Global Journal of Scientific Researches

Available online at gjsr.blue-ap.org

©2013 GJSR Journal. Vol. 1(2), pp. 42-47, 12 December, 2013

Removal of Ammonia Gas Emission from Broiler Litter

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Received: 22 November, 2013 *Accepted: 30 November, 2013* *Published: 12 December, 2013*

A B S T R A C T

Microbial mineralization of urea and uric acid in poultry litter results in the production of ammonia, which can lead to decreased poultry performance, malodorous emissions, and loss of poultry litter value as a fertilizer. The experiment was conducted to test the validity of novel amendments to reduce the presence of these ammonia producing microbes and reduce ammonia emissions from poultry houses. The experiment was consisted of 4 treatments x 2 replication, each 150 broiler chicks of both sexes per pen (treatment A: 2% Sodium perborate, treatment B: 2% TiO2 Photocatalyst and treatment D: 2% TiO2 + 0.25 % Paraformaldehyd granules). The results revealed that:1) Sodium perborate treatment reduced the total bacterial population by 2 log within 2 wk and ammonia concentrations were 20,15,18,15,20,25,25 and 20 mg/m3 at 7,14,20,25,30,35,40 and 45 days of the cycle period, respectively 2) TiO2 Photocatalyst of the poultry litter resulted in >2 log decreases in total fungal concentrations, and bacterial decreasing by >3 logs within the first 2 to 3 wk of the litter treatment as well as delayed mineralization events for both uric acid and urea (ammonia concentrations were 15 and 25 mg/m3 at,40 and 45 days ,respectively). 3) Ammonia concentrations in TiO2 + Paraformaldehyde granules treated group were significantly ($P< 0.05$) lower than in the control and other treated groups. Ammonia concentrations were 10 mg m3 up to 35 days and slightly increased to 15 mg/ m3 up to 45 days of the cycle period.

Keywords: *Gas, Broiler Litter, Emission.*

INTRODUCTION

Ammonia or azane is a compound of nitrogen and hydrogen with the formula NH_3. It is a colorless gas with a characteristic pungent smell that irritates the eyes and respiratory system and can reduce resistance to infection in poultry. At high-enough concentrations (above 10 ppm), ammonia will reduce feed efficiency and growth while increasing mortality and carcass condemnations. The result is economic loss to the grower and integrator.

Environmental ammonia inside broiler houses arises from the microbial breakdown of uric acid of the excrements (Carlile, 1984). The efficiency of this conversion is affected by different factors as temperature, PH and moisture of the litter, properties of bedding material or ventilation flow and management techniques (Elliott and Collins, 1982; Patterson and Adrizal, 2005). Increased moisture levels promote proliferation of microorganisms in the litter, increasing the production and volatilization of ammonia (Groot Koerkamp *et al.,* 1999; Al Homidan et al., 2003; Oviedo, 2005).

Due to the volatile and water-soluble nature of ammonia, it can be dissolved into the mucous membranes of the respiratory epithelium and eyes of animals, being responsible for the onset of sneezing, dyspnoea, inflammation of the air sacs, respiratory diseases and keratoconjunctivitis (Carlile, 1984). Further investigations suggested that lung diseases, as well as inhalation of airborne irritants such as ammonia, result in reduced pulmonary gas exchange causing also an exacerbation of ascites (Charles and Payne, 1966). Indeed, Scheele *et al.,* (1991) reported that broilers with respiratory infections are more susceptible to ascites and have decreased capacities for O_2 consumption when compared with their disease-free counterparts. Some studies even reported higher mortality and lower feed consumption (Carlile, 1984; Miles, 2004), lower vaccine response (Caveny, 1981) or increased disease susceptibility (Beker et al, 2004). Therefore, high levels of ammonia in farm inner environment may have a negative effect on animal health, reducing also, the performance of broilers (Kristensen and Wathes, 2000; Miles et al., 2002, 2004; Beker et al, 2004).

Broiler and turkey litter typically consists of wood shavings, rice hulls, or peanut hulls. Uric acid and organic nitrogen (N) in the bird excreta and spilled feed are converted to ammonium (NH_{4+}) by the microbes in the litter. Ammonium, a plant-available N form, can bind to litter and also dissolve in water. Depending on the moisture content, temperature, and acidity of the litter, a portion of the ammonium will be converted into ammonia (NH_3). Ammonia production is favored by high temperature and high pH (i.e., alkaline conditions).

Several investigators (McCrory and Hobbs, 2001; Blake and Hess, 2001; Sanjay Shah et al., 2006) studied the effect of chemicals on poultry litter and litter treatments to reduce ammonia and/or bacterial populations. Selecting the best litter treatment is dependent on matching the characteristics of the product with treatment goals. The acidifying litter treatments currently dominate the market due to their efficacy in reducing ammonia and lowering litter pH which aids in suppressing microbial populations. Maintaining desirable litter moisture and reducing litter pH are two means frequently used to reduce ammonia volatilization (and bacterial populations) in used litter. Chemical, microbial and enzymatic litter treatments are being used to reduce ammonia and/or bacterial populations (Bud, 2006).

Objective

Test the validity of some new compounds as amendments in reducing the emission of ammonia gas from poultry litter and houses.

MATERIALS AND METHODS

Birds and Diets

These experiments were conducted from January to March of 2011. A total 1200 of commercial one day-old Hubbard chicks of both sexes were used, at the poultry facilities located in broiler farm. Four identical experimental rooms (Room 1, 2, 3 and 4; 4.5 x 2.5 m.) were used for this purpose.
The concrete floor of the rooms was covered with a 10 cm depth straw shavings litter.
Three of the rooms were subjected to treatment (1, 2 and 3) and the other one (4) was used as control (C) room. The birds were reared during a 45-day cycle.

Housing conditions simulated those found in most commercial farms (opened system). Each room was equipped with 4 feeders and 15 drinkers (distributed in 2 and 3 lines, respectively). Temperature and relative humidity (RH) were maintained according to breeder's recommendations and lighting regime varied gradually from a 23:1 scheme (23 hours of light and 1 hour of darkness) during the first three days to a 24 scheme. Feed and water were provided *ad libitum* throughout the experiment. Two different types of feed were used: starter feed, used from day 0 to day 21 and grower feed, from day 21 to day 45.

The chicks were brooded between 31 and 32°C on wk 1, and the temperature was lowered gradually each week until 24 to 27°C was achieved. The composition of the basal diets is presented in Table 1. Routine management, vaccinations and medications were administered according to methods of Oluyemi and Roberts, (1979).

Table 1. *Composition of basal diets (%)*

Ingredients	Starter (0 – 21 d)	Finisher (22 – 42 d)
Yellow corn	50.86	58.66
Corn gluten	5.00	3.00
Soybean meal	35.0	30.00
Soy oil	5.80	5.00
Dicalcium phosphate	2.50	2.50
Lime stone	0.13	0.13
Common salt	0.33	0.33
DL-Methionine	0.05	0.05
L-lysine	0.03	0.03
Broiler premix[1]	0.30	0.30
Nutrient Profile:		
ME (kcal/kg)	3184.21	3187.81
Crude protein%	22.82	20.00
C / P ratio	139.5	159.4
Crude fat%	7.3	6.1
Crude fibre%	4.3	4.8
Total ash%	6.1	6.2
Calcium%	0.9	0.9
Non-phytate phosphorus%	0.46	0.48

[1] Supplied per kilogram of diet: vitamin A, 10000 IU; vitamin D_3 , 9790 IU; vitamin E, 121 IU; B_{12}, 20 µg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 µg; thiamin, 4 mg; zinc sulfate, 60 mg; manganese oxide, 60.

Experimental

The experiment was conducted to test the validity of novel amendments to reduce the presence of these ammonia producing microbes and reduce ammonia emissions from poultry houses. The experiment was consisted of 4 treatments x 2 replication, each 150 broiler chicks of both sexes per pen.

Experimental treatments: Experimental treatments were:
Treatment A: 0.2% Sodium perborate, $Na_2H_4B_2O_8$.
Treatment B: 0.2% TiO_2 (nanotitanium oxide:15 nm diamter) Photocatalyst.
Treatment D: 0.02% TiO_2 (nanotitanium oxide: 15 nm diamter) Photocatalyst + 0.25 % Paraformaldehyd granules.
Treatment C: Nontreated poultry litter.
Samples of the litter were taken weekly from each room, according to the protocol proposed by Tasistro et al., (2004) and were analyzed for**:**

1. Ammonia gas emission (mg\ m^3) Ammonia gas emission (mg\ m^3).Ammonia gas levels were measured by Bellows and gas Detection Tubes.
2. Total bacterial count (cfu gm^{-1}) (A.P.H.A.,1984)
3. Total fungal count (cfu gm^{-1}) (A.P.H.A.,1984)

PH of poultry litter (Brake et al.,1992)

RESULTS AND DISCUSSION

Microbial mineralization

Microbial mineralization of urea and uric acid in poultry litter results in the production of ammonia, which can lead to decreased poultry performance, malodorous emissions, and loss of poultry litter value as a fertilizer (Rothrock et al., 2008).

The results in Table 2 revealed that, nontreated poultry litter had relatively high total bacterial count (10^8 cfu g^{-1} litters) and 10^6 cfu g^{-1} itter of fungal populations. Sodium perborate treatment reduced the total bacterial population by 2 log_{10} within 2 wk and increase fungal population by 2 log_{10} within 3-4 wk than in non-treated litter (10^6 c f u g^{-1} litter). Sodium perborate is useful because it is a stable, nontoxic source of peroxide anions. When dissolved in water it forms some hydrogen peroxide, but also perborate anion [B (OOH) (OH) $_3^-$] which is activated for nucleophilic oxidation.

(TiO_2) Photocatalyst of the poultry litter resulted in >2 log_{10} decreases in total fungal concentrations, and bacterial decreasing by >3 l log_{10} within the first 2 to 3 wk of the litter treatment. TiO_2 Photocatalyst resulted in delayed mineralization events for both uric acid and urea respectively) .Once bacterial cell concentrations decreased the activity of these bacterial populations will be decreased and ammonia volatilization will be reduced . Photocatalyst can effectively decompose harmful pollutants such as formaldehyde, benzene, toluene, dimethylbenzene, ammonia and TVOC, with wide-spectrum sterilizing effect, capable of killing and inhibiting bacteria, fungi and viruses.

Table 2. Effect of the new amendments on ammonia emissions, microbes producing ammonia and PH of treated poultry litters

Agents	Sodium perborate[1]				TiO_2 + Paraformaldehyd granules[2]				TiO_2 Photocatalyst[3]				Untreated[4]			
Parameters	PH	Log_{10}		NH_3	PH	Log_{10}		NH_3	PH	Log_{10}		NH_3	PH	Log_{10}		NH_3
Days		FC	BC			FC	BC			FC	BC			FC	BC	
7	6.5	0	0	20	5.5	0	0	10	6.5	2	2	15	7	0	0	20
14	5.8	0	2	15	5.5	2^{+2}	2	10	6.5	2	2	20	7.8	0	1	35
20	6.2	2^{+2}	2	18	4.5	2^{+2}	2	10	6.5	2	3	20	8	1	1	40
25	6	2^{+2}	3	15	5.5	2^{+2}	3	10	6.5	2	3	20	8	2	0	45
30	6	2^{+2}	3	20	4.5	2^{+2}	3	10	6.5	2	3	20	7.8	2	0	60
35	5.8	2^{+2}	3	25	5	2^{+2}	3	10	6.5	2	3	25	8.1	2	0	65
40	5	2^{+2}	3	25	6.5	2^{+2}	2	15	6.5	2	3	20	8.5	2	0	88
45	6	2^{+2}	3	20	6.5	2^{+2}	2	15	6.5	2	2	25	8.8	2	0	120

1:Treatment A: 0.2% Sodium perborate, $Na_2H_4B_2O_8$;2: Treatment B: 0.02% TiO_2 (nanotitanium oxide:15 nm diamter) Photocatalyst + 0.25 % Paraformaldehyd granules ;3: Treatment D: 0.2% TiO_2 (nanotitanium oxide:15 nm diamter) Photocatalyst;4: Treatment C: Nontreated poultry litter.FC: Total fungal count (cfu gm^{-1});TC: Total bacterial count (cfu gm^{-1}); NH_3: Ammonia gas emission (mg\ m^3)

PH of litter

The decrease in pH (> 6.5) produced by Sodium perborate, TiO_2 Photocatalyst and TiO2+ Paraformaldehyd granules treatment are believed to inhibit bacterial populations.

The poultry build up litter has an average pH of 8.0 – 9.0, this is considered a high pH or alkaline. The pH can influence the ammonia volatilization. Ammonia release from litter is reduced when litter pH is below 7; emission exceeds when pH is 8 and above. At litter pH lower than 4.6, the economically devastating bacteria like *E.coli, Salmonella, Clostridium, and*

Campylobacter do not grow. Respiratory tract is the first to be affected. Birds become prone to variety of respiratory infections such as CRD coupled with E coli etc. Ammonia gas in poultry houses is also regarded as one of the contributing causes of Ascitis in fast growing broilers. So right solution is sanitization of litter with litter conditioner which drastically lowers pH of the litter to become acidic and environment friendly too.

These amendments (Sodium perborate, TiO_2 Photocatalyst and TiO_2+ Paraformaldehyd granules) create acidic conditions (pH less than 7) in the litter, resulting in more of the ammoniacal-N being retained as ammonium rather than ammonia. The acidity also creates unfavorable conditions for the bacteria and enzymes that contribute to ammonia formation, resulting in reduced ammonia production. These amendments (Sodium perborate, TiO_2 Photocatalyst and TiO_2+ Paraformaldehyd granules) have wide-spectrum of sterilizing or antimicrobial effect that leads to a state of equilibrium among microbial populations of mineralization as well as the ability to decompose ammonia in poultry litter.

Acidifying additives that reduce the pH of the litter can greatly reduce ammonia volatilization. Potential treatments include acids, base precipitating salts, and labile carbon (McCrory and Hobbs, 2001). A number of acids can be used to decrease manure pH, but problems that deter their use include high cost, corrosiveness, and hazards to animal and human health. Many different types of acidifiers, such as alum, sodium bisulfate, ferrous sulfate, and phosphoric acid, were found to be effective in controlled studies. However, some acidifiers are not recommended for use in poultry houses for reasons such as bird toxicity (ferrous sulfate) or increased phosphorus (P) levels in the already P-rich litter (phosphoric acid).

Ammonia emission

The concentrations of ammonia, as shown in Table 2 and Figure 1, in the C room were 20, 35, 40, 45, 60, 65, 88 and 120 mg/m^3 at 7,14,20,25,30,35,40 and 45 days of the cycle period, respectively. This distinctive feature of ammonia concentrations pattern was that it started to increase sharply at the end of the cycle. This could be because of an increment in ammonia production as litter pH approaches more than 7.0 (Reece et al., 1980; Elliot and Collins, 1982; Carr et al., 1990). Besides, as environmental RH rises, ammonia levels may also increase (Weaver and Meijerhof, 1999).

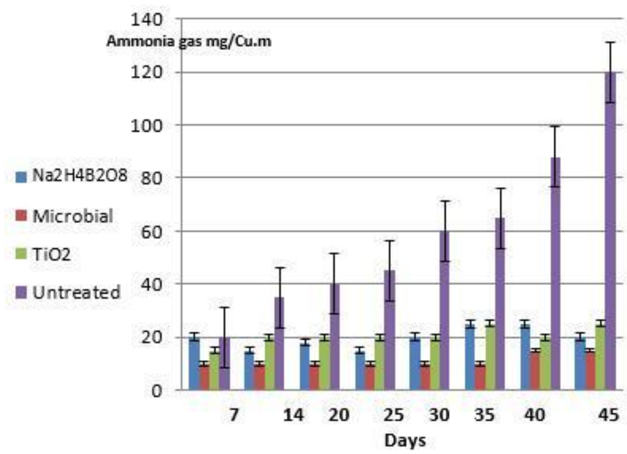

Figure 1. Effect of the new amendments on ammonia emissions of treated poultry litters

On the other hand, this harsh increase of environmental ammonia did not take place at the same moment in the treated groups.

Ammonia concentrations were 20,15,18,15,20,25,25 and 20 mg/m^3 at 7,14,20,25,30,35,40 and 45 days of the cycle period, respectively in $Na_2H_4B_2O_8$-treated group.

Ammonia concentrations in TiO_2 + Paraformaldehyde granules treated group were significantly *($P>0.05$)* lower than in the control and other treated groups. Ammonia concentrations were 10 mg $/m^3$ up to 35 days and slightly increased to 15 mg $/m^3$ up to 45 days of the cycle period. Paraformaldehyde granules depolarized into formaldehyde which induced antibacterial and antifungal agent and reacted with ammonia gas and form hexamine or decomposed by TiO_2 Photocatalyst into water and CO_2.

In TiO_2 Photocatalyst-treated group, ammonia concentrations were 15,20,20,20,20,25,20 and 25 mg/m^3 at 7,14,20,25,30,35,40 and 45 days of the cycle period, respectively. Clays such as bentonite and sepiolite have been largely studied since they show catalytic or adsorptive properties. As far as adsorptive properties are concerned, bentonite has been used to remove a number of chemical species: ammonium and ammonia (Bernal and Lopez-Real, 1993). TiO2 has been the photocatalyst of choice due to its photostability, non-toxicity, red-ox efficiency and availability.

The concentrations of ammonia gas in the three trials were below the threshold which may affect human wellbeing and welfare and productive parameters in broilers, settled at 17 - 25 mg/m^3 (ppm) of ammonia by Al-Homidan et al, (2003), Carlile, (1984) and the CIGR, (1992).

Deleterious effects of ammonia depend on its concentration to which the birds get a prolonged exposure. Even lowest concentration of 10 - 20 ppm hampers the performance of bird.

Our results confirmed that, acidification of the poultry litter resulted in increase of total fungal concentrations, with both uricolytic (uric acid degrading) and ureolytic (urea degrading) fungi increasing by >2 logs within the first 2 to 4 wk in the litter. Conversely, total, uricolytic, and ureolytic bacterial populations all significantly declined during this same time period. While uric acid and urea mineralization occurred within the first 2 wk in the untreated control litter, acidification resulted in delayed mineralization events for both uric acid and urea (2 and 4 wk delay, respectively) once fungal cell concentrations exceeded a threshold level. Therefore, fungi, and especially uricolytic fungi, appear to have a vital role in the mineralization of organic N in low-pH, high-N environments, and the activity of these fungi should be considered in best management practices to reduce ammonia volatilization from acidified poultry litter (Rothrock et al., 2010).

Acidifying additives that reduce the pH of the litter can greatly reduce ammonia volatilization. Potential treatments include acids, base precipitating salts, and labile carbon (McCrory and Hobbs, 2001). A number of acids can be used to decrease manure pH, but problems that deter their use include high cost, corrosiveness, and hazards to animal and human health. Many different types of acidifiers, such as alum, sodium bisulfate, ferrous sulfate, and phosphoric acid, were found to be effective in controlled studies. However, some acidifiers are not recommended for use in poultry houses for reasons such as bird toxicity (ferrous sulfate) or increased phosphorus (P) levels in the already P-rich litter (phosphoric acid).

CONCLUSIONS

The concentrations of ammonia gas in the three trials were below the threshold which may affect welfare and productive parameters in broilers. In These amendments (Sodium perborate, TiO_2 Photocatalyst and TiO_2+ Paraformaldehyd granules) have wide-spectrum of sterilizing or antimicrobial effect that leads to a state of equilibrium among microbial populations of mineralization as well as the ability to decompose ammonia in poultry litter.

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