Litter Management Strategies in Relation to Ammonia Emissions from Floor-Raised Birds

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Species: Poultry (Broiler Chicken and Turkey)
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Technology Category: Management and Chemical Amendment
Air Mitigated Pollutants: Ammonia

Description:

Poultry producers in the United States have attempted to maintain barn aerial ammonia (NH_3) levels below 25 ppm to improve air quality and, more recently, to decrease gas emissions to the atmosphere. Poultry are most susceptible to elevated ammonia level during 1 to 21 days after hatching, the *brooding period*. Ammonia emission to the atmosphere contributes to fine particulate matter formation, regional haze, nitrogen deposition in sensitive ecosystems, and acidification of soils. Regulatory scrutiny of ammonia emissions from animal agriculture is currently increasing.

Broiler chickens and turkeys are floor-raised on litter that starts as new bedding (sawdust, wood shavings, rice hulls, etc.) and becomes a mixture of decomposing manure and bedding as birds grow. Litter is the source of volatilizing ammonia in poultry production and its management is a key factor affecting emission rate and bird health. Various strategies are currently employed to manage litter to minimize bird exposure to high ammonia concentrations. Reducing litter moisture content and pH are the major means of reducing ammonia volatilization. Litter pH is reduced by applying acidifying compounds to litter prior to new flock placement.

New bedding may be placed in the barn every one to two years and then used repeatedly over many flocks, which is known as *built-up* litter. The accumulated built-up litter is eventually removed from the barn and fresh bedding is added. This reuse of litter is currently the most common American industry practice. A minority of USA broiler barns receive new bedding for each flock although this is common practice, particularly in the brood area, in other countries (Australia, Brazil and much of Europe). Turkey are raised in a two-step housing process with poults placed on new litter every flock in the brooding-house but the finishing-house typically utilizes built-up litter.

Use of new bedding every flock is intuitively a management choice for good air quality with reduced ammonia concentration within the house for bird and worker health while concurrently reducing ammonia emissions to the environment. Ammonia levels in the chick/poult environment are negligible for the first several days after placement.

New bedding for every flock has been *inhibited* for the following reasons:

- Cost of new bedding
- Real or perceived shortage of suitable bedding materials
- Limited litter-manure storage capacity, market for increased litter volume, or land for application
- Lack of tradition for this poultry management approach in the USA

New bedding for every flock has been *adopted* for the following reasons:

- Greatly improved brooding environment ammonia levels
- Lower ventilation rate, and fuel savings, early in flock
- Reduced disease challenge from previous flocks
- Nearly equivalent labor time for litter management between flocks for new or built-up litter

Acid-treated litter remains a popular ammonia control management option particularly for flocks started during cold weather. Acid treatment products useful in poultry housing include alum (aluminum sulfate), sulfuric acid, and sodium bisulfate; trade names, respectively, include Al+Clear, Poultry Guard, and Poultry Litter Treatment [PLT]. Litter treatments produce variable results, depending on material choice, product application rate and house management (ventilation, moisture control, etc.). Rather than being strictly used to improve air quality, litter treatments are often combined with reduced ventilation rate during the brooding period to save fuel.

Litter acid treatments have been *inhibited* due to:

- Inconsistent results in ammonia reduction to recommended levels
- Materials cost and labor for application

Litter acid treatments have been *adopted* for the following reasons:

- Simple, ease of use with relatively low cost
- Reduced ventilation rate possible to reduce supplemental heat needs
- Familiar management approach

Mitigation Mechanism:

For built-up litter, the current strategy is to reduce litter moisture and/or pH to reduce ammonia volatilization. Litter moisture is controlled year-round through reducing drinking water delivery system leaks with additional effort during cold weather to eliminate condensation drips from cold water pipes and walls and litter wetting from poor distribution of cold ventilation inlet air. Proper litter moisture is maintained by adequate ventilation air exchange based on humidity control that removes moisture-laden air, which impacts litter moisture levels. Beyond this, the most widely used method of suppressing ammonia volatilization from poultry litter is the application of acidic materials to reduce litter pH.

The production and volatilization of ammonia is inhibited by litter pH below 7 and can be substantial above pH 8. Keeping litter pH below 7 is the key to reducing ammonia volatilization. Uric acid is excreted in poultry manure and is the precursor to ammonia through a series of microbial and enzymatic processes. Uric acid breakdown is favored in alkaline conditions (above neutral pH 7). Acidic pH, below 7, also favors equilibrium of ammonium (NH_4^+), which does not volatilize, versus ammonia (NH_3). Acidic litter has unfavorable conditions for microbial and enzymatic reactions needed to convert uric acid in the manure to ammonia compounds; uricase, which degrades uric acid, reaches it peak at pH 9. However, control of litter pH over the life of the flock has proven to be a difficult task, in part because litter pH is not commonly measured, the effect of treatment is not long-lasting (typically only 10-14 days), and repeated treatments are usually impractical with birds in the building. The acidifying compound is applied to the litter, per manufacturer recommended rate, just prior to chick placement in the barn with an expectation of lowered ammonia volatilization during the critical brooding period (up to 21 d).

Ammonia also increases volatilization with increasing temperature, however, warm litter temperatures are required during the chick brooding period (28-34^oC [85-92^oF]) and then throughout the flock cycle (down to about 21^oC [70^oF]). Separately stored manure will be at a reduced outdoor temperature with lower ammonia volatilization potential and opportunity to apply other management tools that are impractical when birds are present.

New litter every flock obviously removes the ammonia source, the accumulated manure, from the bird environment to storage where it can be more aggressively managed for reduced ammonia emission.

Applicability:

Floor-raised birds starting on new litter each flock is common for turkey poults and for broiler chick management throughout most of the world. Antibiotic-free chicken production is more likely to utilize new litter each flock to decrease disease challenge. New litter is an option where suitable bedding material is available at a reasonable price. New litter results in nearly 0 ppm ammonia level in the bird environment for the first week of production. Ammonia concentration increase after that is dependent upon overall house management (litter moisture, ventilation rate, etc.). Emissions from new litter raised birds may be represented by equations found in Figure 1 (Wheeler et al., 2006).

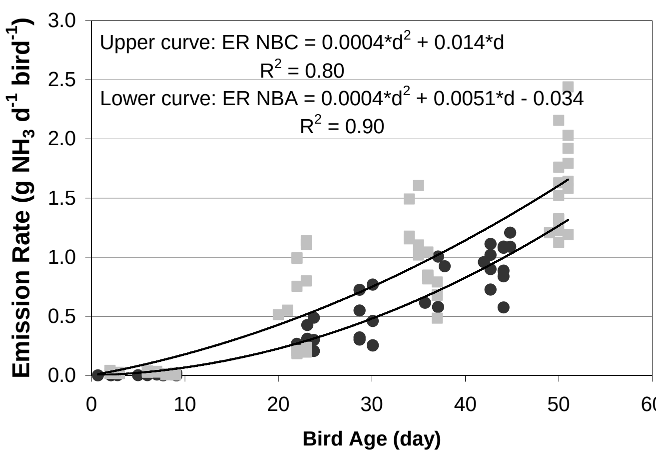

Figure 1. New bedding emission rate (ER) is expressed with second-order polynomials to characterize the near zero ER during the first week of the flock; NBC is *new bedding litter* flock after annual litter *cleanout*; NBA is *new bedding litter always* (every flock). Data are from 10 flocks over one year of data collection at commercial broiler houses: 2 NBA houses on one farm x five flocks each; 10 NBC houses on three farms x one flock each.

The practice of acidifying litter to reduce ammonia volatilization is widespread where built-up litter is used. The addition of granular or liquid acidifying compounds onto the built-up litter is relatively easy prior to bird placement in the house but may not be practical after birds are present. There is evidence that manufacturer's recommended product application rate is not reducing pH below 7 for favorable ammonia-ammonium balance in the field. This is further supported by higher application rates proving more effective in reducing aerial ammonia concentration. Most studies have focused on in-house aerial ammonia levels with more recent studies also incorporating emission rate.

Table 1. Summary of ammonia emission rate (ER) equations for the litter management strategies described and an estimate of daily per bird emission at various bird ages. Data are from 397 days of data collection from 12 houses on four commercial broiler farms in Kentucky and Pennsylvania.

Litter Code	ER Equation	R^2	ER ($g\ NH_3\ b^{-1}\ d^{-1}$) day of age				
			1	7	20	42	60
NBA	= 0.0004*d2 + 0.0051*d - 0.034	0.90	0.00	0.02	0.23	0.89	1.71*
NBC	= 0.0004*d2 + 0.0140*d	0.80	0.01	0.12	0.44	1.29	2.28
TL	= 0.0295*d + 0.0121	0.66	0.04	0.22	0.60	1.25	1.78
BL	= 0.0311*d + 0.0824	0.60	0.11	0.30	0.70	1.39	1.95
AL	= 0.0308*d - 0.0321	0.64	0.00	0.18	0.58	1.26	1.82

NBA = new bedding always; NBC = new bedding after cleanout; TL = treated litter; BL = built-up litter; AL = all litter in this study. *extrapolated beyond 45 day data collection timeframe.

Table 2. Emission rate (ER) of ammonia from side-by-side comparison of four broiler houses on one farm where two had acid-treated built-up litter (TL) and two were built-up litter (BL). All four houses had an annual new litter cleanout (NLC). All houses on this farm are summarized as AL.

Litter Code	ER Equation	R^2	ER ($g\ NH_3\ b^{-1}\ d^{-1}$) day of age				
			1	7	20	42	60
NBC	= 0.0006*d2 - 0.0038*d	0.93	0.00	0.00	0.16	0.90	1.93
TL	= 0.0266*d + 0.156	0.49	0.18	0.34	0.69	1.27	1.75
BL	= 0.0282*d + 0.080	0.45	0.11	0.28	0.64	1.26	1.77
AL	= 0.0280*d + 0.031	0.50	0.06	0.23	0.59	1.21	1.71

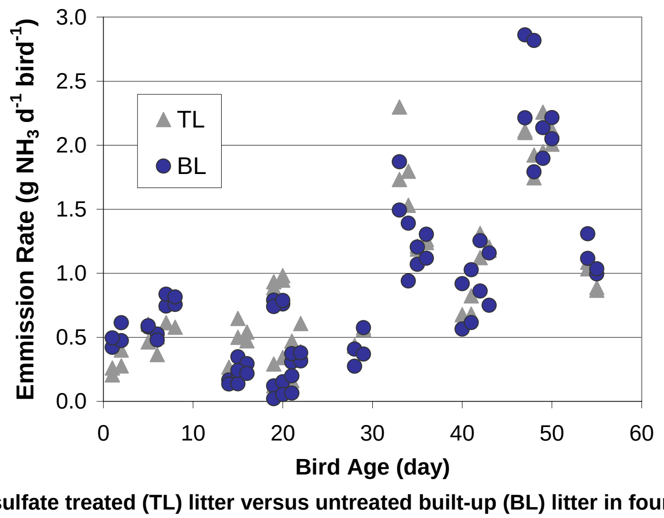

Figure 2. Field study of sodium bisulfate treated (TL) litter versus untreated built-up (BL) litter in four commercial broiler houses (2 TL; 2 BL) on same farm for direct comparison of ammonia emission rates (ER); additional data in Table 2. Minimum cold-weather ventilation was provided by timer fans on a 10 minute interval at 3 minutes run time in the TL houses whereas the BL houses utilized 5 minutes run time, 67% more, in an attempt to control ammonia levels. Note that the daily ammonia ER is higher for the BL houses during the first 10 days then this pattern reverses after about two weeks when the TL house emissions are greater than the BL houses for a given day. This indicates a release of the ammonia held in the treated litter as the acidifying power of the treatment product is depleted. The litter pH was above 8 for all four houses on the day of chick placement.

Limitations:

Acidifying compounds can reduce aerial ammonia concentration within a poultry house. Heavier than manufacturer-recommended acid application rates appear to result in improved air quality but with increased cost. When acid treatment is used in conjunction with reduced ventilation rate, in an attempt to lower fuel costs, the ammonia reduction benefit is minimized. Data from field trials indicate that acid treated litter is used as often for fuel reduction as it is an attempt to improve the bird environment ammonia level. A side-by-side study of four broiler houses, two with sodium bisulfate (PLT) acid treated litter and two houses with no acid treatment, showed that ammonium held in the acidified litter during the first two weeks was subsequently released and resulted in essentially the same ammonia emissions from all four houses over the course of the flock (figure 2, table 2). Other research has failed to demonstrate a difference in ammonia emissions from litter treated with sodium bisulfate and untreated litter (Moore et al., 1996).

Cost:

It takes a similar amount of time to prepare a house with new bedding or built-up litter for the next flock. This relates to the one-time effort for full litter removal versus more careful and repeated management needed for built-up litter preparations. Management priorities vary greatly throughout the country, partially dependent on climate, and we try to capture some of that variation here.

A full cleanout of litter takes about 16-man-hours, including stockpiling litter into a covered storage. It takes an additional 2 man-hours using a bedding spreader to apply new bedding. Cost of new bedding is quite variable from about $600 [wood shavings in NE] to $1000 [rice hull + wood shaving mix in SE]. Accounting for differences in house size between regions and bird placement numbers, new bedding cost ranges from $0.018 to $0.045 per bird. Ventilation rate is substantially reduced during the first few days after bird placement on fresh bedding to levels needed for moisture control. Ventilation rate to keep aerial ammonia within the 25 ppm guideline on built-up litter can be 10 times higher than for moisture control alone. Energy savings can be substantial on new bedding through reduced supplemental fuel use during the warmest period of brooding. A slightly increased bird placement density on new bedding may be acceptable due to the reduced environment challenges versus a built-up litter house.

About 16 man-hours are needed to properly prepare a built-up litter house for the next flock. During built-up litter decaking (removing caked litter under the feed and water lines), about one-fourth of the litter is removed to the manure storage; 15 US-ton litter/house/flock (US-ton = 2000 lb or 909 kg). The remaining litter is bladed to evenly distribute and then harrowed (roto-tilled; housekeeping machine, etc.) everyday for 2 or 4 days to help dry the litter.

If an acid litter treatment is applied, this takes about 1 man-hour per house-section using a small spreader pulled behind a lawn tractor. Treatment is applied 2 to 24 hours before bird placement, in stages as different sections of the house are prepared to receive birds. Broiler production often divides the house into subsections to reduce the heated area during brooding higher temperatures. The first one-half of the building is used for brooding, then additional area is opened. A cost estimate is available from the study that monitored treated litter houses (Figures 1 and 2). Cost of sodium bisulfate (PLT) is about $13 per 22.7 kg (50-lb) bag when purchased by the US-ton (one pallet), plus delivery (2008 price). At an application rate of 0.24 kg/m^2 (50-lbs per 1000 ft^2) 25 bags are needed ($335) per 14.6 m x 152.4m (50 ft x 500 ft) house placing 32,500 birds for $0.01 per bird. In moderate climate regions, only the brooding area is treated at half this cost.

The built-up and caked litter removed to storage may be stockpiled for crop use or sold to specialized outlets such as composting or mushroom substrate operations at $4.5/US-ton. Alum can stabilize ammonium into ammonium sulfate to further reduce volatilization. Alum-treated litter reduces losses of soluble and total phosphorous (P) in runoff from land-applied litter and benefits P-based land application guidelines.

Implementation:

Acid-litter treatments are usually applied according to product manufacturer's directions. Consider that several studies have found increased effectiveness under commercial conditions when the product is applied at a higher rate, particularly when built-up litter has accumulated from several flocks (perhaps 4 or more). One way to gauge effectiveness of an acidifying treatment is to check litter pH to be sure it is reduced below 7 after acid treatment. For example, Wheeler et al. 2008 report that after five flock growouts the litter pH at chick placement was about 8.05 for two PLT-treated houses (at recommended rate of 0.24 kg/m^2), which was lower than two untreated houses (pH 8.3) on the same farm. After 7 days pH was 8.2 in the treated houses with all four houses having essentially the same pH at flock end. More acidifying material was needed on the accumulated litter material to reduce the pH below 7 for this acid treatment to be effective.

Technology Summary:

Managing floor-raised poultry offers options for providing a suitable environment for the bird productivity and an opportunity to reduce environmental pollution. Reduction of aerial ammonia concentration within the poultry house will benefit bird health for improved productivity and reduce emissions from the building. Three management options were discussed here: 1. new bedding every flock; 2. built-up litter; 3. built-up litter with acidifying product.

Indoor ammonia level and emissions are most improved with use of new litter every flock. Adoption of this practice is very limited in the USA. Built-up litter is most common in the USA. Acidifying treatments are applied to built-up litter in an attempt to reduce litter pH below 7 to overcome the substantial ammonia volatilization.

Acid treatments have offered variable results under field conditions in reducing in-house aerial ammonia levels and associated emissions. Variable results are, in part, due to a primary management objective to reduce ventilation rates to lower supplemental heat expenditures after application of acid treatment. Reduced ventilation fresh air exchange results in increased house humidity and ammonia concentration within the building. Attention to litter pH and aerial humidity after application of acid-treatment should improve results for more consistent aerial environment improvement.

Cost of implementing new litter every flock equivalent to the labor cost for built-up litter. New bedding material cost is higher than acid-treatment cost at additive manufacturer rates. New litter benefit reported here does not account for reduced energy use during brooding and increased bird placement numbers with the improved environment

Additional Resources:

Blake, J. P. and J. B. Hess. 2001. Auburn University, AL. Available www at:

- Aluminum Sulfate (Alum) as a Litter Treatment, ANR-1202. www.aces.edu/pubs/docs/A/ANR-1202/
- Litter Treatments for Poultry, ANR-1199. www.aces.edu/pubs/docs/A/ANR-1199/
- Poultry Guard™ as a Litter Amendment, ANR-1209. www.aces.edu/pubs/docs/A/ANR-1209/
- Sodium Bisulfate (PLT) as a Litter Treatment, ANR-1208. www.aces.edu/pubs/docs/A/ANR-1208/

Poultry Litter Amendments. 2006. S. Shah, P. Westerman and J. Parsons. North Carolina Cooperative Extension Service. www.bae.ncsu.edu/programs/extension/publicat/wqwm/poultry/factsheet_agw657long.pdf

Wheeler, E. F., K.D. Casey, R.S. Gates, and H. Xin. 2008. Ammonia emissions from USA broiler barns managed with new, built-up, or acid-treated litter. *Proceedings of the Eighth International Livestock Environment Symposium*. Iguassu Falls City, Brazil. ASABE. St. Joseph, MI. 10 pp.

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