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Use of Biochar in Poultry Barns for Nutrient Recovery and Ammonia Mitigation – Literature Review and Recommendations

A growing body of research indicates that adding biochar to poultry litter can both control ammonia emissions and prevent nutrient loss in the composted litter, while improving the health of the animals.

Biochar can be added to the manure after it is removed from the barn, but it will be more effective to add the biochar in the bedding where it can absorb ammonia as it is generated and prevent it from volatilizing. Reducing ammonia in the barn environment will benefit the health of the poultry, resulting in less respiratory harm and injury to the feet.

Not all biochars are created equal, and the biochar materials that will be most effective in adsorbing ammonia will have high surface area similar to activated carbon, low moisture content, and a granular particle size. Treating the biochar to lower pH can also improve the effectiveness of the material for adsorbing ammonia.

One very effective way to acidify biochar in a barn environment is to inoculate the bedding with lactic acid generating microbes. Effective inoculants include silage inoculant, sauerkraut juice and EM-1 (Effective Microorganisms from Teraganix).

Many small farmers and gardeners have begun using biochar in chicken coops, reporting that smells are almost completely eliminated, and birds are healthier.

Biochar Can Sorb Ammonia in Soils, Compost and Bedding

Research literature on biochar and poultry manure indicates that biochar has a considerable capacity for sorbing ammonia, but that other factors, particularly pH, must be controlled for best results. Below, we summarize some of the research results:

Activated carbon is effective in adsorbing ammonia (Rodrigues et al., 2007), and several researchers have looked at different forms of activated charcoal and wood charcoal for this purpose. Tamon and Okazako (1996) found that oxidizing AC to create acid surface oxides greatly improved its ability to adsorb ammonia. Tsutomu et al. (2004) compared AC to wood charcoal as a sorbent for a number of gases and found that for ammonia, the wood charcoal outperformed the AC, even though it had less total surface area and pore volume.

The process of sorption has different mechanisms, and can be impacted by operating temperature, pore volume and size, available surface area and chemistry of the surface area.

In the study by Tsutomu et al. (2004), they found that the wood charcoal, because it is made at lower temperature than the AC, had retained acidic functional groups that reacted with the alkaline NH3- gas.

Several studies have shown that biochar enhances nitrogen retention in compost, reducing ammonia emissions.

Hua et al. (2009) added 9% bamboo charcoal to sewage sludge compost and found that the total nitrogen loss for the full composting process was reduced by 64.1% compared to no biochar. This was due to sorption of ammonium by biochar. Interestingly, they also found that composting had increased the capacity of the biochar to adsorb ammonium, more than doubling the amount of carboxylic (acid) functional groups on the aged biochar.

In experiments with pine biochar and poultry litter, Steiner et al. (2010) observed a 64% increase in total nitrogen retention when 20% pine biochar was added, as compared to no biochar added.

Chen et al. (2010) found that adding 9% bamboo biochar to pig manure compost reduced total nitrogen loss by 65% as compared to the control.

Dias et al. (2010) found that N losses when using biochar made from eucalyptus in a 1:1 mixture as a bulking agent with poultry manure were lower than an equivalent ratio of coffee husks, but greater than when sawdust was used as a bulking agent. They concluded that the high pH of both the poultry manure and the biochar inhibited ammonia adsorption by the biochar.

Janczak et al. (2017) added a wood biochar at rates of 0%, 5% and 10% (wet weight) to poultry manure mixed with wheat straw (in the ratio of 1:0.4 on wet weight). The addition of 5% and 10% of biochar reduced gaseous ammonia emission by 30% and 44%, respectively.

Ritz, et al. (2011) found that biochar applied directly to bedding can reduce ammonia emissions, especially if it has high surface area and/or it has been treated to lower pH. They acidified pine chip and coconut husk with sulfuric acid at a final concentration of 53% producing a pH of 2.0. Application rates ranged from 0 to 0.73 kg/m^2 to the floor of pens containing broilers at a commercial density (0.07 m^2/bird). The addition of non-acidified 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 reductions (about 50%) in NH_3 concentrations.

Zhang et al. (2016) conducted experiments comparing acidified biochar to sodium bisulfate (PLT) and concluded that to achieve a similar reduction in ammonia emissions would require twice the amount acidified biochar as PLT (sodium bisulfate). With the application rate of 200 lb/1000 square feet of acidified biochar, the NH_3 was reduced up to 47%.

The specific surface area, pH and liming capacity of biochar materials can be highly variable, depending on feedstocks and processing parameters. These results show promise for use of biochar in controlling ammonia emissions, but they also indicate the importance of other factors such as pH, C:N ratio and biochar surface chemistry.

Biochar Promotes Microbial Action to Immobilize Nitrogen

Agyarko-Mintah et al. (2016) found that the total nitrogen emitted by poultry litter composted with biochar was 55% to 60% lower than compost without biochar. The biochar amended compost had more microbial enzyme activity and a lower concentration of dissolved organic carbon (DOC). They hypothesized that the lower NH3 emission in the biochar amended compost was caused not just by sorption of the high surface area biochar but could also be due to increased incorporation of ammonium (NH+4) in organic compounds during microbial metabolism of DOC.

Bernal et al. (2009) confirmed the theory that degradable carbon helps to immobilize NH4 nitrogen by increasing microbial activity which ties up nitrogen in organic forms in the microbial biomass. Change from a less degradable carbon bulking material to a more degradable carbon has been found to reduce ammonia losses in poultry manure composting, and addition of a highly degradable carbon source such as molasses can have a large impact. Biochar can adsorb labile, water-soluble carbon compounds to its surfaces, making them temporarily unavailable to microbial metabolism. When biochar is used in conjunction with another highly recalcitrant bulking material like sawdust, it may be necessary to supplement with molasses or some other highly degradable carbon. Jindo et al (2012) added biochar to compost with poultry litter and apple pomace, a source of highly degradable carbon. In this compost mixture, with abundant levels of both nitrogen and degradable carbon, the biochar improved composting conditions and accelerated the compost process.

Clemens, et al. (2002) produced a self-acidification result in cattle manure slurry through the addition of various sugars, relying on endogenous bacteria in the slurry to promote acidification. When the acidified slurry was applied to fields, less than 5% of the ammonia volatilized as compared 26% loss of ammonia from the untreated slurry. Schmidt (2014) successfully used a similar process in a slurry lagoon with addition of sauerkraut juice as an inoculant.

One research group has taken this process further, proposing a process for treating and recycling chicken litter as a protein feed. Jalil et al. (2001) diluted poultry litter with 50% water and added 10% molasses along with lactobacillus starter cultures. After fermentation, this poultry manure silage conserved all of the nitrogen, converting much of it to proteins, while reducing the pH to around 4.0.

Potential for a Biochar-Lactic Acid System for Use in Poultry Barns

Several different systems for controlling ammonia levels in poultry barns are in use. Acidifiers prevent action of the urease enzyme that mineralizes urea into ammonium. The acidity also creates an unfavorable environment for urolytic bacteria reducing the production of enzymes that contribute to ammonia formation, resulting in reduced ammonia production. Because excess moisture increases ammonia volatilization, it is beneficial to use absorbents such as clay or biochar to help control moisture.

Common acidifying litter treatments include citric acid and sodium bisulphate. One problem with relying on sodium bisulphate alone is that once the chemical has reacted with the ammonia, it becomes neutralized and is no longer effective. Generally, this occurs before the grow cycle is complete. Ammonia continues to be generated in the poultry house with no control. A litter treatment product called "Barn Fresh," which uses citric acid, is potentially longer lasting because it also includes clay and diatomaceous earth that can absorb moisture and ammonia.

Biochar with high surface area is effective at absorbing moisture and nitrogen, and it can be effectively acidified with citric acid, acetic acid, or other acidifiers. Biochar also promotes microbial activity, helping to bind nitrogen into non-volatile compounds, preventing ammonia formation.

One approach that has great promise is to apply biochar along with an inoculant that includes lactic acid bacteria and molasses. As the lactic acid bacteria work to break down the litter, they produce organic acids that acidify the biochar. In order to make this self-acidifying process work most effectively, it is beneficial to add a small amount of molasses or other carbohydrate to provide easily degradable carbon for best C:N ratio for the lactic acid bacteria, as discussed above.

Researchers at the University of Hawaii have developed a successful biochar inoculated system for piggeries, called the Inoculated Deep Litter System (IDLS). The IDLS starts with a base of six inches of biochar mixed with cinders, topped with two feet of logs and a foot of green waste chips, all inoculated with lactobacillius and other indigenous microorganisms from the local environment. The IDLS is not removed for cleaning, because it breaks down and composts on its own. Periodically, new wood chips are added. Once the proper microbial environment is established, the bedding composts on its own, with no objectionable odors. It is not aerated, maintaining a condensed pack of manure and organics.

Research shows that maintaining a condensed manure pack without turning can do a better job of retaining nitrogen and avoiding its loss as ammonia. El Kader et al. (2007) found that reducing the free air space in the manure pack by 20–60%, either by compacting or adding water (or both), reduced the ammonia and nitrous oxide emissions by 30–70%. For this reason, it is desirable to avoid the de-caking and windrowing step in poultry houses, if possible.

Recommendations for Establishing a Biochar-Lactic Acid Bacteria System for Broiler Houses

The exact system developed for piggeries by the University of Hawaii may not be appropriate for broiler houses, but we propose two modified versions that could be very effective, described below:

1. Once a year cleanout: If the appropriate microbial environment can be established in the broiler house using inoculated biochar, and caking does not occur, it may be possible to eliminate the de-caking and windrow composting step between grow cycles and limit barn clean out to one total cleanout per year.

2. De-caking as usual: If de-caking is still necessary despite the addition of inoculated biochar.

In either case, the procedure for establishing the Biochar-Lactic Acid Bacteria System (BLABS) should follow these suggested steps for a 40x400ft broiler house:

1. Start with a clean barn
2. Spread 10-20 cubic yards of biochar on the barn floor
3. Spread bedding (wood shavings, chips, etc.) as usual
4. Add inoculant using either alternative **a** or **b**:
    a. Spray with a mixture of molasses and silage inoculant – using 10 gallons of molasses and 10 gallons of inoculant per 200 gallons of water – for a total of 1600 gallons of water and 80 gallons each of molasses and inoculant.
    b. Spread several bales of grass or alfalfa haylage or any kind of silage on top of the bedding layer before spreading the second layer of biochar.
5. Spread 10-20 cubic yards of biochar as a top layer.
6. After the first cycle, assess whether de-caking is needed. The de-caking and windrowing step causes a lot of nitrogen loss and should be avoided if possible.
7. If not de-caking and windrowing, just let the barn air out for the rest period, and apply diatomaceous earth or other pesticides as needed, taking care not to over apply pesticide that could kill off beneficial bacteria
8. It may be beneficial to spread a layer of clay or diatomaceous earth as a desiccant to help avoid the need for de-caking.
9. After de-caking or airing out, just before then new flock enters the house, spread new bedding.
10. Spread a lighter application of biochar – about 10 cubic yards.
11. Spray with a half application of molasses and inoculant – about 800 gallons of water mixed with 40 gallons each of molasses and inoculant. Or spread another application of haylage or silage.
12. After six cycles, completely clean the barn and start again

Another alternative approach would be to mix the initial load of bedding with 20-40 cubic yards of biochar, along with the haylage or inoculant spray. Pile and allow to ferment for 2-3 weeks before spreading mixture in barn. This may be the most effective method.

Ammonia levels should be monitored and application rates re-assessed as needed. These suggested steps are a starting point. Actual rates of biochar and inoculant could be either more or less than what is suggested here. Also, once the new microbial regime is established in the poultry houses, it may be possible to reduce the amount of biochar and/or inoculant required for good results.

However, it is important to begin with a rather aggressive approach in order to disrupt the existing microbial ecology and establish the new, more beneficial one.

Additional advantages of the BLABS that can result in cost savings and greater value

- Healthy Animals. As results from the University of Hawaii IDLS show, animals in these environments are very healthy. Lactic acid bacterial outcompete many pathogens. Animals may experience better weight gain and fewer mortalities with fewer injuries to foot pads and better marketability of these components.

- Darkling Beetles. The acidic environment in the inoculated barn should discourage darkling beetles and save money on pest control.

- Labor costs. If the BLABS eliminates or reduces the need for de-caking and windrowing, this can save time, labor costs and money.

- Salinity issues. Eliminating sodium bisulfate will produce a litter product that makes a better fertilizer with fewer salts contributing to soil salinity.

- Fertilizer value. Retaining more nitrogen in the litter in non-volatile form such as nitrate makes a more valuable fertilizer. The litter will have a better nitrogen to phosphorous ratio and will not need any nitrogen additives to make a balanced fertilizer. Furthermore, nitrate held in biochar is not easily leachable to the water table.

- Soil biology. The litter will also contain lactic acid bacteria which are beneficial to soil.

- Biochar for soil application. The litter will contain biochar, which has many benefits to soil, included increased water holding capacity. Furthermore, the biochar will be charged with nutrients, increasing its value.

Cost Comparison of BLABS to PLT or Barn Fresh

Input costs for biochar and inoculants may be slightly higher than the cost of conventional treatments, but this should be balanced against the potential for:

- Greater meat or egg production

- Fewer pest problems

- More valuable, higher nitrogen content fertilizer

- Lower labor costs

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