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Superabsorbent Polymers as a Poultry Litter Amendment[1]

Jennifer R. Timmons[2] and Jeannine M. Harter-Dennis[3]
[2]University of Maryland Extension, Lower Eastern Shore Research and Education Center,
University of Maryland, 27664 Nanticoke Road, Salisbury MD 21801, USA
[3]Department of Agriculture, Food and Resource Science, University of Maryland, Eastern Shore,
Princess Anne, MD 21853, USA

Abstract: Ammonia volatilization from poultry litter commonly causes a buildup of ammonia in the atmosphere of chicken houses that can have a negative impact on both farm workers and birds. The release of ammonia from poultry houses can also contribute to environmental problems such as atmospheric haze. The most widely accepted management strategy to control ammonia volatilization from poultry houses is the use of litter amendments that are added to the litter. The poultry industry routinely uses dry acids such as aluminum sulfate and sodium bisulfate to reduce ammonia emissions inside the poultry house. Although these products are very effective in controlling ammonia release in poultry houses, they typically only work for about the first three weeks of the grow-out period, after which time litter pH and ammonia levels will begin to rise. As a result, these litter amendments must be reapplied prior to the placement of new chicks in order for ammonia levels to continually remain low. Therefore this research was conducted to evaluate the efficacy of an alternative product for long-term control of ammonia release in poultry houses. This research investigated the efficacy of a single application of superabsorbent polymers to poultry litter for long term in-house ammonia control which could reduce the negative impacts of ammonia on bird health and performance and potentially the environment.

Key words: Broilers, ammonia, superabsorbent polymers, litter amendment

INTRODUCTION

The control of ammonia volatilization in poultry houses is a major concern for the poultry industry. Not only does ammonia impact bird health and performance (Quarles and Kling, 1974; Miles *et al*., 2004), but there is also a concern about its negative impact on public health and the environment. Once ammonia is emitted into the atmosphere it can contribute to the formation of fine Particulate Matter ($PM_{2.5}$) that may cause respiratory illness in humans (Fierro, 2000) and contributes to problematic environmental issues such as an increase in the development of atmospheric haze (ApSimon *et al*., 1987; NRC, 2003).

Currently the most widely accepted management strategy to control ammonia volatilization in poultry houses is the use of litter amendments that are added to the litter. The poultry industry routinely uses dry acids such as aluminum sulfate and sodium bisulfate to reduce ammonia volatilization inside the poultry house (Moore *et al*., 2001). Although these products are very effective in controlling ammonia release in poultry houses, they typically only work for about the first three weeks of the grow-out period, after which time litter pH and ammonia levels will begin to rise (Moore *et al*., 1999). As a result, these litter amendments must be reapplied prior to the placement of new chicks in order for ammonia levels to continually remain low. This not only results in added costs for production and more labor input by the grower but allows for higher ammonia release at the end of the flock consequently contributing to ammonia volatilization into the atmosphere.

Superabsorbent Polymers (SAPs) are hard, dry, granular substances that have the ability to absorb up to 1,000 times their weight of pure water (Buchholz and Graham, 1998). Currently the greatest usage of SAPs is in infant baby diapers to absorb urine (Buchholz and Graham, 1998); however polymers are used for a wide variety of other applications including agriculture. The use of polymers in agriculture is not a new development. Polymers have been used as soil conditioners since the 1950's (Hedrick and Mowry, 1952). New technology has allowed the development of polymers with high molecular weights that require low application rates and provide benefits for agriculture by improving such things as soil water preservation and irrigation efficiency (Sivapalan, 2001).

Superabsorbents have been used to help conserve water in a variety of agriculture and horticultural applications. Soils in environments with little precipitation or that are too porous to hold moisture in the root zone can be improved by adding SAPs (Buchholz and Graham, 1998). The resulting soil mixture

Corresponding Author: Jennifer R. Timmons, University of Maryland Extension, Lower Eastern Shore Research and Education Center, University of Maryland, 27664 Nanticoke Road, Salisbury MD 21801, USA

holds moisture longer and allows plants to live longer after germination thereby improving plant growth and health (Sivapalan, 2001). Some SAPs have also been added to irrigation water to control soil erosion associated with flood furrow and sprinkler irrigation. Researchers have found that mixing SAPs with irrigation water can reduce erosion from furrow-irrigated fields by 80-99% (Woods, 2002). It has also been reported that these polymers have the ability to help keep nutrients, such as phosphorus from traveling beyond the farm into nearby surface waters (Lentz *et al*., 1998). Although it is evident that SAP application to soils and irrigation waters has benefits such as improving plant growth and decreasing nutrient runoff, the benefits of applying SAPs to poultry litter to control ammonia volatilization inside poultry houses are completely unknown.

Therefore this research was conducted to investigate the efficacy of a single application of SAPs to poultry litter for long-term ammonia control. It was hypothesized SAPs would inhibit ammonia production from uric acid by binding the water that is required for uric acid degradation which ultimately produces ammonia.

MATERIALS AND METHODS

Chick selection and housing: All chicks used in these trials were male broiler chicks obtained from a commercial hatchery. Only male birds were used in these trials to reduce biological variation between treatments. Chicks were vaccinated for Mareks Disease virus *in ovo* at 18 d of incubation and on the day of hatch were spray vaccinated for Infectious Bronchitis Virus and Newcastle Disease Virus. Chicks were group weighed and randomly assigned to treatments for each trial. These birds were raised to 6-7 weeks of age.

Chicks for all trials were placed in a thermostatically controlled environment in which the temperatures were maintained similar to the temperature guidelines used in the commercial broiler industry. The floor pens (0.57 m^2) contained used wood shavings/sawdust poultry litter and were equipped with hanging feeders and nipple drinkers. Ventilation was provided by negative pressure and lighting was provided 24 h a day. Environmental conditions (floor space, temperature, lighting and feeder and water space) were similar for all treatments.

The experimental protocols for all trials were submitted to and approved by the University of Maryland Eastern Shore Institutional Animal Care and Use Committee.

Feed and water were offered ad libitum for all trials and any mortalities were weighed and recorded daily. The diets were a standard corn and soybean meal commercial broiler diet. All birds were fed the same diet (Table 1). Body weight gain and feed consumption were recorded for each pen. Upon completion of each trial (Day 42 or 49), birds were sacrificed by carbon dioxide asphyxiation and carcasses were properly composted for disposal.

Table 1: Diets fed to broiler chickens for Superabsorbent Polymer trials

Calculated analysis	Starter (0-21)	Grower (22-35)	Finisher (36-42 or 49)
ME (kcal/kg)	3200.00	3200.00	3200.00
Crude protein (%)	20.00	18.00	16.00
Met + Cys (%)	0.90	0.79	0.70
Lysine (%)	1.10	0.99	0.88
Calcium (%)	0.90	0.90	0.90
Non-phytate P (%)	0.45	0.45	0.45

Litter preparation: All litter was removed from the pens prior to the start of Trial 1 and was mixed together with a total mix ration wagon in order to obtain a uniform mixture of litter. The litter was then weighed and divided equally between treatment groups. Litter for each pen was then weighed and the appropriate SAP resin added and mixed separately using a ribbon mixer (due to the large amount of litter required to fill each pen and the size of the ribbon mixer). Once all of the litter was mixed with the resin, it was spread into its assigned pen. Chicks were then placed in the pens the following day. SAP resin was only applied one time to the treated litter (prior to Trial 1). Additional SAP resin was not applied to the litter for Trials 2 and 3.

Ammonia collection: Litter samples were taken twice per week from each pen throughout the flock. A depth of 5.1-7.6 cm (2-3 inches) of the litter along the drinker line was sampled. Fifty grams of each litter treatment replicate were placed in a plexiglass chamber (26.365 L volume) measuring 28 cm x 30.5 cm x 30.5 cm. Each chamber was sealed with a removable plexiglass lid (12.7 mm thick). Two gas washing bottles that contained 200 ml each of an acid solution (200 mL distilled water with 260 µL 7.4 M H_3PO_4) were attached to each plexiglass chamber. Air was pulled through the system by a vacuum pump and regulated (target air flow was 5 L per minute) using adjustable air flow meters so that air-flow could be kept constant between treatments and replications. Based on preliminary studies that ensured that all ammonia was displaced from the litter after 3 h, the collection period in all ammonia studies was 4 h. After the collection period, the volume in each of the gas washing bottles was recorded and samples were stored in the refrigerator until ammonia analysis could be performed.

Ammonia analysis was performed using an automated flow injection analysis system (Lachat)[4]. The QuikChem® method 10-107-06-1-J was used by this system for ammonia determination. The ammonia was reported as ammonia nitrogen (mg/L) per gram of nitrogen in the litter.

On each day of ammonia collection, the moisture content and water activity of each litter treatment was determined. However, the pH of the litter was only measured in ammonia trials 2 and 3. The moisture content was determined by weighing a sub-sample of each litter sample and drying each sample in an oven for 24 h at 100°C. Subsequently, samples were allowed to cool and dry weight was recorded. The moisture content was then calculated by subtracting the dry weight of the sample from the wet weight. The percentage of moisture was then calculated by dividing the moisture content by the wet weight that was then multiplied by 100 to obtain the moisture percentage (AOAC, 1990). Water activity was determined using an AquaLab® CX-2 meter[5]. The pH was measured by mixing a 10 g sub-sample of litter obtained from each floor pen with 40 ml of distilled water followed by measurement using a pH meter[6]. In addition, at the end of each trial the final nitrogen content of the litter from each pen was determined by an independent lab[7].

Statistical analysis: The dependent variables that were measured were weight gain, feed efficiency, ammonia-nitrogen, final litter nitrogen content, litter moisture, litter water activity and litter pH. Data were analyzed using the General Linear Model procedure for ANOVA (Statistix, 2003). In addition, a two way (SAP treatment X time) repeated measures ANOVA was performed to examine the effects of litter treatment and time on ammonia-nitrogen concentrations of the litter, litter water activity, litter moisture content and litter pH. An ANOVA was conducted with SAP litter application as the fixed effect and block and day as random effects. Significant differences among treatment means were determined using Tukey's-HSD test with a 5% level of probability. Prior to analysis by ANOVA, all data residuals were examined and met ANOVA assumptions for normality and homogenous variances.

Experimental design and treatments: Three trials were conducted using commercial male broilers. These trials used a Randomized Complete Block design using 2 or 4 treatments with 4 replicates per treatment and 5 male broilers per pen (experimental unit). A total of 80 or 40 newly hatched male broiler chicks were used for trial 1 and trials 2 and 3, respectively. Preliminary *in vitro* studies indicated that SAP levels as low as 0.5% applied to poultry litter samples, significantly lowered ammonia output compared to the ammonia output of litter with no added SAPs. However, it was considered that this low level might not be as effective under *in vivo* conditions where moisture and uric acid are constantly being added to the litter by the birds. The treatments included litter with 0%, 2%, 4% and 6% SAP resin (Hysorb®)[8] for trial 1 and 0% and 6% SAP resin for trials 2 and 3.

All pens were fed the same starter (0-21 days), grower (22-35 days) and finisher (36-42 or 49 days) diets throughout the trial. Litter samples were collected twice a week from each pen and ammonia was collected on the same day of sampling. Trials were terminated on Day 42 or 49 for trial 1 and trials 2 and 3 respectively.

RESULTS AND DISCUSSION

For all trials, adding graded levels of SAPs to poultry litter had no effect on bird performance (Table 2, 3 and 4) or mortality. However, at the end of the first trial the final nitrogen content of the litter treated with 6% SAPs (28.7 mg N/g DM) was significantly higher when compared to the other three treatments (24.3, 23.7 and 22.2 mg N/g DM for 0, 2 and 4% SAP treatment, respectively). No differences between treatments were detected in the final nitrogen content of the litter in trials 2 and 3 (Table 3 and 4).

In trial 1, using the repeated measures means for each treatment (Table 2), the 6% SAP level was the only treatment that significantly lowered ammonia volatilization throughout the entire grow-out period compared to the other three treatments (Fig. 1). The inability of the 2% and 4% SAP levels to lower ammonia volatilization may have been due to the continuous addition of moisture to the litter by the birds which may have saturated these SAP treatments sooner compared to the higher 6% SAP level thus reducing their ability to control ammonia. Additionally, the two lower levels of SAPs may have been insufficient to provide a uniform mixture of SAP in the litter. As a result only the 6% SAP treatment was used in Trials 2 and 3.

The 6% SAP treatment applied to the litter controlled ammonia volatilization throughout the time span of two broiler flocks (91 days). This control of ammonia volatilization is much longer than that of the control provided by other commercial litter amendments currently used by the poultry industry (Reece *et al.*, 1979; Moore *et al.*, 1999). Although no statistical differences were detected after the third flock of broilers between the 0 and 6% SAP treatments, there was a 33% numerical reduction in ammonia volatilization from the litter treated with the 6% level of SAPs compared to ammonia volatilization from the untreated litter. Statistical differences in ammonia levels may have been detected if more replications of these two treatments had been conducted, however the number of replications were limited due to the number of boxes used to collect the ammonia from the litter. In addition, these studies were performed in small floor pens where environmental conditions tend to be less extreme than conditions encountered in commercial poultry facilities. Therefore field studies should be conducted to investigate the capacity of these SAP products to control ammonia volatilization from commercial poultry houses, as well as, to determine the best method in which these SAPs should be applied to the litter.

Even though these SAPs are capable of reducing ammonia volatilization from poultry litter, the mode of action of this product is still uncertain. Prior to the start of these trials, it was hypothesized that the addition of SAPs to poultry litter would reduce the water activity of the litter, which would negatively impact the ability of litter microbes to produce ammonia from uric acid. However

Table 2: Trial 1 production performance of 42-d-old broiler chickens, final litter nitrogen content, ammonia-nitrogen (NH_3-N), water activity (Aw) and moisture content of litter treated with four levels of Superabsorbent Polymers (SAP)[1]

Treatments (n = 4)	Weight gain (g)	Feed efficiency	Litter nitrogen (mg)/DM (g)	mg NH_3-N/L/g litter N[2]	Aw[2]	Moisture (%)[2]
Litter with 0% SAP	2457.6	0.577	24.3^B	1,412.1^A	0.83	25.34
Litter with 2% SAP	2478.2	0.573	23.7^B	1,130.9^A	0.83	24.98
Litter with 4% SAP	2471.9	0.572	22.2^B	1,207.7^A	0.83	26.29
Litter with 6% SAP	2581.8	0.602	28.7^A	419.3^B	0.79	23.78
SEM	22.02	0.006	0.7	96.7	0.009	0.61
ANOVA	p = 0.18	p = 0.30	p = 0.002	p = 0.003	p = 0.06	p = 0.187

[1]Hysorb® 8100, BASF Corporation Charlotte, NC 28273.
[2]Repeated measures means.
[A,B]Means within a column with any identical superscripts are not significantly different at p<0.05 by Tukey's-HSD

Table 3: Trial 2 production performance of 49-d-old broiler chickens, final litter nitrogen content, ammonia-nitrogen (NH_3-N), water activity (Aw), pH and moisture content of litter treated with two levels of Superabsorbent Polymers (SAP)[1]

Treatments (n = 4)	Weight gain (g)	Feed efficiency	Litter nitrogen (mg)/DM (g)	mg NH_3-N/L/g litter N[2]	Aw[2]	pH[2]	Moisture (%)[2]
Litter with 0% SAP	2382.8	0.524	22.9	2,143.5	0.80	8.37	22.50
Litter with 6% SAP	2405.4	0.521	22.7	1,043.5	0.79	7.92	22.50
SEM	58.6	0.004	0.7	232.5	0.014	0.09	0.93
ANOVA[3]	p = 0.83	p = 0.81	p = 0.86	p = 0.04	p = 0.40	p<0.01	p = 0.98

[1]Hysorb® 8100, BASF Corporation Charlotte, NC 28273.
[2]Repeated measures means.
[3]Significant differences among treatment means were determined using Tukey's-HSD test with a 5% level of probability

Table 4: Trial 3 production performance of 49-d-old broiler chickens, final litter nitrogen content, ammonia-nitrogen (NH_3-N), water activity (Aw), pH and moisture content of litter treated with two levels of Superabsorbent Polymers (SAP)[1]

Treatments (n = 4)	Weight gain (g)	Feed efficiency	Litter nitrogen (mg)/DM (g)	mg NH_3-N/L/g litter N[2]	Aw[2]	pH[2]	Moisture (%)[2]
Litter with 0% SAP	2439.7	0.552	21.3	1,600.7	0.79	8.41	20.00
Litter with 6% SAP	2505.8	0.558	20.9	1,075.2	0.78	8.21	20.00
SEM	36.7	0.009	0.7	140.1	0.01	0.04	0.68
ANOVA[3]	p = 0.34	p = 0.39	p = 0.79	p = 0.17	p = 0.47	p = 0.04	p = 0.98

[1]Hysorb® 8100, BASF Corporation Charlotte, NC 28273.
[2]Repeated measures means.
[3]Significant differences among treatment means were determined using Tukey's-HSD with a 5% level of probability

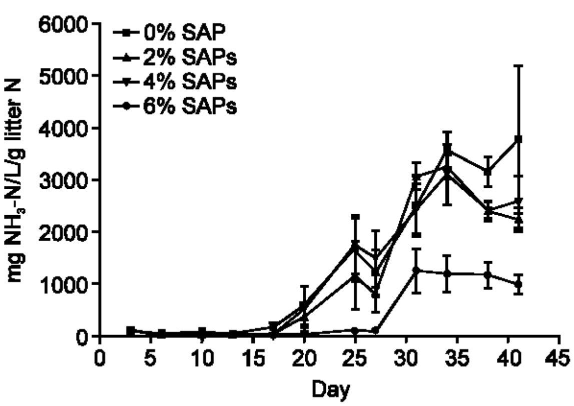

Fig. 1: Ammonia volatilization from poultry litter treated with four levels of superabsorbent polymers (Trial 1)

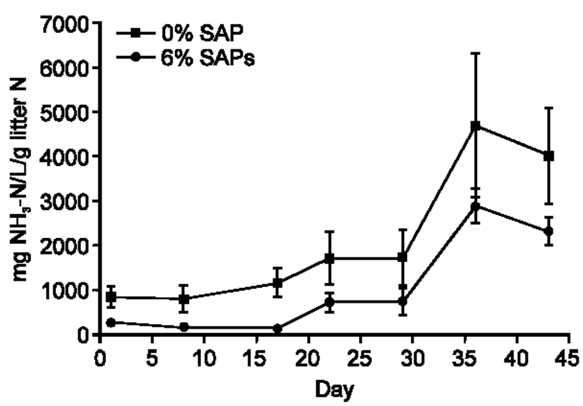

Fig. 2: Ammonia volatilization from poultry litter treated with two levels of superabsorbent polymers (Trial 2)

this was found not to be the case. The water activity was measured in all of the studies and no significant effect on water activity of the litter was detected. However, the pH of the litter that contained the SAPs was found to be significantly lower in trials 2 and 3 in which it was measured. This lower pH may explain some of the reduction in ammonia volatilization from the SAP treated litter (Lehninger *et al*., 1993), but other factors may be involved to create such a long-term reduction of ammonia. Perhaps these SAPs possess an ammonium

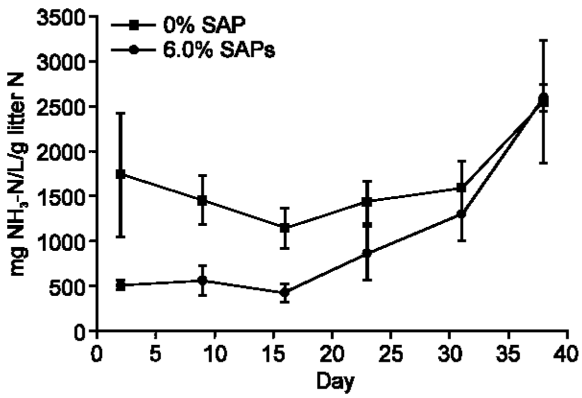

Fig. 3: Ammonia volatilization from poultry litter treated with two levels of superabsorbent polymers (Trial 3)

binding capacity which prevents the shift to ammonia under alkaline conditions. Therefore further studies are needed in order to investigate the mode of action of these polymers and their ability to control ammonia volatilization from poultry litter.

The capacity of a single SAP application to reduce ammonia volatilization from poultry litter for at least two consecutive broiler flocks, suggests that this product may improve bird health and performance due to decreased exposure to high ammonia concentrations (Quarles and Kling, 1974; Miles *et al*., 2004), which may ultimately benefit the industry economically. Other potential benefits of the application of SAPs to poultry litter include lower fuel consumption (Moore *et al*., 1999), less labor input by the grower (since SAPs would only need to be applied every other flock) and an improved working environment for the producer. As a result, field studies investigating these potential benefits are needed in order to determine if SAP application for ammonia control would offer the poultry industry an economically feasible alternative to other commercial litter amendments.

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[5]Decagon Devices, Inc., Pullman, WA 99163.

[6]Denver Instrument, Denver CO 80202.

[7] New Jersey Feed Labs Inc. Trenton, NJ 08638.

[8]BASF Corporation Charlotte, NC 28273.