligrams of NH_4^+-N collected were transformed into millimoles of NH_3 emitted per square meter of floor space, and are reported as total NH_3 flux for the duration of the study. Regression analysis of the data was made using SigmaPlot version 11 [37], with $P < 0.05$.

RESULTS AND DISCUSSION

No differences were found in the performance parameters of the birds. Body weight, feed consumption, feed conversion efficiency, and mortality were not influenced by the surface application of any of the chars compared with the unamended control. No feather discoloration or residues of char on the skin were detected at 35 d of age. The lungs and air sacs of processed birds did not have any visual indication of char accumulation or inflammatory process.

Peanut hull char was not effective in reducing NH_3 emissions, whereas both acidified chars showed comparable statistically significant linear reductions in NH_3 emissions of approximately 440 mmol of NH_3/kg of amendment per m^2 (Figure 1). The ineffectiveness of the peanut hull char to remove NH_3 can be explained by the fact that in the original condition, chars are characterized by hydrophobic surfaces that are considered less effective for polar species such as NH_3 [38]. Additionally, the high pH of the peanut hull-derived char (9.2) could have promoted the conversion of NH_4^+ to the volatile NH_3. Surface treatments, such as acidification, can transform the surface area of chars, making them able to reduce NH_3 emissions, as observed when the acidified pine chips or coconut chars were used. Treatment with acids can oxidize the surface atoms of chars and turn them into functional groups containing O_2 that can adsorb as NH_4^+; alternatively, the unchanged acid residues that remain on the char surfaces can react with NH_4^+ [39]. Noh and Schwarz [31] treated a coconut C with HNO_3 and lowered the point of zero charge, which indicated that acidic groups, such as carboxyl groups, were formed. The same authors reported good correlations between NH_3 adsorption and point of zero charge values. Oya and Iu [40] concluded that low-quality chars can be changed into high-quality, functional materials to remove alkaline gases, such as NH_3, by loading H_3PO_4 on their particles.

The reduction in NH_3 volatilization by the acidified chars also could have been due to the reduction of litter pH (Figure 2). Acidifying litter amendments typical of the industry usually have a pH range of 2.0 to 4.0, and as such will suppress NH_3 volatilization from the litter. Within this study, 1 wk after the treatment applications, the pH of the untreated litter was 6.8, whereas the pH of the litters treated at the highest rate of acidification was 4.5 for both the coconut char and the pine chip char (Figure 2). By the end of the study, the acidified chars had caused a significant decline in litter pH, whereas the peanut char did not lower pH. Splitting the 0.73 kg of char/m^2 application into 2 applications of 0.37 kg/m^2 did not result in less NH_3 volatilization compared with the single application at the beginning of the flock.

Litter amendment and NH_3 control options are needed that are environmentally acceptable while at the same time ensuring the economic viability of producers and poultry companies. Adsorptive C materials may play a role in future efforts to reduce NH_3 emissions from the poultry production environment. Further investigation into the use of chars and activated C products for NH_3 control in poultry houses is warranted.

CONCLUSIONS AND APPLICATIONS

1. Surface application of peanut hull char in its original condition was not effective in reducing NH_3 emissions in broiler production.
2. The use of acidified chars as litter amendments resulted in a significant linear reduction in NH_3 volatilization in broiler production.

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