FIELD TRIALS OF ALUM AMENDMENT OF BROILER LITTER TO REDUCE SOLUBLE PHOSPHORUS

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Abstract. Aluminum sulfate (alum) has been demonstrated to reduce ventilation and heating requirements by lowering pH and thus reducing ammonia release from broiler litter during brooding of broiler chickens raised on previously used litter. It also has been shown to reduce runoff of phosphorus from fields where litter is applied, and increase nitrogen levels in treated litter. Most previous research, however, has been done in locations and under different litter management than is common in Georgia. This research compared broiler houses in North Georgia operated under a common management scheme with other houses using alum amendment of the litter. The second stage compared houses with alum added at full rate with others where alum was added at half the recommended rate. This research demonstrated that much of the economic benefit of adding alum can be achieved by adding only half the recommended rate. Soluble phosphorus and ammonium nitrogen levels were adversely affected by reducing application rates. While the environmental benefit of phosphorus runoff reduction would be lessened by adding less alum, an advantage may be realized industry wide by reducing the application rate since more growers would be likely to use it due to economic benefits.

INTRODUCTION

Aluminum sulfate ($Al_2(SO_4)_3 \cdot 14H_2O$), commonly called alum, has been shown to be effective at reducing ammonia emissions when added to broiler litter. This reduction has been shown to significantly reduce ventilation and thus heating requirements during winter flocks. Additional benefits include improved bird performance, reduction in the need for shavings as a bedding material, reduced runoff of phosphorus from fields fertilized with alum amended litter, reduction in darkling beetle populations, and increased levels of available nitrogen in litter. The amount of alum recommended for reduction of phosphorus runoff is 10% of manure weight. It has been observed through field experimentation that ammonia emissions are effectively reduced at lower levels of alum amendment, although the effects do not last as long, and some of the other benefits may be reduced by lowering application rates. Most of the research on this product has been done in Arkansas where alum-amended houses were compared to litter in untreated houses where no additional shavings were added after the first flock of birds were removed. This research was done in North Georgia and the control houses had a half-layer of fresh shavings applied after each flock (common practice in this area.)

BACKGROUND

A number of chemical amendments were evaluated by Moore et al. (1995, 1996) for their effectiveness in reducing ammonia emissions from poultry litter and for their effect on soluble phosphorus levels. These include alum ($Al_2(SO_4)_3 \cdot 14H_2O$), ferrous sulfate, phosphoric acid, ferric chloride, calcium hydroxide, sodium bisulfate, and MLT (Multipurpose Litter Treatment, a commercial product). They found that alum, ferrous sulfate, and phosphoric acid were all effective at reducing ammonia levels. Phosphoric acid, however, greatly increased the phosphorus level in litter. The product that was most effective at both ammonia reduction and soluble phosphorus reduction was alum. Moore and Miller (1994) found that the addition of alum, slaked lime, quick lime, ferrous chloride, ferric chloride, ferrous sulfate, and ferric sulfate under favorable pH conditions were all effective in reducing phosphorus solubility. Of these, alum and lime are the most economical; however, only alum economically reduces soluble phosphorus while also reducing ammonia volatilization. Shreve et al. (1995) showed that alum-treated poultry manure reduced phosphorus runoff from treated plots by 63 to 87% over litter alone and also increased the production of fescue by 28%, presumably due to the increased nitrogen content of the alum-treated litter.

METHODS

Part I

Tests were run from October, 1996 until March 1997 on a four-house commercial broiler farm in North Georgia. The first flock of birds (all four houses) was placed on 10 cm (4 in) of clean shavings after cleaning the houses out. For the next two flocks, alum ($Al_2(SO_4)_3 \cdot 14H_2O$) was placed in two houses at the rate of 0.976 kg/m^2 (0.20 lb/ft^2). No shavings were added to the houses after the first flock. Parameters monitored in the tests included ammonia levels, gas usage, bird performance, darkling beetle populations, and litter composition. The farm raised broilers to six weeks of age. The houses were post type construction with a dropped ceiling and radiant brooders. Each house was 12 x 152 m (40 x 500 ft) and the ventilation system was controlled by a computer based controller.

Gas levels in tanks supplying each house were recorded at the beginning and end of each growout, and purchases of gas for each house were kept separate. Ammonia levels were monitored using an ammonia meter (model NH3, Sensidyne Corp.). Ammonia levels in all houses were kept below 25 ppm by increasing the minimum ventilation rate as needed.

Darkling beetle populations were monitored by placing five traps (a 3.8 cm [1.5 inch] diameter PVC pipe stuffed with cardboard) in each house during the fifth week of each growout. The traps were placed near the wall, distributed throughout the length of the house, and removed after one week. The number of adult beetles and larvae were then counted for each trap. These traps do not contain any attractant, but simply represent an attractive environment for the beetles, and are an accepted indicator of beetle populations (Safret and Axtell, 1984). Since the farm was experiencing high beetle populations, the control houses were treated with boric acid at 100 lb per house spread in bands under the feed lines. Therefore the test was a comparison of two control methods rather than a test against no treatment.

Bird performance was monitored by keeping separate records for each pair of houses. As nearly as possible, an equal number of genetically similar birds was placed in each pair of houses. If a supply of birds from one source was not available for all four houses on a farm, the groups of birds were mixed so that an equal number from each source was placed in each pair. Feed and processing records were maintained separately for each pair. It was not possible to keep feed separate for each house since two houses shared a common feed bin.

Litter samples were taken from each house after each flock and analyzed for nutrients including soluble and total phosphorus and nitrate, ammonium, and total nitrogen levels. Total Kjeldahl Nitrogen and total P in broiler litter were determined by measuring NH_4-N and PQ -P in a Kjeldahl digest (Nelson and Sommers, 1973). The concentration of NH_4^+N in the digest was determined by the salicylate-hypochlorite method (Crooke and Simpson, 1971), and the concentration of PO_4-P by the colorimetric molybdenum-blue method of Murphy and Riley (1962). Inorganic N was determined by extracting 0.2 g of fresh litter with 40 mL of 1 *M* KCl for 30 min and measuring inorganic N concentrations in the supernatant volume. Ammonium-N in the supernatant was measured as described above and nitrite+nitrate-N was measured by the Griess-Ilosvay technique (Keeney and Nelson, 1982) after reduction of nitrate to nitrite with a cadmium column. Total Nitrogen was then calculated by adding TKN (total Kjeldahl nitrogen) to nitrate nitrogen. Water-soluble P was measured by extracting 0.2 g of fresh litter with 40 mL of deionized water for 30 min, and measuring PO_4-P in the supernatant as described above. The water content of the litter was determined by drying 5 g of fresh litter at 60° C for 48 h.

Part II

Tests were run from October, 1997 until February, 1998 on the same four-house commercial broiler farm in North Georgia as part I. The procedures for this portion of the test were identical to those in the first part with the following exception. After the first flock, alum was placed in two houses at the rate of 0.976 kg/m^2 (0.20 lb/ft$^{2)}$ and in the other two houses at the rate of 0.488 kg/m^2 (0.10 lb/ft^2).

RESULTS

Energy

Propane gas usage is shown in Tables 1a and 1b. In the first trial (Table 1a), houses with alum treatment used an average of 200 gallons less propane per flock than control houses with fresh shavings. In the second trial (Table 1b), there was no difference between gas usage in houses with half-rate and full-rate alum applications.

Bird Performance

No significant difference in bird performance was shown for either part of the trial including bird weight, feed conversion, and % mortality.

Beetle Populations

The results of the beetle population tests are shown in Tables 3a and 3b. In the first test (Table 3a), boric acid seemed to be doing a better job of suppressing beetle populations for flock 1, but the results reversed in flock 2. Unfortunately, due to miscommunications, the traps were not placed for flock 3, so no results were obtained. For the second test (Table 3b), beetle populations in the half-rate houses were significantly higher for both adult and larvae in flock 2, indicating that higher levels of alum application may have some beneficial effects in beetle population suppression. The trend continued in flock 3, but the differences were not significant. Larvae counts were fairly high for all four houses.

Litter

Analysis of litter is shown in Tables 4a and 4b. Total nitrogen levels were generally slightly higher (though not significantly) for higher levels of alum application. Ammonium nitrogen was significantly higher in the litter for each flock raised on alum and for full vs. half-rate application of alum. This result is consistent with the expectation that reduced ammonia gas release will result in increased ammonium in litter. Nitrate nitrogen levels are high after flock 1 of 4b, but much of this nitrate nitrogen was lost before the end of flock 3, probably due to denitrification.

Total phosphorus was the same in all flocks except flock 1 in 4a. In the first test, soluble phosphorus is 15% higher in alum houses for flock 2, but 22% lower for flock 3. In the second test soluble phosphorus is 10% lower in the full-rate houses than the half rate houses for flock 2. The results in flock 2 of 4a could be explained by sampling error or random variation. Note that soluble phosphorus levels were also higher in the "Base" flock of 4a even though all houses were treated identically for this flock. In each case, the last flock data represents the time that litter would be applied to crop land, and in each case, soluble phosphorus is lower with higher alum (22% for alum vs. no treatment and 10% for full vs. half-rate alum.)

Table 1a. Propane Gas Usage in Gallons for Alum vs. No Treatment

Flock	1	2	3
Ending date	12/7/96	2/1/97	3/29/97
Alum 1	680	580	740
Alum 2	660	560	650
Alum Avg	670	570	695
Control 1	700	750	1060
Control 2	860	840	1030
Control Avg	780	795	1045
Difference	110	225	350

Table 1b. Propane Gas usage in Gallons for Alum added at Half vs. Full Rate

Flock	Base*	1	2
Ending date	10/22/97	12/23/97	2/20/98
Alum applied at half the recommended rate			
House 1	180	820	925
House 2	120	850	1225
Half Rate Avg	150	835	1075
Alum applied at the recommended rate			
House 3	160	925	1070
House 4	150	885	990
Full Rate Avg	155	905	1030
Difference	5	-70	45

* Base flock houses were all managed the same with no alum application, therefore no difference was expected.

Table 3a. Darkling Beetle Populations (average number of beetles in each trap.) for Alum vs. No Treatment

Flock Ending date	Base* 10/16/96	1 12/7/96	2 2/1/97	3 3/29/97
Adult Beetles				
Alum Avg	112	204^A	70	N/A
Control Avg	148	81	120	N/A
Beetle Larvae				
Alum Avg	2382	3598^A	1766	N/A
Control Avg	2510	791	3042	N/A
Total Beetles				
Alum Avg	2494	3802^A	1836	N/A
Control Avg	2658	872	3161	N/A
Difference	164	-2930	1325	N/A

* Base flock houses were all managed the same with no alum application, therefore no difference was expected.
^A Significant difference at the alpha = 0.05 level (ANOVA)

Table 3b. Darkling Beetle Populations (average number of beetles in each trap) for Half vs. Full Rate of Alum Applied

Flock Ending date	Base* 10/22/97	1 12/23/97	2 2/20/98
Adult Beetles			
Half Rate	46	133^A	113
Full Rate	119	29	84
Beetle Larvae			
Half Rate	1174	1521^A	1189
Full Rate	1318	555	1094
Total Beetles			
Half Rate	1220	1654^A	1303
Full Rate	1437	584	1178
Difference	217	1070	125

* Base flock houses were all managed the same with no alum application, therefore no difference was expected.
^A Significant difference at the alpha = 0.05 level (ANOVA)

Table 4a. Litter Analysis for Alum vs. Control Test. All figures given in % dry basis (g/100g dm).

Flock Ending date	Base* 10/16/96	1 12/7/96	2 2/1/97	3 3/29/97
Total Nitrogen (%)				
Alum	2.94	4.20 ^A	4.45	5.44
Control	2.83	3.93	4.08	4.91
NH_4 Nitrogen (%)				
Alum	0.31	0.51 ^A	0.53 ^A	0.68 ^A
Control	0.27	0.45	0.42	0.42
NO_3 Nitrogen (%)				
Alum	0.00 ^A	0.05 ^A	0.02 ^A	0.26 ^A
Control	0.08	0.08	0.05	0.13
Total Phosphorus (%)				
Alum	1.20	1.17 ^A	1.38	1.22
Control	1.17	1.04	1.20	1.14
Soluble Phosphorus (%)				
Alum	0.23 ^A	0.19	0.27 ^A	0.27 ^A
Control	0.20	0.19	0.23	0.33

Table 4b. Litter Analysis of half vs. Full Rate Test. All figures are given in % dry basis (g/100 g dm).

Flock Ending date	Base* 10/22/97	1 12/23/97	2 2/20/98
Total Nitrogen (%)			
Half Rate	4.16	4.83	4.07
Full Rate	4.27	4.81	4.20
NH_4 Nitrogen (%)			
Half Rate	0.38	0.52^A	0.47^A
Full Rate	0.44	0.62	0.64
NO_3 Nitrogen (%)			
Half Rate	0.13	0.80	0.41
Full Rate	0.24	0.82	0.33
Total Phosphorus (%)			
Half Rate	1.36	1.79	1.53
Full Rate	1.51	1.72	1.58
Soluble Phosphorus (%)			
Half Rate	0.18	0.21	0.22^A
Full Rate	0.22	0.22	0.17

* Base flock houses were all managed the same with no alum application, therefore no difference was expected.
^A Significant difference at the alpha = 0.05 level (ANOVA)

DISCUSSION

When applied at the recommended rate of approximately 10% by weight to broiler litter, alum reduces ammonia volatilization, thus reducing the need for ventilation and fuel use to reheat ventilation air. Thus, significant fuel savings can be attained, helping to offset the cost of alum application. In addition, darkling beetle populations may be suppressed, fewer shavings are needed, litter has a higher level of available nitrogen, and bird performance is not hindered. (Other tests have shown improvements in bird performance, but the data in this test did not.) Soluble phosphorus levels are reduced by the addition of alum to the litter, but at this point, there is no economic advantage to the grower or integrator to achieve this reduction. When applied at this rate, the cost of alum application is approximately offset by savings to the grower on winter flocks and would represent a net loss on summer flocks.

The use of one-half the recommended rate of alum (5% instead of 10% of manure dry weight) is an economically viable alternative. Gas savings were unaffected by the reduction in alum application. Although smaller amounts of alum would not last as long as the full amount (chemical reaction would use it up sooner), most of the gas savings occur during the first two weeks of bird life. After the first 10 days to two weeks, brooding temperatures are lower, birds are producing more heat, and minimum ventilation rates are increased to the point that ammonia is no longer the controlling factor in setting ventilation rates.

Beetle population control showed some indication that lower application rates may reduce its effectiveness for this purpose. Some decreases in litter quality (available nitrogen and soluble phosphorus) also resulted from decreased alum application rates. The reduction in soluble phosphorus of approximately 10% at clean-out is consistent with the theory that the full rate of alum is necessary to maximize the reduction of runoff from alum treated litter.

While the use of less alum in a house may reduce the environmental benefit of phosphorus runoff reduction from that house, the benefits industry wide could be greatly increased as a result of the information learned in this study because this level of application is economically beneficial to the grower even without considering the environmental benefits. The cost of application could probably be reduced even further by applying alum only in the brooding end of the house. If the ventilation system were properly managed so that no air from the cold end of the house were brought into the brooding end, ammonia volatilized from the cold end would not affect the birds for the first 10 days when most of the gas savings take place.

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