THE USE OF SODIUM BISULFATE AS A BEST MANAGEMENT PRACTICE FOR REDUCING AMMONIA EMISSIONS FROM POULTRY MANURES

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Abstract

Sodium bisulfate is used extensively by commercial broiler integrators and growers in the United States, Canada, and Latin America to reduce ammonia and pathogen levels in the presence of birds as a Best Management Practice for animal welfare and bird health. This paper will discuss the usage of sodium bisulfate as a Best Management Practice for reducing ammonia emissions from both commercial broiler and commercial layer facilities and the economic benefits in bird production associated with its use. Data from an ongoing 2-yr ammonia emissions study in a broiler facility in Georgia will be presented along with data on ammonia emissions and fly control from a commercial egg facility in Pennsylvania. Also, economic data from two, large-scale (60 M birds each), complex-wide commercial field trials will be presented.

Introduction

The production of ammonia (NH_3), volatile organic compounds (VOCs) and greenhouse gases (GHG) by animal manures has received increased scrutiny by both state and national regulatory agencies and the community-at-large. These gaseous releases are produced by microbial activity on the nitrogen and carbon compounds not utilized by the animals for either maintenance or growth and excreted in the feces and /or urine (Carey, et al., 2004; Mutlu, et al. 2005). While much debate continues in the United States at the Federal level regarding both the applicability of CERCLA/EPCRA reporting limits for gases derived from animal manures and whether or not NH_3 should be defined as a precursor pollutant to PM 2.5 under the Clean Air Act (CAA), state governments and the courts, most noticeably in California, have decided to regulate gaseous emissions from animal agriculture under both environmental pollution and nuisance odor statutes.

This has left livestock and poultry producers with the need to implement effective best management practices to control both ammonia and VOCs emissions from animal housing and manure storage facilities (Dragosits, et al. 2002). This is also critical to European livestock & poultry producers as the BMPs implemented there were not enough to reach the emissions targets set in the Netherlands for the year 2000. It has been suggested that the only way to reach the target goals for NH_3 emissions ($30GgNH_3$/yr) set for 2030 in the Netherlands would be to completely eliminate all poultry & swine production and house all cattle in low-emission stables year-round (de Vries, et al. 2001). In addition, tremendous consumer focus on animal welfare has instituted strict limits on ammonia levels inside confinement animal facilities, mostly poultry & swine. Since the

current management strategies often rely on being able to exhaust as much ammonia from the house as possible, alternatives are clearly needed (Ritz, et al. 2004).
The release of ammonia from animal manure is dependent upon the amount of ammoniacal nitrogen present, pH, surface area, temperature, and the amount of urease present (Mutlu, et al., 2005; Gay and Knowlton, 2005). Therefore, for any emissions intervention to be effective, it must exploit at least one of these avenues to prevent NH_3 release into the atmosphere (Jongebreur and Monteny, 2001). VOCs are mostly derived from the bacterial degradation of manures soon after excretion (Mitloehner, 2005). Decreasing the bacterial activity in freshly excreted manures should then reduce the production & subsequent emissions of VOCs.

Sodium Bisulfate Characteristics

Sodium bisulfate (SBS) is a dry, granular acid salt that has been used for many years as a pH reducer in a variety of agricultural, industrial, and food applications. The anti-bacterial properties of sodium bisulfate have been exploited in its application as a toilet-bowl sanitizer (i.e. EPA Reg #1913-24-AA) and as a preservative in EPA method #5035 "Closed-System Purge-and-Trap & Extraction for Volatile Organics in Soil & Waste Samples," to prevent microbial activity leading to VOC release. These properties along with the safety and ease of use of SBS have led to its use for ammonia binding (Fig.1) and bacterial reduction in poultry, dairy, and equine manure and bedding materials (Ullman, et al., 2004; Blake and Hess, 2001; Sweeney, et al., 1996; Harper, 2002). Currently, 30-40% of all broilers produced in the United States are raised on SBS treated litter (PLT® litter acidifier, Jones-Hamilton Co., Walbridge, OH) for the purpose of controlling interior ammonia levels and reducing litter bacterial levels for bird welfare and performance reasons. Additional research is ongoing to modify the current SBS-BMP used for production purposes to a BMP that maximizes ammonia emissions reductions in poultry & dairy, VOC emissions reductions in dairy, and fly control in egg-layers using SBS. Sodium bisulfate has been widely tested to establish efficacy as both an ammonia controlling agent and a bacterial reducer.

100 lbs. Of SBS Binds 14 lbs. NH_3								
2 $NaHSO_4$	+	$2NH_4OH$	$\longrightarrow$	$(NH_4)_2SO_4$	+	Na_2SO_4	+	$2H_2O$
100 lbs.		29 lbs.		55 lbs.		59 lbs.		15 lbs.

Figure 1. Binding of Ammonia by SBS to produce Ammonium Sulfate

Ammonia emission from animal housing is calculated by multiplying ammonia concentration by airflow. The use of SBS reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. Sodium bisulfate is hygroscopic. As water is adsorbed into the SBS bead from the humidity in the air, the SBS is dissolved into its Na^+, H^{+}, and $SO_4^{=}$ constituents. The hydrogen ion reduces the pH of the litter and protonates the ammonia molecule. The resulting ammonium is then bound by the sulfate component. This formation of ammonium sulfate is non reversible therefore the nitrogen in the litter is not released as the pH increases (Ullman, et al., 2004). This is illustrated in work done by Mitloehner et al (publication pending) on the effect of SBS on dairy manure slurry. At 72 hrs post-SBS application, slurry pH ranged from 7.68 – 9.00 with no significant differences between treatments (Fig. 2).

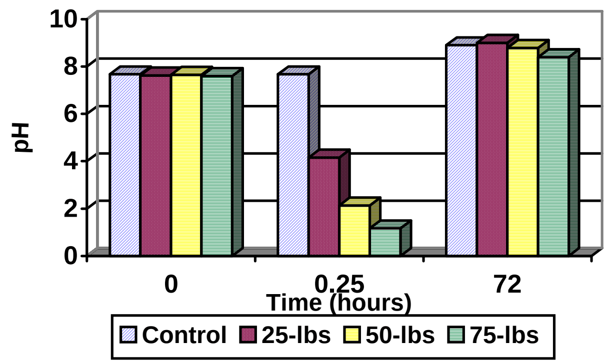


Figure 2. pH readings of dairy slurry treated with SBS (lbs/1000 sqft) over time.

Most interestingly, NH_3 flux at 72 hrs was still substantively decreased over control even though pH levels between treatment groups were not significantly different and most were above a pH of 8.0. This indicates that the ammonia being produced by the slurry is being converted to and retained as ammonium sulfate and is not released as pH rises.

The sodium and hydrogen ions of SBS exert negative pressure on the bacterial populations of the litter; decreasing total aerobic population counts 2-3 logs (Pope and Cherry, 2000). This may also serve to decrease urease concentration in the litter for additional ammonia reductions (Ullman, et al., 2004). Once the ammonia concentration at bird level has been reduced, the poultry houses can be minimally ventilated for relative humidity control as they were designed rather than over-ventilated for NH_3 removal (Czarick and Lacey, 1998).

SBS Use in Poultry- Literature Review

Reduction of ambient ammonia levels in broiler housing has been demonstrated in a variety of studies. Pope and Cherry (2000) applied PLT® litter treatment 12-24 hours prior to bird placement at a rate of 2.27 kg/9.29m^2 in three houses each on two 12-house farms. The average litter pH was 1.2 in the houses treated with PLT compared with 8.0 in the untreated controls. Ammonia levels were 90% lower post PLT application with an average of 6.2 PPM of NH_3 in the treated houses and 62.3 PPM in the control houses. Two weeks after application, the ammonia levels in the treated houses were still reduced by 50% compared to control houses. In the winter of 1996, 200 commercial broiler houses were studied in Delaware and Maryland by Terzich (1997) with 100 houses treated with PLT® and 100 houses serving as control. Ammonia levels averaged 127 PPM pre-treatment and were all 0 PPM post-treatment (Table 1). Consequent to the improved air quality, bird performance was significantly improved in the treated houses (1,282,256 birds) with better mortality rates, average weights, average daily gain, and percentage of respiratory lesions at processing compared to controls (1,219,918 birds). Fuel usage was also reported to be 43% less in the treated houses. At a cost of $120/house for the PLT® litter treatment, the resulting production increases and fuel savings provided the producer

Table 1. Average ammonia levels and litter pH values in 100 houses in which litter was treated with sodium bisulfate compared with 100 houses that were untreated controls.

		Pre-Treatment	Post-Treatment	Time (weeks)						
				1	2	3	4	5	6	7
Ammonia (PPM)	Treated	127	0	0	5	8	15	19	20	18
	Control	119	119	125	125	138	114	128	98	97
Litter pH	Treated	8.5	1.7	2.1	3.4	4.5	5.0	5.5	5.9	6.4
	Control	8.9	8.9	8.7	9.1	8.5	9.3	8.6	8.1	8.9

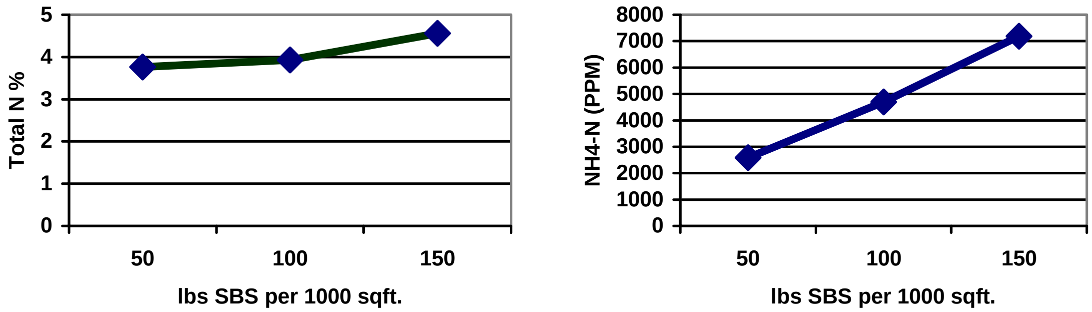
with a substantial return on investment that would support increased PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998; Terzich et al, Apr 1998).

Current SBS Research in Poultry

A one-year NH_3 emissions study on a broiler farm in Georgia is currently being conducted by the Poultry Science and Biological & Agricultural Engineering Departments at the University of Georgia. Three of the broiler houses on a 6-house farm in Northeast Georgia are receiving PLT® litter acidifier at 50, 100, or 150 lbs. per 1000 sq ft over the entire area of the house (20,000 sq ft). Based on empirical calculations, 140, 280, and 420 lbs. of NH_3 should be bound per flock at the 50, 100, and 150 lbs. PLT per 1000 sq ft treatment levels, respectively. This farm averages 5.5 flocks per year.

House temperature, relative humidity and ventilation rates are being monitored by the computer controller in each house. The ventilation management is identical for each house regardless of treatment in order to simplify data analysis. Normally, ventilation rates would be adjusted based on ammonia and relative humidity levels in each house. A house with lower ambient ammonia levels would have reduced ventilation at a rate sufficient to maintain proper relative humidity within the house.

The initial experimental design called for the use of Dosi-tubes two days a week to establish a time weighted average as well as the use of Drager-Pac III electrochemical sensors to evaluate ammonia levels. Due to the lack of reliability of these sensors in a dry-litter broiler house, the rate of ammonia leaving the house is now being evaluated using litter nitrogen retention analysis (Carey, et al., 2005; Keener and Michel, 2005). Given that the amount of nitrogen entering the system (birds, feed, & sawdust litter) is identical for all three houses, increases in the amount of nitrogen retained in the litter are indicative of a decrease in the amount of ammonia being exhausted from the house. After 3 flocks, a linear increase is evident in both N and NH_4-N retained in the litter as the amount of PLT applied is increased (Fig. 3 & 4). The higher amounts of retained nitrogen in the litter of the 150-lb. treatment group, indicates a reduction in ammonia emissions in this house over the lower treatment rates based on the mass-balance model. Interestingly, total phosphorus levels were 20% lower in the 100 lb. & 150 lb. houses when compared to the 50 lb. house. The mechanism for the decrease in total phosphorus is mostly likely through dilution due to the level of amendment added.



Figures 3 & 4. Amount of retained Total Nitrogen and NH4-N in broiler litter after three flocks of SBS usage on re-used litter.

Patterson, et al. (2006) recently completed a study in a high-rise commercial egg-layer facility to evaluate the use of PLT litter amendment for the reduction of ammonia and flies. PLT® was applied either at the rate of 0.97 kg/m^2 or 1.95 kg/m^2 on eight separate occasions during two 45-day experimental periods on a central row in the pit area of the house. A third row was left untreated as a control. Because layer manure does not contain a plant substrate, as does broiler litter, the moisture and ammonia content tend to be greater. Repeated applications of a litter amendment at higher rates are often necessary before significant changes in manure characteristics are observed. The same observations were made in this study where the higher rate of PLT showed the most consistent decrease in ammonia emissions (ppm/sec) with emission rates significantly lower than the control row on three out of the five sampling periods (0.2178, 0.8394, and 0.6435 for the high-treated vs. 0.6140, 0.9883, and 1.1863 for the controls respectively). Similar results were seen for the rate of Ammonia Linear Flux ($mg/cm^2/min$). As in the UGA study, manure ammonium (NH_4^+) nitrogen and P_2O_5 were positively altered by treatment group with the high-rate treatment group having the highest level of retained nitrogen and the lowest level of P_2O_5 (table 2).

Table 2. Commercial Layer Manure Analysis after 8 PLT® treatments over a 45-day period

Treatment	Total N (lbs/ton)	NH_4-N (lbs/ton)	Total Phosphate (P_2O_5) (lbs/ton)
Control	38.37^{b}	11.08^{c}	71.63^{a}
PLT-150	40.50^{ab}	13.75^{b}	62.38^{b}
PLT-300	46.08^{a}	17.06^{a}	55.48^{c}
P-value	0.0551	<0.0001	0.0004

Economics of SBS Use in Poultry

Multiple field demonstrations of PLT litter amendment use in commercial poultry complexes have also documented the economic benefits of using PLT® litter acidifier. Two field demonstrations completed in 1999 are discussed here.

A commercial broiler complex in the Southeast raising both a large (7.0 lb. or 3.2 kg) and small (4.5 lb. or 2.05 kg) bird evaluated the economic and performance benefits of using litter amendments from January – August 2000. Contract growers were given a choice of either using PLT® or an alum litter amendment (Al+Clear, General Chemical Corp., Parsippany, NJ) at the rate of 2.27 kg/9.29m^2 (50 lbs. /1000 sq ft) in the brood chamber (10,000 sq ft). Eighty-seven percent of the big bird growers and eighty-two percent of small bird growers chose PLT. The remaining thirteen percent of the big-bird and eighteen percent of the small-bird growers chose to use alum in an identical manner to the PLT. A total of 43.9 million birds were evaluated in this demonstration. The variety of housing and management types were similar between the treatment groups. Both the small and large bird groups raised on PLT substantially out performed the birds raised on alum (table3). In a complex of this size, the general rule of thumb used in the U.S. poultry industry is that an improvement in feed conversion of 0.01 lbs. of weight gain / lb. of feed consumption is worth $1 Million per year (Agrimetrics Associates, Inc., Midlothian, VA). The large birds raised on PLT had a feed conversion improved by 0.02 and the feed conversion of the small birds was improved by 0.04 over the birds raised on alum. This reduced performance shown by the birds raised on alum is consistent with production losses due to ammonia exposure reported in the literature (Miles, et al., 2004). This resulted in a net return of $2.7 million /yr over the cost of PLT ($305,000) on improved feed conversion alone in that complex. Additional economic benefit would have also been realized by the grower and the poultry integrator from the increases in weight and livability observed in this trial. The monetary return on investment observed would easily support an increased PLT application rate for the objective of ammonia emissions control. Similar results were achieved in another complex in the South-Central part of the U.S. where the same rate of PLT application was compared with untreated litter (table 4). The economic viability of the use of PLT for reducing ammonia emissions is the reason why so many poultry growers have voluntarily adopted this BMP.

Table 3. Production Data from Southeast Commercial Broiler Complex for all flocks raised on either SBS or alum from January-August 2000.

Bird Size	Performance Parameter	SBS	Alum
Large (7.0 lb/3.2 kg)	Total Number of Birds	19, 086, 816	2,846,212
	Livability (%)	88.86[1]	87.66
	Feed Conversion	2.27	2.29
	Weight (lbs)	6.92	6.81
	Condemnation (%)	1.77	2.11
Small (4.5 lb/2.05 kg)	Total Number of Birds	18,091,297	3,869,792
	Livability (%)	93.2	92.06
	Feed Conversion	2.05	2.09
	Weight (lbs)	4.52	4.5
	Condemnation (%)	1.07	1.99

[1] Includes Three flocks with livability <20% due to an ice storm and subsequent roof collapse

Table 4. Production data from South-Central Commercial Broiler Complex for all flocks raised on either SBS or untreated litter from October, 1999-March, 2000.

Performance Parameter	Untreated Control	SBS-Treated
Total Number of Birds Placed	9,101,579	9,921,203
Age (days)	40	39
Weight (lbs)	3.87	3.88
Livability (%)	96.73	96.84
Condemnation (%)	0.34	0.32
Feed Conversion	1.87	1.85

Summary

The use of sodium bisulfate as a best management practice for the reduction of ammonia release by the bacterial degradation of animal manures is well documented. The profitable economics of its use in commercial broiler operations is well recognized and has resulted in the voluntary adoption of this BMP by a substantial portion of the U.S. broiler industry. Its safety profile and the ability to apply SBS in the presence of animals should allow for the adaptation of this BMP to many other animal species.

Footnote

PLT® is a registered trademarks of Jones-Hamilton Co., Walbridge, OH.

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