# Evaluation of Air and Litter Quality with Microbiological Fluctuations in Commercial Broiler Facilities Using a Biological or Chemical Litter Treatment

by

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## Abstract

Litter Guard (LG) is a recently introduced poultry litter amendment consisting of a blend of different bacteria and soluble humates. LG is believed to reduce the ammonia emission rates and the concentration of bacteria in poultry litter. Poultry Litter Treatment (PLT) is a commonly used chemical litter amendment and is proven to reduce the pH and ammonia emission rates in poultry litter. Thus a comparative field study was conducted to evaluate the efficacy of LG compared to PLT in reducing ammonia and microbial load in poultry litter over three consecutive broiler flocks.

Six commercial broiler houses (12.2 × 152.4 m) were screened for three consecutive flocks. Three houses were treated with LG 7 d before bird placement; 18.9L in 378.5 L water throughout the entire house. The other three houses were treated with PLT, 24 h before bird placement; applied in the central brooding area at the rate of 24.4 kg/100$m^2$. For all three flocks litter samples were collected before application of treatments and at approximately 1, 8, 15, 22, 29, 36 and 43 d of age at four equidistant locations in each house. Litter samples were analyzed for pH, water activity, moisture and microbiological analysis. Microbiological analysis included enumeration of total aerobic, anaerobic, enteric, *Cl.perfringens* and *E.coli* (cfu/gm). Concurrent with litter sample collection a Drager CMS analyzer was used for ammonia measurements. At the time of each flock's processing five hundred paws were collected from each house and lesion scored. Results showed that PLT application significantly ($P < 0.05$) decreased ammonia levels on d 1 compared with LG (37.9 vs. 59.4 ppm), but PLT was unable to maintain low levels after d

8. Litter sample pH levels were significantly reduced ($P < 0.10$) by PLT on d 1 compared with LG (7.91 vs. 8.43). Whereas LG application gradually decreased pH until d 22, showing a gradual rise thereafter. This delayed affect on pH may be related to the increased bacterial potential of the LG application with time.

Aerobic bacterial counts were significantly decreased ($P < 0.10$) by PLT on d 22 compared with LG application (8.78 vs. 9.22) on all three trials. Anaerobic counts were significantly reduced ($P < 0.10$) by PLT on d 22 compared with LG (6.76 vs. 6.96) on all three trials. PLT may have contributed to a reduction in the growth potential of these two microorganisms after a given period of exposure. *Cl.perfringens,* enteric and *E.coli* counts fluctuated for the duration of the experiment. Footpad dermatitis assessment results indicate no detrimental effects attributed to either litter treatment. Compared to PLT, LG was less effective in maintaining low ammonia levels and both treatments were ineffective in maintaining bacterial levels.

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## General Introduction

Three important factors controlling poultry health are management, nutrition and pathogen load. Poultry diseases are the leading cause for substantial reduction in production and are primarily influenced by the ambient climate in poultry houses. Ammonia is a colorless gas generated in poultry houses by the decomposition of poultry litter by ureolytic bacteria. High moisture and temperature promote bacterial growth and ammonia production. Ammonia is responsible for causing severe health effects including respiratory problems and severe footpad dermatitis. Poultry litter also hosts a variety of bacterial species, which can cause a number of diseases. Some gastrointestinal diseases and respiratory diseases are found conditions caused by various bacterial species acquired through the litter.

Several strategies have been applied to reduce ammonia production and bacterial load in poultry litter ranging from mechanical litter manipulation, chemical treatment to biological treatments. Chemical litter amendments have been the most common choice to reduce ammonia emission and bacterial load in the commercial poultry facilities. This is due to their high and immediate effect on poultry litter ammonia emissions. Poultry Litter Treatment (PLT) is a common chemical litter amendments used in commercial poultry. Since PLT is a known to be a highly effective litter amendment, it is used in this comparative study. Litter Guard (LG) is a newly introduced biological litter amendment to reduce ammonia emission rates and bacterial load in poultry litter. LG is a blend of bacterial species that reduce the ureolytic bacteria that produce ammonia in poultry litter. LG also reduces the total bacterial count of poultry litter thereby potentially reducing the rate of infection to birds and reducing disease conditions

## Review of literature

Health of poultry is compromised by several factors that include but are not limited to nutrition, pathogen load and management. The factor that has been overlooked several times is the environment in which the birds are raised. There has been an increasing awareness among the general community regarding the microenvironment in which birds are raised. According to the National Chicken Council (2003) welfare guidelines for broilers, the maximum level of ammonia in a poultry house at the height of birds should not exceed 25 parts per million (ppm). According to the National Institute of Occupational Safety and Health (NIOSH, 1977) the maximum levels of ammonia are set to 25 ppm and Occupational Safety and Health Administration (OSHA) has a maximum limit of 50 ppm for human being working in poultry farms for a period of 8 hours in USA (OSHA Guidelines, 1991). High levels of ammonia have a negative effect on weight gain, feed conversion, livability and condemnation rates at processing.

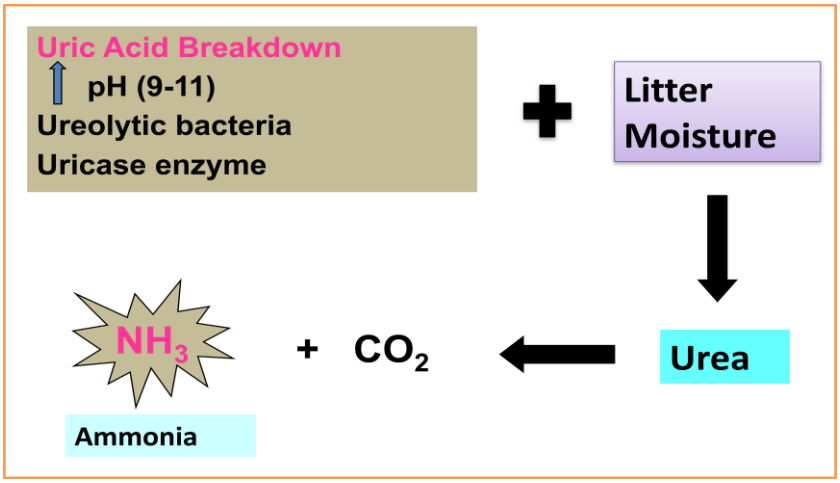


Figure 1. Formation and release of ammonia from poultry litter.

Normal pH of poultry litter is between 8 and 10. Ureolytic bacteria (ex: *Bacillus pasteuri*) are highly functional at pH 9 and above, thus poultry litter provides favorable condition for their multiplication and ammonia production (Figure 1). Ureolytic bacteria

take up the litter moisture and convert uric acid in the poultry litter to ammonia and ammonium. Ammonia is volatile while ammonium is soluble with water and is retained in the litter. Uricase enzyme synthesized by ureolytic bacteria is used to breakdown urea to ammonia and carbon-dioxide. Ammonia being a volatile gas, is dissipated out of the litter with carbon-dioxide.

Poultry litter is the primary site for ammonia generation on a poultry farm, and may be composed of pine shavings, peanut hulls, sawdust or straw. Poultry litter is laden with several other products as it is used multiple times in the US. This includes feed, excreta, dander, bacterial load and darkling beetles. Ammonia is a volatile gas generated as a product of microbial decomposition of nitrogenous compounds in the litter, principally uric acid voided in the fecal matter of birds. The decomposition of uric acid to ammonia is attributed to the enzyme uricase produced by ureolytic bacteria such as *Bacillus pasteuri* which can be found in poultry litter. The activity of uricase enzyme is directly proportional to the pH, water activity and temperature of litter. Uric acid decomposition is most favored under alkaline conditions (pH>7) and uricase enzyme has maximum activity at a pH of 9.

**Detrimental effects of ammonia**

Ammonia generated from the poultry litter has several detrimental effects on the immune status of birds and production. Health effects of ammonia on poultry are more pronounced than on people working in poultry facilities due to the chronic/long term exposure and the intimate contact with litter from which ammonia is emitted continuously. Various studies suggest that ammonia exposure to poultry causes irritation to mucous membranes in the eyes and the respiratory system. This can increase

susceptibility to respiratory disease and may affect food intake, feed conversion and growth rate (Kristensen and Wathes, 2000).

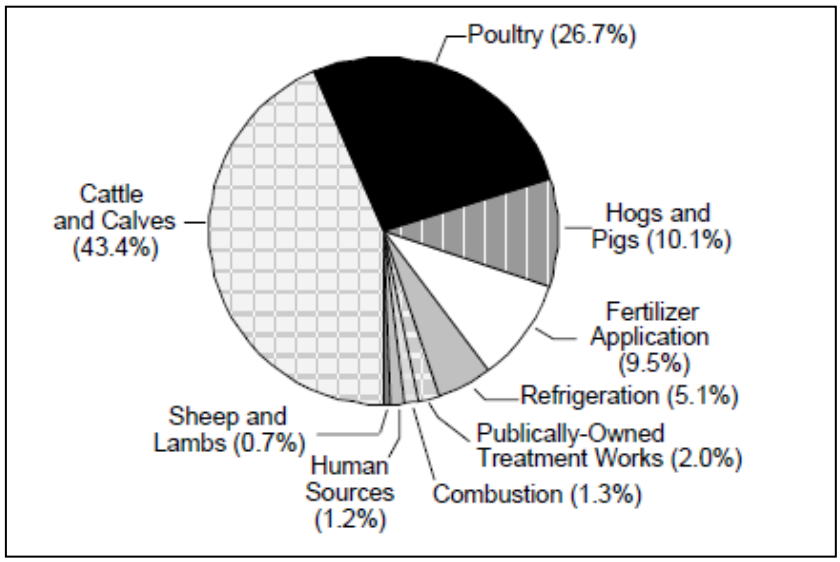


Figure 2. Estimated ammonia emission from livestock production facilities and other human activities (adapted from Battye et al. 2003).

Ammonia has a wide range of sources and causes severe consequences on the environment if not checked for its production. The primary sources of ammonia to environment are domestic animals like cattle and calves that emit a huge amount of ammonia to the environment (Figure 2). Figure 2 shows an enormous amount of ammonia generated from poultry facilities (26.7%) in the United States. Poultry is the second most contributing factor in increasing the environmental ammonia concentration (Battye et al. 2003).

Several methods have been applied for measuring ammonia levels. The CSM Drager Analyzer has been commercially used for the measurement of ammonia levels in commercial poultry farms (Son and Striebig, 2003). Son and Striebig (2003) used the CSM Drager Analyzer for analyzing the odor from sludge. The CSM Drager Analyzer

with remote system is a portable detection system currently available for spot determination of ammonia. This instrument uses chemical chips that range from 0.2 to 2000 ppm levels for ammonia determination.

Varying levels of ammonia have different consequences on the health of birds. At 10 ppm level of ammonia, there may be tracheal irritation and nasal discharge condition in turkey and broiler birds. At 20 ppm of ammonia, increased rate of infection can be observed with constant vaccine failure. With 25 ppm of ammonia there may be a decrease in growth rate, feed conversion and ultimately reduced final body weight. Reading of ammonia up to 50 ppm leads to air sacculitis by mycoplasma and other bacteria with secondary bacterial and viral infection (Estevez and Angel, 2002). Readings above 50 ppm result in keratoconjunctivitis. Readings as high as 100 ppm, lead to increased chick mortality (Estevez, 2007). The prime health effects of ammonia on poultry include foot, hock and breast burns that can be a gateway for bacteria causing further health problems. Tracheal and lung lesions are associated with fluid accumulation and low blood oxygen, rendering the birds more susceptible to secondary bacterial infection (Oyetunde et al., 1978).

Several other studies found that the incidence of ascites was directly related to the increased levels of ammonia in poultry farms rather than any other nutritional or metabolic factors (Lopez Coello et al., 1985). A study involving the comparison of three levels of relative humidity and air movement on ammonia levels and carcass quality showed that there was an increase in levels of ammonia with increase in relative humidity of litter. It was concluded that an increase in relative humidity helps to foster the growth

of ureolytic bacteria leading to production of ammonia in the poultry facility (Weaver and Miejerhof, 1991).

Footpad dermatitis is a condition caused by necrotic lesions on the plantar surface of footpads of poultry raised on litter material with high moisture levels or ammonia levels leading to secondary bacterial infection and complications leading to lameness. Footpad dermatitis is the early stage that develops into hyperkeratosis, erosion and discoloration of the skin ultimately resulting into ulcers (Berg, 1998). This condition of footpads is a concern for animal welfare in the United States. Footpad dermatitis causes downgrades and condemnation of saleable chicken paws. The revenue generated from footpad export by the US in 2008 was $280 million (Shepherd and Fairchild, 2010). Hence any decrease in the footpad quality will directly affect the revenue generated from the export as strict regulations are followed for the same. The two prime reasons for decreased footpad quality are increased litter moisture and ammonia generated from the litter. Climatic condition, ventilation and even feed have an effect on the foodpad dermatitis. Footpad lesions are important from a health point of view as these lesions cause constant erosion of skin on the plantar surface forming painful ulcers that act as an entry point for secondary bacterial infections.

One accepted pattern of scoring footpad lesions is score 0, score 1 and score 2 (Bilgili et al., 2006). Score 0 indicates clean footpad with no lesion or erosion of skin. Score 1 is with slight damage to the plantar surface of footpad and score 3 is with severe dermatitis of the plantar surface of the footpad.

Litter amendments are also highly effective in reducing the incidence of footpad dermatitis and breast blisters commonly observed in poultry. A field trial to assess the

effect of a litter amendment (sodium bisulfate) on footpad dermatitis was conducted using four treatments including control, sodium bisulfate at 1× rate (0.22kg/$m^2$) applied at the day of placement of birds, sodium bisulfate with 2× rate on the day of placement of birds and sodium bisulfate applied at 1× rate on day of placement of chicks and on day 21 at 1× rate. Footpads were scored for severity of footpad dermatitis on day 42 and 49 of trial (age of birds). It was observed that there was a reduction in the number of birds with footpad dermatitis reared on litter treated $NaHSO_4$. Though there was no significant effect on live performance of birds with either treatments but the ammonia concentrations were significantly reduced in the sodium bisulfate treated litter (Nagaraj et al., 2007).

**Types of bedding materials**

Several different types of bedding material have been used as bedding materials in poultry houses over a period of time in order to reduce litter moisture, ammonia, microbial load and the cost of production. A comparative study using three types of litter including refused tea, sawdust and rice paddy husks showed that emissions of ammonia from the poultry house could be reduced substantially with refused tea. Ammonia emission from the refused tea (13.2 mg/kg of litter per hour) on day 36 was 61% less than that from sawdust and paddy husk. Refused tea also showed significantly lower ammonia reading on day 42 (13 mg/kg per hour) compared to sawdust (54 mg/kg per hour) and paddy husk (44 mg/kg per hour) (Atapattu et al., 2008). Another study revealed that refused tea is a better litter material option as compared to paddy husk because of the fact that refused tea contains higher nitrogen content making it a better organic fertilizer and ruminant feed (Atapattu and Wickramasinghe, 2007).

Sand and vermiculite containing litter samples were compared with commercially used wood shavings and rice hulls for the assessment of ammonia production. This experiment showed that the sand and vermiculite containing litter generated much more ammonia (5.3 and 9.1 mg of nitrogen, respectively) compared to wood shavings and commercial rice hulls generated the least ammonia levels (0.9-2.6 mg of nitrogen) (Miles et al., 2011). A field trial that compared processed newspaper with sawdust for body weight gain showed that processed newspaper had significantly higher body weights compared to sawdust. It was also revealed that birds reared on sawdust had a significantly higher mortality than those reared on processed newspaper (Malone and Chaloupka, 1983). Peanut hulls have also been used as a source of bedding material in broiler facilities and have performed similarly as pine shavings except for the potential threat of peanut hulls acting as a source of aflatoxins (Lien et al., 1998). A study that used fresh and reused kenaf core (*Hibiscus cannabinus*) revealed that kenaf core can be used as a substitute for pine shavings as a bedding source (Malone et al., 1990). Whole chopped kenaf and kenaf core, when compared to sawdust for suitability as bedding material revealed no significant changes in weight gain, feed conversion and mortality except the fact that chopped kenaf had more litter caking than sawdust (Brake et al., 1993).

Paddy hull products when compared to sawdust as bedding material showed that rice hulls could be used a suitable bedding material (Veltmann et al., 1984). Cotton waste, gypsum and old newsprints when compared with pine shavings revealed that these could be used as litter material (Grimes et al., 2006). Plant leaves were used as an option or in combination with wood shavings showed promising results as that of wood shavings

(Willis et al., 1997). Several other unmentioned alternatives have been tried for use as bedding materials for broiler birds with varying success.

**Uses of poultry litter**

Built-up poultry litter can be used for several flocks without changing. It is typically only changed due to managemental practices. Exceptions are made if the litter is too wet or there has been a disease issue on the farm. Litter is a source of nitrogen and some minerals. It can be used as a fertilizer for crops. Broiler litter is a source of nitrogen, which on an average contains 3.1% of nitrogen (Mitchell and Donald, 1995). Two major poultry litter wastes produced are broiler litter and caged layer manure. Broiler litter includes all floor reared birds such as broiler, pullets and floor layers reared on bedding material, which may be wood shavings or peanut hulls. Whereas caged layer litter is usually free from bedding material and usually has a high moisture content. Both the floor reared and cage layer waste will contain excreta, feathers and some wasted feed.

On average 0.5 to 0.7 pounds of litter is produced per pound of market weight of poultry produced on commercial broiler farms. Less waste is produced per pound of market weight than was produced 10 years ago when about 1 pound of litter per pound of market weight was produced. This is due to the use of drier litter (20% compared to more than 30% 10 years ago), improved feed conversion rate and more birds on less bedding material (Mitchell and Donald, 1995).

Land application of litter is a common practice in the United States. It is performed in order to reduce the cost for expensive fertilizers. Before land application of litter it should be analyzed for its nutrient contents. Total moisture and nitrogen should be estimated prior to land application in order to reduce the overuse of litter and leaching of

valuable nutrients. This is done in order to meet the nitrogen needs of the crop being grown on the land where litter is being applied.

Poultry litter can also be used pelletized. This can then ultimately be used as biofuel for various heat generation purposes. Pelletizing is currently practiced in AgriRecycle Plant in Seaford, Delware. Cogeneration is an efficient way to utilize poultry litter. Poultry litter can be burned to produce electricity for processing plants, but this method is not in practice currently. Composting of poultry litter serves as an efficient alternative but is constrained by retail sector for the sale of composted litter. The highest value use of poultry litter is application of nearby croplands followed by forest fertilization, pellatization, compost, cogeneration and electricity generation (Lichtenberg et al., 2002).

Constantly increasing prices of wood shavings and the scarcity of land for application have lead to the prolonged use of litter material for two or more years. Only the crust or cake of the litter must be removed after every flock. The increased duration between the complete cleanout of litter material on the poultry farm has led to a greater buildup of litter and ammonia with an increased microbial load. Since chicks are highly susceptible to the negative effects of ammonia, placing birds in such houses will have a detrimental effect on the health and ultimately the production of the birds. Factors that increase temperature during brooding, increase the volatilization of ammonia in the house. Winter has a high impact on ventilation. In order to maintain a constant internal temperature in the poultry house during winter, least amount of air is vented out leading to an accumulation of ammonia in the poultry houses. If the house is ventilated in order to get rid of the ammonia generated, a high amount of energy (gas or electricity) is

utilized to maintain a normal temperature in poultry houses. This is uneconomical and will add to the cost of production (Shah et al., 2006).

**Methods for controlling ammonia volatilization**

Several methods have been applied in order to reduce the ammonia contents in houses. These methods comprise of physical, chemical and biological methods. Physical methods to reduce ammonia and microbial load in poultry houses include litter conditioning, windrow composting, ventilation and removal of litter crust after every flock.

Tilling and de-caking of litter is the simplest approach to conditioning the litter and making it ready for the next flock. Cake in poultry litter have about 40 to 60% moisture. These cakes increase the moisture and ammonia levels drastically making any chemical litter amendment difficult to be effective. Hence cakes should be removed from the litter as soon as poultry are marketed.

Deep litter tilling can be used as a follow-up to decaking. Tilling increases the microbial activity and the increases ammonia production from litter. It should be noted that if the litter is tilled or de-caked, then the litter should be mixed or conditioned at least once in a couple of days after the initial tilling. This fluffing is to speed up and promote drying of the litter and promotes the release of ammonia. If a second tilling is not undertaken, then there is an increased chance of ammonia levels being too high during the first week of brooding as the litter will not have dissipated the ammonia and moisture from the prior flock (Macklin et al., 2008). The major problem with tilling and de-caking is that both of these methods will create a lot of dust and release ammonia in the poultry house making it a major ventilation issue. It is important that the poultry grower should

allow at least three days for the ammonia emitted from the litter to ventilate and the dust to settle.

Ventilation being a major factor during the grow-out of birds should be critically managed to ensure proper health and production benefits. The first 7-10 days of brooding are crucial in aspect of ventilation, even if certain litter treatments are used for the same. Litter treatments will not allow the minimum ventilation run time to be reduced. But, failure to provide minimum ventilation will only decrease the effectiveness of the litter amendments used. Ventilation needs to be increased with increase in bird size. Excess heat needs to be dissipated out with the increase in bird size. This is predominantly due to the fact that there is an increase in moisture levels with the increase in bird size making the ventilation more crucial in maintaining the internal atmosphere. Increase in litter moisture over 25% will foster the growth of microbes in litter and will negatively affect bird health and paw quality. Litter management will certainly affect the bird health in the successive flock.

**Windrow composting**

Windrow composting is currently a well accepted method of litter conditioning. This is also a cost effective and reliable method for the reduction of ammonia and microbial load in litter. Traditional windrow composting method takes several weeks, but the new windrow composting method takes 5-10 days for the entire process to complete. In this shortened composting it can also be called “pasteurization” of litter as the process involves heat killing of most pathogens but not as complete as traditional composting (Macklin, 2008).

After 3-4 days the internal temperature should achieve at least 130 F (54 C). The internal temperature may rise up to 170 F (77 C) depending upon the moisture content of litter and the microbial load. At this point about 50% of the entire mass has been pasteurized. In order for the entire mass to become pasteurized it is important to aerate the compost pile. Each time a windrow is aerated the floor underneath is exposed to the air for drying and the moisture and ammonia from the litter will be volatilized out. This leads to the destruction of more microorganisms and insects. Most of the microorganisms that grow in litter grow at a temperature of about 105-107 F (41 to 42 C). Hence an increase in temperature of about 20-30 F (6.7 to 12.2) will eliminate most microorganisms. It can be assumed that most of the organisms that are generally found in litter material are killed during the process of windrow composting (Macklin, 2008).

After composting the windrows are then spread throughout the house in order to make even bedding. This will allow the excess moisture in the litter to evaporate. Once the litter is dried a new flock of birds can be placed on it.

Moisture plays an important role in the process of composting. It has been shown that 30% moisture is considered ideal for the purpose of windrow composting (Lavergne et al., 2004). Typical poultry litter has a moisture level of about 20-25%. It has been found that the maximum temperature (130-140 F) in the windrow is reached within 36 hours and is maintained for at least 48 hours. This temperature is high enough for most pathogenic microorganisms to be killed and reduces the microbial load considerably (Macklin et al., 2008). A downtime of 10-14 days between flocks is ideal for composting process to be complete and still have sufficient time for the litter to dry before the arrival of chicks. Generally a period of 5-7 days following the spreading of litter is sufficient.

Besides the heat generated in the windrow pile the microorganisms in the litter are killed by the ammonia trapped in the piles and potentially by other beneficial bacteria in litter (Macklin et al., 2007). A most important effect of windrow composting was the reduction in *Clostridium perfringens* counts. *Clostridium perfringens* is a highly pathogenic bacterium that causes necrotic enteritis and gangrenous dermatitis in poultry. Since *Clostridium perfringens* is a spore forming bacterium it becomes difficult to eliminate once the bacteria goes into a dormant phase (i.e. spore). This is due to the fact that the spores are highly resistant to virtually all disinfectants, cold, heat and desiccation. The results indicated that *Clostridium perfringens* was reduced 99.99% compared to litter from a house that was not composted (windrow composting). Another significant finding was the reduction of infectious larygotracheitis virus (ILTV) in composted litter. ILTV is a highly pathogenic respiratory virus that can cause severe economic losses in poultry.

Other then reducing the load of potential hazardous organisms in litter, this technique has an advantage from an economical standpoint. Reduced levels of *Campylobacter* and ILTV counts will insure improved poultry performance and reduced human health risks (Macklin et al., 2008). It is not convenient for many poultry growers to clean out litter after a few flocks due to seasonal limitations, limited availability of land for application and limited availability of pine shavings. Thus, in house composting serves as an alternative. Even though there is not complete eradication of the microbial load and guarantee for sanitation, health and performance, the risks associated with all these factors will be reduced. By utilizing this technique one can ensure the prolonged use of litter material and the flexibility to cleanout and replace the litter when the conditions are favorable for the poultry grower.

Mineral saturation is one problem with composting. There is a buildup of the litter minerals overtime with the exception of nitrogen (Lavergne et al., 2004). This may be due to the fact that windrow composting allows the litter ammonia to volatilize from the litter, which reduces the total nitrogen content of litter. This leads to the imbalance of other minerals such as phosphorous and potash. The ratio of nitrogen to phosphorous and potash decreases overtime thus unbalancing the nutrient levels in the litter. It can be concluded that in-house windrow composting can be used to reduce the litter ammonia, microbial load and extend the life of poultry litter. The only disadvantage being is the reduction in nitrogen content in ratio to other nutrients.

**Chemical litter amendments**

Chemical litter amendments are commercially used in poultry farms to reduce the ammonia emissions, microbial load and the parasites in the litter. Chemical litter amendments can further be classified according to the nature of the chemical agent used. Chemical litter treatments are classified as acidic, alkaline, adsorbers and inhibitors.

Acidifiers are the most commonly used chemical litter treatments. Most common of these are alum and sodium bisulfate. Phosphoric acid is not commonly used as it is rich in phosphorous and increases phosphorous levels in already phosphorous rich poultry litter. Acidic litter treatments act by lowering the pH of litter. The acidic conditions created by the amendments in poultry litter leads to the retention of the ammonical nitrogen as ammonium rather than ammonia. The acidity also creates an un-favorable condition for bacteria and enzymes that contribute to ammonia formation resulting in reduced ammonia production. Since ammonia is volatile, its conversion to ammonium will certainly reduce the ammonia output in poultry houses.

Alum as a compound is aluminium sulfate and is soluble in water, is an astringent, acidic and sweat to taste. Alum may be used in solid (powdered or granules) or in liquid form. Liquid alum can be directly applied to litter. Alum is applied to the litter generally seven days prior to the placement of birds. This is in order to avoid the detrimental effects of alum on chicks. The 7-day period allows alum to act on the litter in order to reduce the ammonia and microbial load in the litter just before the birds are placed on it.

Alum is generally applied at the rate of 50 to 75 lb per 1000 $ft^2$ space, but the application rates may jump as high as 100 lb per 1000 $ft^2$ for built up litter due to the fact that built up litter contains more organic matter and ammonia (Shah et al., 2006). Alum can be surface applied to dry poultry litter and should be mixed into the top ½ inches. Mixing alum in the litter makes it less hazardous even though it comes in contact with the day old birds.

Aluminium sulfate [$(Al_2 (SO_4)_3$] and aluminium chloride ($AlCl_3$) are the two commonly used as poultry litter amendments from the alum group. Choi and Moore (2008) studied the effect of liquid aluminium chloride on the broiler performance, ammonia fluxes and chemical characteristics of the litter. A total of 800 broiler chicks were used for this experiment and liquid aluminium chloride was used at the rate of 100, 200 and 300 gm of liquid $AlCl_3$/kg of litter material. Untreated litter served as control for the trial. The results indicated that at the two lower rates of alum application (100 and 200 gm/kg of litter) there was a significant improvement in weight gain and feed intake but no effect on feed conversion or mortality was observed. The highest rate (300 gm/kg of litter) of application had a negative effect on feed intake. There was a significant decrease the ammonia production with alum application. The treatments 100, 200 and

300 gm of liquid alum reduced the ammonia levels by 63, 76 and 76% respectively throughout the six weeks of experiment compared to the control. The most important advantage of using alum was the reduction in the phosphorous (P) runoff from the litter. The addition of liquid alum reduced P levels in the litter by 24, 30 and 36 % for the three treatments (100, 200 and 300 gm respectively). These results indicate that the addition of aluminium chloride can provide a good environment for poultry (Choi and Moore, 2008).

Moore et al. (1996) conducted a comparative study to evaluate the efficacy of several chemical litter amendments on ammonia volatilization. The litter treatments used were alum, ferrous sulfate and phosphoric acid. The results from this comparative study showed that alum, ferrous sulfate, and phosphoric acid significantly reduced the ammonia levels in the poultry litter as compared to the control. On the other hand, litter treated with sodium bisulfate and Ca-Fe silicate had the same ammonia levels as that of the control litter. Alum and ferrous sulfate also reduced the water soluble P levels in litter, whereas phosphoric acid greatly increased the water soluble P levels. The study implied that the most effective compound in aspects of reducing the ammonia and P levels was alum.

Alkis and Celen (2009) used aluminum sulfate as a litter amendment in a growth performance study. They used untreated straw, untreated sawdust, and compared them to alum treated straw and alum treated sawdust. Live weights at the end of the experiment showed that poultry grown on alum treated litter had a significantly higher body weight for both males and females. It was concluded that alum treatment has a significant effect on the weight gain of poultry (Alkis and Celen, 2009).

Alum has also a significant effect on the microbial community of litter. Rothrock et al. conducted a study in 2008 evaluating the effect of alum on the microbial population in litter. Several molecular techniques were used to evaluate the microbial communities and their shift with the alum addition to litter. According to the results of the trial there was a significant reduction in the levels of both *Campylobacter jejuni* and *Escherichia coli* at the end of the first month of the experiment (3 logs and 2 logs respectively). The concentrations of *Salmonella spp* were below detection ($<5 \times 10^3$ cells/gm of litter). There was a significant shift in the fungal population, with a large increase in diversity and abundance within one month of alum application. Thus the results suggest that the application of alum shifts the microbial population from bacterially to fungal dominated populations (Rothrock et al., 2008).

Line conducted a similar experiment in 2002 to determine the effect of aluminum sulfate and sodium bisulfate on *Campylobacter* and *Salmonella* colonization frequencies and populations with broilers raised on treated pine litter. He examined *Campylobacter* and *Salmonella* populations associated with ceca and whole carcass rinse (WCR). It was found that no *Campylobacter* was recovered from the WCR samples associated with highest levels of aluminum sulfate treated litter. In comparison, the control pens were 95, 78 and 38% positive for weeks 1, 4 and 6 respectively for the same WCR. It was interesting to note that *Salmonella* colonization frequency and population in the ceca were not significantly decreased by either treatment. This trial suggests that effective pathogen control will require a combination of litter treatments (Line, 2002).

Line and Bailey (2006) conducted the same trial with aluminum sulfate and sodium bisulfate on a large scale to evaluate their effect on *Campylobacter* and

*Salmonella* populations in the excreta samples recovered. They found that *Salmonella* levels were not affected throughout the experiment with either treatment. But there was a slight delay in the onset of *Campylobacter* colonization in broiler chicks. This indicates that aluminum sulfate had an effect in reducing the *Campylobacter* population in litter.

Moore et al. (1999) conducted a study in conjunction with the Environmental Protection Agency (EPA) to ascertain the positive effect of alum on poultry production by decreasing the ammonia levels and the reduction of phosphorous runoff. Initially they conducted laboratory studies to ensure that Al, Ca and Fe amendments are useful in reducing the P runoff from the litter. Later these studies were conducted on small plots, which showed a significant decrease in the P runoff from the litter treated with alum by about 87%. There was a significant reduction in pH of the alum treated litter during the first 3 to 4 weeks of each grow out. This resulted in lowered atmospheric ammonia generation in the poultry houses. There was a significant decrease in ammonia levels from litter to about 97% compared to the initial levels for the first 4 weeks after application of alum. Also the broilers grown on alum treated litter showed higher body weight compared to the broilers grown on control litter (1.73 vs. 1.66 kg). They also had lower mortality (3.9 vs. 4.2%) and better feed conversion efficiency (1.98 vs. 2.04). The economics of alum application to the grower and integrator showed that, the benefit: cost ratio of alum was 1.96. It was concluded that alum application to litter resulted in lower soil P levels and doesn't increase the Al availability in the soil for the uptake for plants.

Miles et al. (2003) conducted a pen trial to determine the effect of alum treatment on P retention in poultry litter. He used several different types of diets to see their effect on the total P content of litter. They found that the control pens had the highest levels of

P compared to the alum treated pens. There was no effect of diet on the final P level in poultry litter.

Several other researchers showed that alum treatment of poultry litter has a significant effect on the ammonia production in poultry houses. Do et al. in 2005 conducted a comparative evaluation of six different litter amendments and their effect on ammonia levels. It was found that aluminum chloride had the greatest effect on the reduction of ammonia, which was about 97.2%. It was found that alum and aluminum chloride were the most effective compounds with respect to phosphorous solubility and mortality (Do et al., 2005).

**Poultry Litter Treatment (PLT)**

Another poultry chemical litter amendment that is commonly used is sodium bisulfate or commercially known as Poultry Litter Treatment (PLT). Sodium bisulfate is an acid salt, which is a dry granular product. For the purpose of litter application, PLT is used as 93% sodium bisulfate granules.

PLT is applied to the litter directly in the form of granules. It can be applied to the litter 1 to 24 hours prior to the placement of birds in the house. Being only a mild irritant (OSHA Communication Standard for Safety), sodium bisulfate does not have any major side effects on the health of birds. The application rate for PLT is 50 to 100 lb per 1000 $ft^2$ of litter area. The application rate may be increased from 75 to 150 lb per 1000 $ft^2$ of litter area for litter older than a year or deep litter (Shah et al., 2006).

Sodium bisulfate being an acidic litter amendment will produce hydrogen ions ($H^+$) when it gets dissolved. The hydrogen thus formed reacts with the ammonia present in the litter to form ammonium, which is a non-volatile form of ammonia. The

ammonium formed will further react with the sulfate ion from sodium bisulfate to from ammonium sulfate, which is a water-soluble fertilizer. Thus the ammonia generated from the litter is trapped in the litter as ammonium sulfate ultimately increasing the nitrogen content of litter (Blake and Hess, 2001a).

Sodium bisulfate also has a significant effect on the *Campylobacter* and *Salmonella* populations in broiler litter. Line and Bailey (2006) conducted a field study to access the effect of sodium bisulfate on the *Campylobacter* and *Salmonella* population in commercial broiler facilities. A total of 20 broiler houses were monitored for this trial, of which 10 were control houses. Sodium bisulfate was surface applied using a manual spreader at an initial rate of 3.63 kg/9.3 m2 (8 lb/100 ft2), followed at 28 d by a second application of 4.54 kg/9.3 m2 (10 lb/100 ft2). The second application occurred when the flock was present in the house. Aluminum sulfate was applied in a single application of 9.07 kg/9.3 m2 (20 lb/100 ft2). The results suggested that there was a slight delay in the onset of *Campylobacter* colonization in broiler chicks, but there was no significant effect on the *Salmonella* counts throughout the trail. Thus it was interpreted that PLT is efficient in reducing the *Campylobacter* population of litter to a certain extent and it has no effect on *Salmonella*.

Two studies investigating the effect of sodium bisulfate on ammonia levels, pH changes and microbial variation was done by Pope and Cherry in 2000. The results indicated that PLT helped to maintain ammonia levels in the broiler houses to 10.7 ppm by the second week. pH levels of the litter were also significantly reduced on the day of application to 1.2 followed by 6.2 in second week and 6.9 in the third week. There was a significant effect on the *Escherichia coli* count in the week of application, which showed

0 counts. The level of *E.coli* was maintained low for the next 2 weeks. Birds were further evaluated for rinse *E.coli* count and this saw a significant decrease in the total *E.coli* load in the PLT treated houses. Hence, these results suggest that sodium bisulfate (PLT) is highly effective in reducing the ammonia, pH and *E.coli* in commercial facilities.

Terzich et al. (1998) conducted an extensive field trial for the effect of PLT on ascites, ammonia and litter moisture. The results of this field trial suggested that deaths due to ascites in broilers raised on PLT treated litter (5.9%) was significantly lower compared to those raised on untreated litter (31.5%). Ammonia levels in the pens treated with PLT were significantly lower compared to control pens. But there was no significant difference in the litter moisture and litter nitrogen levels throughout the experiment with either of the treatments. Thus PLT was highly effective in reducing the ammonia levels and reducing the death rate due to ascites.

**Poultry Guard**

Poultry Guard is the commercial name of an acidified clay that contains 36% sulfuric acid soaked in clay. According to the OSHA Communication Standard for Safety, Poultry Guard is highly corrosive and precautions must be taken while handling and applying it (OSHA, 1991).

Being highly corrosive, Poultry Guard needs to be applied to the litter 3 days prior to the placement of birds, as it will give some time for the acid to react with the litter. Thus the birds will not be in direct contact with the highly concentrated sulfuric acid. Direct contact of the birds with the acidified clay will lead to erosion of the skin of footpad and consumption of such treated litter may have serious effects (Shah et al., 2006).

Poultry Guard eliminates the ammonia production in poultry houses by converting the ammonia into ammonium sulfate. Being acidic Poultry Guard will significantly lower the pH and provide an ionic effect that enhances acidification. Poultry Guard has an absorbent carrier material as clay, which releases hydrogen ions ($H^+$). This hydrogen ion will bind with the ammonia to form ammonium, which is a non-volatile form of ammonia. This ammonium formed will further react with the sulfate ion in the acid to form ammonium sulfate, which is a water-soluble fertilizer. Thus the ammonia produced from the litter is ultimately converted to a non-volatile form that can be retained in the litter increasing the nitrogen content of the litter and decreasing the volatile ammonia levels in the house (Blake and Hess, 2001b).

A field trial conducted by McWard and Taylor (2000) evaluated the impact of Poultry Guard, sodium bisulfate and alum on the performance of broilers. They conducted two trails with varying levels of acidified clay (36% and 46% by weight). In trial one, 36%-acidified clay was used which had the same effect as that of sodium bisulfate and alum treated litter. The second trial applied the 46% acidified clay and gave a statistically significant improvement in feed conversion, reduction in ammonia and weight gain compared to sodium bisulfate (93 lb/1000 $ft^2$) and alum (100 lb/1000 $ft^2$) treated litter birds. The results indicate that the application of higher percentage acidified clay can have a significant effect on the ammonia production and performance of birds.

Acidified clay also has an effect on the bacterial counts in litter. Vicente et al. conducted a field trial in 2007 to evaluate the effect of Poultry Guard on the *Salmonella enteritidis* counts. Two trials of this experiment were conducted using two levels of acidified clay, which were low dose (360 gm/$m^2$) and high dose (720 gm/$m^2$). The birds

used in these trials were challenged with *Salmonella enteritidis* prior to using them for the trial and the recovery of this bacterium was recorded. The recovery of *Salmonella* from litter was evaluated on day 11 and 21. The use of low as well as high levels of acidified clay reduced the recovery of *Salmonella* compared to the control (control: 28%, low dose: 0% and high dose: 3%) litter on day 11 after placement of birds. There was a significant increase in the body weight detected in birds reared on litter treated with high dose of acidified clay as compared to the low dose and the control. Experiment two indicated a reduced *Salmonella* counts at day 11 with high dose of acidified clay compared to the control (control: 46%, low dose: 23% and high dose: 18%). These experiments suggest that acidified clay has a significant effect in lowering the total *Salmonella* count of the litter and has a suppressive effect on the *Salmonella* level in litter.

**Ferric sulfate**

Ferric sulfate has been shown to be effective litter amendment in reducing ammonia emissions from poultry houses. A field trial was performed by Ritz et al. (2006a) to evaluate the effect of ferric sulfate on ammonia control in commercial broiler facilities. Ferric sulfate (commercial products: Ferix-3 and Kemiron, Inc) was applied to the litter at the rate of 100 lb per 1000 $ft^2$ one day prior to the placement of birds. Ferric sulfate was applied to two houses. Alum (commercial products: Al+Clear, General Chemical, Inc) was applied in two house at the rate of 100 lb per 1000 $ft^2$ of litter area. The results of this trial indicated that ferric sulfate had a significant lowering effect on the ammonia reading compared to the control treatment of alum for the first 10 to 12 days of trial.

An acidifier litter treatment can serve as an alternative litter treatment over other hazardous and costly amendments. Most of the studies regarding acidified litter treatments indicate that these treatments suppress ammonia levels below 25 ppm for at least three weeks from the day of application and may last even longer. Certainly the extent of ammonia suppression will depend on litter age, moisture and amount of amendment used. The reduced ammonia levels not only improve the health of birds, but also help to improve the production. Litter treatments are more efficient to use during the winter months as they reduce the heating cost significantly by reducing the need to ventilate the house consistently (Shah et al., 2006).

**Alkaline litter amendments**

Alkaline litter amendments are not used to control ammonia emissions in poultry houses. Alkaline materials used as litter amendments are agricultural lime, hydrated lime or slaked lime and brunt lime. These treatments act by increasing the pH of litter and try to convert most of the ammonium in the litter to ammonia and ventilate it into the atmosphere. The amount of ammonia generated will certainly depend upon the type and concentration of amendment used. The pH of the litter plays an important role in ventilating ammonia out of litter. Using alkaline material has a certain disadvantage on the nutrient value of litter. The nutrient value of litter is decreased due to the constant ventilation of nitrogen in the form of ammonia from the litter. This may also create a negative impact on the environment. A second disadvantage of alkaline treatment is that if the alkaline material is not completely utilized before placement of birds, then it will keep ventilating ammonia out of litter even after the placement of birds. This is directly harmful to the birds (Shah et al., 2006).

Hydrated lime is documented as a litter amendment in various instances. Hydrated lime is the product of series of reactions that release a large amount of heat when quick lime is mixed with water. A field trial was conducted by Stringham et al. (2000) to note the effect of hydrated lime on the various litter parameters. Four rates of hydrated lime (equivalent to 50, 100, 125 and 200 lb per 1,000 $ft^2$) and a control were used. Used poultry litter was treated with these designated rates of hydrated lime and mixed thoroughly. Three replicate each of the darkling beetle larva and adults (20 insects per replicate) were assigned per treatment. The survival rates of larva were noted each week. These treatment trials were repeated five times at four different moisture levels (48%, 58%, 61% and 68%). The results indicate that hydrated lime was effective in reducing the beetle population over the control. It was noted that the impact of lime on beetle population is severe at 68% litter moisture. But only the adult beetles were highly affected throughout the trial. This impact of lime on beetles at higher moisture is due to the abrupt change in pH at higher moisture levels (68%). Hydrated lime produced and maintained the pH in the litter around 12 for 6 hours on application. Low application rate produced a diminishing level of pH and this could not be sustained for more than 24 hours.

A study was conducted at Auburn University by Blake et al. (2007) to evaluate the effect of hydrated lime on litter pH and ammonia volatilization. The litter treatments included an untreated control and hydrated lime at application rate of 50, 100 and 150 lbs per 1,000 $ft^2$ of floor space. Litter and air quality samples were taken on day 7, 14, 21, 28, 35, 42 and 49 of the experiment. There was a significantly high pH with the hydrated lime treated litter through 21 days as compared to the control readings. The initial pH

reading for hydrated lime application at 50, 100 and 150 lbs per 1,000 $ft^2$ were 6.35, 12.45 and 12.82 respectively. By the 21-day the pH readings were 7.25, 8.92 and 9.38. After day 21 there were no differences in the pH reading. There were no significant effects on ammonia levels throughout the trial.

Hydrated lime also impacts microbial counts in the litter. Bennett et al. (2005) conducted a study to note the effect of hydrated lime on the recovery of selected bacteria and turkey poult performance. Three trials were conducted with varying levels of hydrated lime application. It was found that 10 and 20% (wt/vol) hydrated lime used in the poultry litter significantly reduced *Salmonella enteritidis* survival rates. But it was also found that excess of lime in new litter could cause respiratory and ocular irritations. Lower concentrations of hydrated lime in new pine shavings (0.2, 1 and 5% wt/vol) had significant effect in reducing the recovery of *Salmonella* in the litter. Though lime had no effect on body weight until week 3, at the age of 7 weeks the turkeys from 0.2% treated pen were significantly heavier (219 gm/bird) than turkeys grown on control. Lime also reduced the overall aerobic counts in the litter significantly.

Quicklime (Calcium oxide) is also a chemical agent that can be used as a litter alkalizer. Calcium oxide also called burnt lime is a white, caustic, alkaline crystal solid at room temperature. Ruiz et al. (2008) conducted a study with quicklime at varying treatments. The major objective of their research was to develop a process using quicklime that would reduce the phosphorous solubility and bacterial load of litter. Four litter treatments evaluated in this study were new wood shavings without addition of quicklime, used untreated broiler litter, used broiler litter with 10% quicklime and used litter with 15% quicklime. Body weight and feed conversion were monitored weekly

throughout the trial. Litter pH, total phosphorous, nitrogen, litter moisture and total plate count were measured for each litter treatment on day 7 and 42. The results indicated that there were no significant effects on the body growth performance measures. But on day 7, 15% quicklime had higher pH (11.2) when compared to other treatments. Also the soluble phosphorous was lower for 15% quicklime (2.75) compared to the new wood shavings (42.2), untreated broiler litter (439.2) and 10% quicklime (35.0). The treatment with 15% quicklime had lower total plate counts compared to other treatments but was not significant. It was concluded that the use of quicklime will initially decrease the nitrogen and soluble phosphorous and bacterial counts without affecting the productivity of birds.

Stringfellow et al. (2010) studied the combined effect of steam and quicklime on *Salmonella typhimurium* populations in poultry litter. Quicklime when mixed with water undergoes an exothermic reaction thus increasing the pH. A homogenized sample of litter was exposed to steam for 0, 5, 30 and 120 minutes. Quicklime was used at concentration of 0 (control), 2.5, 5.0 and 10.0%. It was observed that all the steam treatments reduced the *Salmonella* population irrespective of the quicklime addition. There was also a significant reduction in the *Salmonella* population with the addition of quicklime to the litter alone. Thus the entire process of pasteurization was highly effective in reducing the *Salmonella* population in poultry litter.

Alkaline litter amendments are useful not only in reducing the ammonia output from poultry litter by increasing ammonia volatilization prior to bird placement, but also to reduce microbial load in the litter. The constraints of using an alkaline litter amendment are the reduction in the fertilizer value of litter due to excessive volatilization

of litter nitrogen in the form of ammonia. The second constraint of using an alkaline litter amendment is the fact that the alkaline material may not be completely used before the placement of birds. This will lead to excessive production of ammonia during grow out period that will severely affect the performance of birds. These points need to be considered prior to the application of an alkaline litter amendment.

**Adsorber litter amendments**

Adsorbers are another innovative group of agents that can be used as litter amendments for poultry to reduce ammonia volatilization and microbial load. Clinoptilolite is a metal from a zeolites group that is generally used as an adsorbent of ammonia produced in poultry litter. There has been a mixed performance with the use of zeolites in poultry farms to reduce ammonia volatilization. Peat is also an effective adsorbent, but is not generally used since it is expensive compared to pine shaving used.

Cook et al. (2011) studied the effect of two adsorbers on ammonia production and microbial load in poultry litter in a comparative study. The zeolites used were chitosin and water treatment residual (WTR or AI-oxyhydroxide). Chitosin is one of the most abundant sources of carbon on earth and has the ability to scavenge heavy metals, including $Hg^{2+}$, $Cu^{2+}$, $Ni^{2+}$ and $Zn^{2+}$. Water treatment residuals used act as coagulant and flocculent to remove impurities. The results indicated that both compounds reduced the nitrogen loss from litter significantly and also the concentration of ammonia producing bacteria and fungi were reduced significantly.

Li et al. (2008) performed a comparative study to notice the effects of zeolites on ammonia production in poultry litter. Zeolites were applied to the poultry litter at the rate of 0, 2.5, 5 and 10%. Ammonia emission rate from the litter was 18.3, 6.15, 1.61 and 0.73

gm/day/$m^2$ for the application rates described previously respectively. There was a reduction in the ammonia of about 66, 91 and 96% for the application rates of 2.5, 5 and 10% respectively. It was inferred that zeolites have a significant effect on the total ammonia production in poultry litter.

**Inhibitor litter amendments**

Besides adsorbers, inhibitors are also used to reduce the conversion of uric acid to ammonia by inhibiting enzyme. Phenyl phosphorodiamidate is an example of an inhibitor used as litter amendment. McCrory and Hobbs (2001) found that phenyl phosphorodiamidate can be used as an inhibitor to inhibit the urease activity by reducing the conversion of urea into ammonia. He also reported that inhibitors are currently too expensive and too easily broken to be practical for use in poultry farms as a litter amendment.

**Other techniques to control ammonia**

Other than chemical and mechanical treatments, electric treatments are also used in certain experimental areas to reduce the dust and ammonia in the poultry farms. Ritz et al. (2006b) conducted a field trial using electrostatic space charge system (ESCS) to improve the air quality of commercial poultry facilities. An ESCS was designed to reduce the airborne dust and ammonia emission from commercial poultry houses. Two commercial broiler houses (a control and one outfitted with ESCS) were monitored for dust and ammonia emission rates over a period of seven flocks. The results of this study indicated that ECSC significantly reduced the airborne dust by an average of 43% and the ammonia emissions were reduced by an average of 13%. The power consumption for the ESCS system was less than 100 watt when the system was in operation. Thus it can be

said that the commercial application of this system has a potential to improve in-house air quality and reduce the particulate emissions.

**Biological litter amendment**

Biological litter amendments are becoming more popular due to the environmental friendly and organic production motives of most poultry companies. Several research trials have been performed on the use of microbial litter amendments to reduce the ammonia and microbial load in poultry houses. Rehberger had filed a patent in 1999 for a microbial treatment, which he proved to decrease the ammonia production as well as the pathogenic bacteria present in poultry litter. This biological treatment was a proprietary mixture of certain bacteria that was not disclosed. The application of this unique combination of bacteria results in several biochemical effects proving to be beneficial to the quality of litter and ultimately the health of birds. The most important result of this combination on litter bacteria was that it acted as a broad-spectrum antimicrobial and specifically reduced the gram-negative (-ve) bacteria. The reduction in the level of gram –ve bacteria lead to the ultimate reduction of various bacteria in the litter that break down uric acid to ammonia. Additionally it was found that bacteria in the preparation use uric acid as substrate thus inhibiting the reduction of uric acid to ammonia. It was found that some proteolytic enzymes are produced by the bacteria in the preparation, which led to the breakdown of protein excretion products. Some starch fermentation and organic acid breakdown was found in the biological products which reduced the litter pH and thus the ureolytic bacteria load.

USM-98 (UPA Southwest Pittsburg, Texas, USA) is a commercially available natural microbial catalyst, which is believed to reduce the ammonia production from

poultry waste. It's basically a blend of microbial enzymes and specific catalyst. USM-98 is applied directly to litter by spraying. The results of using USM-98 suggest that using it will reduce the ammonia output in the poultry houses making the ambient environment favorable for poultry. Field trials with USM-98 suggest a substantial decrease in the ammonia production in commercial poultry houses (Shah et al., 2006).

Litter Guard is a recently launched commercially available microbial litter treatment used in commercial poultry houses to reduce the ammonia production and microbial load. Litter Guard is a proprietary blend of selected microbes and humates. This treatment is believed to reduce the ammonia emission rate and microbial load in broiler facilities. There has never been a comparative experiment to notice the effects of using a chemical litter treatment and Litter Guard in commercial broiler facilities. Thus, three research trials were conducted by Auburn University, Department of Poultry Science to assess the comparative effect of using PLT (chemical treatment) and Litter Guard (biological treatment) in commercial broiler facilities.

The objective of this study was the evaluation of air and litter quality with microbial load in commercial broiler facilities using a PLT and a Litter Guard. Ammonia levels were measured for air quality assessment and pH, moisture and water activity were monitored for the litter quality assessment. Microbial analysis included total aerobic, total anaerobic, enteric, *Cl perfringens, E.coli* and *Salmonella spp*. Daily mortality and footpad dermatitis was measured at the end of each trial.

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## Materials and Methods

Three consecutive experimental trials were conducted at a commercial poultry farm in Craigsford, AL. The farm consisted of six commercial broiler houses with dimensions 43 x 510 ft; 12.2 x 152.4 m. At the commencement of the trial, house 1 and 2 had six flock litter, house 4 and 5 had three flock litter and house 3 and 6 had two flock litter. All six houses contained identical system for brooding, feeding, watering and tunnel ventilation system. Number of birds placed in each house was approximately 28,000 head.

For trial 1 three broiler houses (1, 3 and 5) were treated with LG (Litter Guard$^{TM}$; DSM Nutritional Products, Parsippany, NJ, USA) 7 days prior to bird placement (Table 1). LG was applied at the rate of 5.28 gals (18.9 L) mixed into 100 gallons (378.5 L) of water and applied over the entire house. The other three houses (2, 4 and 6) were treated with PLT (Poultry Litter Treatment$^{TM}$; Jones Hamilton Co, Walbridge, OH, USA) in the central brooding area only comprising ½ of the house. PLT was applied 24 hours before bird the placement at the rate of 50 lbs/1000 ft$^2$ (24.4kg/100 m$^2$). Litter samples and ammonia measurements were collected seven days before the placement of birds and on days 1, 8, 22, 29, 36 and 43.

**Table 1: Flock history for trial 1, 2 and 3**

| House | Flock History* | | | Treatment (Commercial Rate) |
|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | |
| **1** | **6** | **7** | **8** | Litter Guard @ 5.28 gallons added to 100 gals water |
| **2** | **6** | **7** | **8** | PLT @ 100lbs/1,000 ft$^2$ (Brood area only) |
| **3** | **2** | **3** | **4** | Litter Guard @ 5.28 gallons added to 100 gals water |
| **4** | **3** | **4** | **5** | PLT @ 100lbs/1,000 ft$^2$ (Brood area only) |
| **5** | **3** | **4** | **5** | Litter Guard @ 5.28 gallons added to 100 gals water |
| **6** | **2** | **3** | **4** | PLT @ 100lbs/1,000 ft$^2$ (Brood area only) |

*Number of flocks on litter prior to study.

For trial 2 and 3 the same three houses (1, 3 and 5) were treated with LG (Litter Guard) 7 days prior to the placement of birds at the previous rate. The other three houses (2, 4 and 6) were treated with PLT at the previous rate to the central brooding area only. Litter samples and ammonia measurements were obtained initially seven days before the placement of birds and on days 1, 8, 22, 29, 36 and 45 in trial 2 and on days 4, 11, 18, 25, 32, 39 and 46 in trial 3.

**Litter sample collection**

Each house was divided into four equidistant areas and each area had a sampling location identified for consistent sample collection. Litter samples were manually collected from each house at the specified dates at four locations in each house. Litter samples were collected by taking a scoop of litter from the center of the house, under the waterer, and under the feeder. These samples were then mixed thoroughly to make one composite sample. All litter samples were stored in zip lock bags and returned to the laboratory for further physiochemical and microbiological analyses.

**Ammonia measurement**

Ammonia measurements were obtained at each of the four identified locations within each house initially and at intervals as previously described during a typical 6-7 week trial period. Ammonia measurements were conducted using a closed container of specified dimension (15.5 x 12 x 5 in; 39.4 x 30.5 x 12.7 cm) as an indexing measure inverted over the litter bed using a Drager CMS Analyzer equipped with a remote air sampling pump (Drager Safety Inc, Pittsburgh, PA) attached to a 12 in (30 cm) sampling hose located in the top center of the container. An appropriate ammonia chip card (0.2-5, 2-50, or 10-150 ppm) was inserted into the unit and the sampling pump was evacuated

(calibrated) for 60 seconds followed by a measurement period of up to 300 seconds. Most readings were usually achieved within 60 seconds following evacuation. This type of approach offers a reliable method for indexing of ammonia levels under the parameters established for an individual trial.

**Litter pH**

Litter pH was determined by mixing 5 g of litter from the composite sample and placing it into a beaker containing 45 ml of distilled water. The litter was mixed thoroughly and allowed to sit for 45 minutes. After 45 minutes the pH of this solution was measured using a Fisher Scientific Accumet pH meter, (Denver Instrument Company, Bohemia, NY, USA).

**Water activity**

Water activity ($a_w$) was measured using a Rotronic Hygrolab $a_w$ measurement kit (Rotronic Instruments Ltd, Crompton Fields, Crompton Way, Crawley, West Sussex, UK). Five gram of litter sample was placed in a plastic measuring cup and the cup was placed in Rotronic Hygrolab $a_w$ measurement kit until it gave a reading for $a_w$.

**Litter moisture**

Litter moisture was determined by weighing 10 g of litter in a glass beaker. This litter sample was placed in drying oven maintained at 104 C (219.2 F) for 48 hours. The litter samples were recovered after 48 hours and the loss of moisture content was determined by weighing the litter sample again.

**Bacterial enumeration**

A 10 g sample of litter was mixed with 90 ml of Phosphate Buffered Saline (PBS) in sterile whirl pak bag to get a 10-fold dilution. The litter PBS solution was then

placed in a stomacher (AES Laboratories, AES Chemunex Inc, Corporate Drive, Suite G, Cranbury, NJ 08512, USA). A 1 ml aliquot removed and was pipetted into a glass tube containing 9 ml of PBS making it a 100-fold (-2) dilution. This dilution process was continued to make dilutions up to -7. From these diluted samples 0.1 ml was plated onto two different dilution factors on each agar plate with three replicates for each dilution factor. This was performed on the following media: Plate Count Agar (Difco™ Plate Count Agar, Becton Dickinson & Company, Franklin Lake, New Jersey, USA) was used to estimate the total aerobic bacteria. MacConkey's Agar (Difco™) was used to enumerate the lactose-fermenting Gram-negative bacteria. Eosin Methylene Blue Agar (Difco™) was used to enumerate the total Gram-negative bacteria i.e. enteric bacteria. Xylose-Lysine-Tergitol 4 agar (XLT4; Difco™) was used to determine the total Salmonella count. XLT4 was specifically used to enumerate Salmonella. Anaerobic agar (Difco™) was used to enumerate the total anaerobic bacteria. Tryptose Sulfite Cycloserine Agar (TSC; Oxoid Ltd, Basingstoke, Hampshire, England) was used in combination with TSC Supplement according to manufacturer's recommendations. TSC agar was specifically used to enumerate *Clostridium perfringens*.

**Incubation and counting of colonies**

Plate count agar, MacConkey agar, Eosin Methylene Blue agar and XLT4 agar plates were incubated aerobically for 18-24 hours maintained at 37 C. These plates were removed after 18-24 hours from the incubator and colonies enumerated (between 30 and 300). Anaerobic agar and Tryptose Sulfite Cycloserine agar plates were incubated in an anaerobic chamber (5% $CO_2$, 5% $H_2$, 90% $N_2$) for 18-24 hours at 37 C. These plates were recovered after 18-24 hours and colonies were enumerated.

**Foot pad dermatitis assessment**

At the processing plant, 500 paws were procured randomly from each house for all three trials. These paws were transported to Auburn University Poultry Science Research Unit and scored for dermatitis depending upon the severity of lesions as score 0 (no lesions for dermatitis), score 1 (mild dermatitis) and score 2 (severe dermatitis) as described by Bilgili et al. (2006).

**Collection of additional empirical data**

Additional information was obtained concerning mortality losses by the poultry grower daily.

**Data analysis**

Data was analyzed using JMP$^{R}$ 7.0.2 using the linear models procedure with $P< 0.10$ (90% confidence level was used since there were only 12 replicated for each treatment) level of significance for all three trials. Student's t test was used to compare treatment means. One-way ANOVA was used for analysis of house and location effects and where applicable Tukey's Honestly Significant Difference Test was used for separation of means. The microbial counts cfu/mg were transformed to $\log_{10}$ prior to statistical analysis.

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## Results and Discussion

### Effect of Poultry Litter Treatment (PLT) and Litter Guard (LG) on air and litter quality with microbiological fluctuations in commercial broiler facilities over three consecutive flocks.

### Trial 1

Ammonia levels were significantly *(P<0.10)* affected by litter treatments (Table 2). Initial measurement showed that LG treated litter had significantly *(P<0.10)* lower ammonia readings compared to PLT treated litter (43.4 vs. 59.8 ppm). Ammonia readings on day 1 were reversed with PLT treated litter showing significantly lower ammonia levels as compared to LG treated litter (19.4 vs. 38.8 ppm). LG gave the lowest ammonia reading on day 22 (8.8 vs. 11.1 ppm). Effect of houses as a treatment on ammonia levels was significant but fluctuated among all six houses. Litter age showed significant effect on ammonia levels with 2 flock litter having the lowest reading for most of the trial compared to 3 and 6 flock litter for most of the samplings. Six flock litter had significantly higher readings on day 1 and 8 of sampling, after which, 3 flock litter showed elevated levels on day 22 and 29 of sampling. Sampling locations did not have any significant effect on the ammonia levels except on initial day of sampling where location 1 had the lowest reading and location 3 the highest reading (36.4 vs. 62.2 ppm).

pH levels were significantly affected by litter treatments with LG showing significantly *(P<0.10)* lower pH levels on initial day of sampling as compared to PLT (8.38 vs. 8.55) (Table 3). pH levels were significantly lowered by PLT application on day 1 than LG treated litter (7.96 vs. 8.45). No significant *(P>0.10)* differences were observed in pH levels on day 8, 15, 22, 29 and 43 of the trial. Houses as treatment showed significant *(P<0.10)* effect on pH levels on initial day, day 22 and 29 of

sampling. Litter age showed significant *(P<0.10)* differences on initial day, day 15, 22, 29 and 43 of sampling. Different locations of sampling had a significant effect on ammonia levels only on day 8 and 43 of sampling with the other sampling dates having random fluctuations.

LG and PLT did not show any significant *(P<0.10)* effect on litter moisture levels for the entire trial (Table 4). A gradual increase in moisture levels was noticed after day 1 of sampling until day 43. House as a treatment did not show any significant *(P>0.10)* difference in moisture levels throughout the trial. Litter age had a significant *(P<0.10)* difference on moisture level only on day 1 of sampling with 6 flock litter showing highest moisture level (14.92%) and 2 flock litter with least (13.42%). Sampling locations did not have any significant *(P<0.10)* differences on the moisture levels for the entire trial.

Litter treatments significantly *(P<0.10)* affected water activity ($a_w$) only on day 36 of sampling with PLT treated litter showing higher $a_w$ (0.983) compared LG treated litter (0.902) (Table 4). House as a treatment had significant *(P<0.10)* effect on $a_w$ levels on initial day of sampling and day 36 and of sampling. Litter age significantly *(P<0.10)* affected the $a_w$ of litter on day 1, 8 and 15 of sampling with random fluctuation among the three litter ages without any specific pattern. Sampling locations did not show any significant *(P>0.10)* effect on the $a_w$ of litter for the entire trial. Day 43 $a_w$ readings are not available due to non operational equipment.

Aerobic bacterial counts were not affected by any of the litter treatments for the entire trial except on day 36 of sampling at which time PLT treated litter had significantly higher aerobic bacterial counts (9.43 cfu/gm) compared to LG treated litter (8.73 cfu/gm) (Table 6). Houses showed significant *(P<0.10)* differences in aerobic bacterial counts on

initial day of sampling, day 29 and 36. Sampling locations did not have any significant differences *(P>0.10)* on the aerobic bacterial counts of litter except on day 22 of sampling with location 3 litter showing the highest aerobic bacterial counts (9.26 cfu/gm) and location 2 with lowest count (7.67 cfu/gm).

Neither of the litter treatments had a significant *(P>0.10)* effect on the total coliform count of litter for the entire trial (Table 7). There was a gradual increase in total coliform count from day1 until day 15, at which time it plateaued until day 43 of sampling. Houses had significant *(P<0.10)* effect on the total coliform count on day 8 and day 36 of sampling with house 5 treated with LG showing high readings for both these samplings. Random fluctuations were found in total coliform counts for all other samplings. Litter age had less impact on total coliform counts as the only significant difference was observed on day 8 of sampling with 3 flocks litter having the highest count (6.07 cfu/gm) and 6 flocks litter having the lowest count (2.73 cfu/gm). Litter age did not show any significant difference on the total coliform count for any other sampling. Sampling location affected the total coliform count only on day 8 of sampling with location 3 having the highest count (6.02 cfu/gm) and location 4 the lower count (3.25 cfu/gm).

*E.coli* counts were not affected *(P>0.10)* by either of the litter treatments throughout the trial (Table 8). There was a decrease in the *E.coli* counts after application of LG (2.50 to 1.76 cfu/gm) or PLT (2.87 to 1.86 cfu/gm) between the initial and day 1 period. There was a gradual increase in *E.coli* counts from day 1 to day 29 followed by was a decrease in counts on day 36 and 43for both litter treatments. Litter age has no significant effect on *E.coli* counts throughout the trial. Sampling locations had a

significant effect on *E.coli* counts only on initial day of sampling with location 1 showing the highest *E.coli* reading (3.83 cfu/gm) and location 3 the least (1.24 cfu/gm).

Anaerobic counts were significantly *(P<0.10)* affected by litter treatments on day 8 and 15 only (Table 9). Houses showed a significant *(P<0.10)* difference in anaerobic bacterial counts on day 1 and 43 of sampling. Litter age significantly affected the anaerobic counts on day 22 and 43 of trial with 2 flock litter having highest counts and 3 flock litter having the lowest readings. Sampling locations had no significant effect on the anaerobic bacterial count of litter for the entire trial with gradual fluctuations.

Litter treatment did not have any significant *(P>0.10)* effect on the *Cl.perfringens* counts throughout the trial (Table 10). Houses showed a significant *(P<0.10)* difference in *Cl.perfringens* counts on initial day of sampling, day 8 and day 22. Litter age had a significant effect on *Cl.perfringens* counts on initial day of sampling, day 22 and day 29 with no consistent results among litter ages. Sampling location did not have any significant *(P>0.10)* difference in *Cl.perfringens* counts for the entire trial.

Mortality data revealed that PLT treated litter had a higher overall mortality (797) compared to LG treated (734) (Table 11). There were no significant *(P>0.10)* differences in the mortality rates by both litter treatments. Footpad dermatitis evaluation showed no differences due to litter treatment. Litter age also did not have any effect on footpad dermatitis scores.

**Discussion**

Poultry Litter Treatment (PLT) being an acidifier reduced the ammonia emission rates. Choi and Moore (2008) noted similar results while conducting a comparative study

to determine the effect of PLT, alum, aluminum chloride and Poultry Guard on ammonia levels from litter. They found that PLT was the most effective litter amendment in reducing ammonia levels and decreased ammonia levels up to 87% of their original emission rates.

Application of PLT to the litter showed a significant decrease in pH levels for the entire trial as compared to LG treated litter. The lowest pH level was noticed on day 1 after application of PLT. Pope and Cherry (2000) conducted an experiment to evaluate the effect of PLT on litter parameters and microbial counts and observed that PLT decreased the pH of litter up to 1.2 on the day of application. These results prove that PLT can be effiectively used as a litter acidifier.

Aerobic bacterial counts showed constant fluctuations throughout the trial. *E.coli* counts were drastically lowered on application of both litter treatments. Pope and Cherry (2000) noticed similar results in that PLT application led to a considerable decrease in total *E.coli* counts compared to the control litter. They also found that PLT treated litter had lower mean levels of colony forming units per gram of total bacteria during the first week of trial.

*Cl.perfringens* counts were not affected by either of the litter treatments. There has been evidences implying PLT being efficient in reducing *Cl.perfringens*. There has been a study using metam-sodium, which proved to be effective in reducing the counts of *Cl.perfringens* in poultry litter (Macklin and Krehling, 2010).

## References

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Table 2. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of litter ammonia volatilization (ppm) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 43.4[b] | 38.8[a] | 18.9 | 21.2 | 8.8[b] | 41.0 | 82.2 | 118.2 |
| PLT | 59.8[a] | 19.4[b] | 20.6 | 22.0 | 11.1[a] | 51.7 | 84.9 | 115.9 |
| SEM | 4.9 | 6.7 | 2.8 | 1.9 | 0.91 | 7.4 | 10.8 | 11.8 |
| P-value | 0.0262 | 0.0521 | 0.6618 | 0.7418 | 0.0870 | 0.3134 | 0.8576 | 0.8906 |
| House (H) | | | | | | | | |
| 1—LG | 49.3[ab] | 72.3[a] | 24.0[ab] | 25.8[ab] | 7.9[cd] | 25.5[b] | 60.6 | 113.0 |
| 2—PLT | 56.8[ab] | 34.1[b] | 32.9[a] | 28.0[a] | 11.4[abc] | 25.0[b] | 57.7 | 122.8 |
| 3—LG | 25.6[b] | 18.7[bc] | 10.8[b] | 13.3[c] | 5.6[d] | 49.0[ab] | 121.2 | 101.8 |
| 4—PLT | 58.5[ab] | 20.4[bc] | 17.0[b] | 20.7[abc] | 13.3[a] | 56.0[ab] | 99.4 | 143.5 |
| 5—LG | 55.3[ab] | 25.4[bc] | 21.8[ab] | 24.4[ab] | 12.9[ab] | 48.5[ab] | 64.8 | 139.8 |
| 6—PLT | 64.3[a] | 3.7[c] | 12.1[b] | 17.4[bc] | 8.7[bcd] | 74.3[a] | 97.7 | 81.3 |
| SEM | 7.6 | 6.5 | 3.3 | 2.0 | 0.98 | 10.5 | 15.4 | 18.8 |
| P-value | 0.0308 | 0.0001 | 0.0016 | 0.0006 | 0.0001 | 0.0293 | 0.0435 | 0.2193 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 44.9 | 11.2[b] | 11.4[b] | 15.3[b] | 7.1[b] | 61.6[a] | 109.4[a] | 91.5[b] |
| 3 | 56.9 | 22.9[b] | 19.4[b] | 22.5[a] | 13.1[a] | 52.3[a] | 82.1[ab] | 141.6[a] |
| 6 | 53.0 | 53.2[a] | 28.4[a] | 26.9[a] | 9.6[b] | 25.3[b] | 59.1[b] | 117.9[ab] |
| SEM | 6.6 | 6.2 | 2.4 | 1.5 | 0.82 | 7.4 | 11.1 | 12.6 |
| P-value | 0.4384 | 0.0003 | 0.0003 | 0.0001 | 0.0002 | 0.0065 | 0.0148 | 0.0344 |
| Location (L)[4] | | | | | | | | |
| 1 | 36.4[b] | 38.2 | 23.7 | 20.4 | 8.8 | 38.3 | 77.6 | 91.9 |
| 2 | 47.9[ab] | 23.2 | 20.5 | 21.2 | 9.1 | 43.7 | 99.8 | 120.2 |
| 3 | 62.2[a] | 22.0 | 17.7 | 23.7 | 10.2 | 40.0 | 71.3 | 114.7 |
| 4 | 59.9[a] | 32.9 | 17.1 | 21.1 | 11.7 | 63.5 | 85.5 | 141.3 |
| SEM | 6.7 | 10.4 | 4.1 | 2.7 | 1.4 | 10.2 | 15.2 | 15.6 |
| P-value | 0.0463 | 0.6433 | 0.6544 | 0.8255 | 0.4603 | 0.3013 | 0.5919 | 0.1991 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

Table 3. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of litter pH levels (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.38[b] | 8.45[a] | 8.13 | 7.96 | 7.99 | 8.00 | 8.24[b] | 8.23 |
| PLT | 8.55[a] | 7.96[b] | 8.20 | 8.00 | 7.93 | 8.09 | 8.40[a] | 8.19 |
| SEM | 0.035 | 0.126 | 0.092 | 0.074 | 0.085 | 0.071 | 0.059 | 0.058 |
| P-value | 0.0033 | 0.0129 | 0.5796 | 0.7594 | 0.6728 | 0.3991 | 0.0737 | 0.7003 |
| House (H) | | | | | | | | |
| 1—LG | 8.32[c] | 8.37 | 8.12 | 7.95 | 7.94[ab] | 7.73[d] | 8.17 | 8.13 |
| 2—PLT | 8.44[b] | 8.14 | 8.20 | 7.97 | 7.87[b] | 7.92[cd] | 8.33 | 8.02 |
| 3—LG | 8.33[c] | 8.48 | 8.09 | 7.82 | 7.78[b] | 8.05[bc] | 8.13 | 8.18 |
| 4—PLT | 8.68[a] | 7.93 | 8.39 | 8.17 | 8.19[a] | 8.31[a] | 8.59 | 8.28 |
| 5—LG | 8.49[b] | 8.50 | 8.05 | 8.13 | 8.23[a] | 8.22[ab] | 8.25 | 8.38 |
| 6—PLT | 8.52[b] | 7.82 | 8.02 | 7.85 | 7.75[b] | 8.04[bc] | 8.29 | 8.28 |
| SEM | 0.0453 | 0.235 | 0.162 | 0.120 | 0.123 | 0.088 | 0.096 | 0.091 |
| P-value | 0.0003 | 0.2391 | 0.6190 | 0.2644 | 0.0531 | 0.0032 | 0.1110 | 0.1434 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 8.42[b] | 8.15 | 8.05 | 7.83[b] | 7.77[b] | 8.05[b] | 8.30 | 8.23[ab] |
| 3 | 8.58[a] | 8.21 | 8.22 | 8.15[a] | 8.21[a] | 8.26[a] | 8.42 | 8.33[a] |
| 6 | 8.38[b] | 8.26 | 8.21 | 7.96[ab] | 7.90[b] | 7.83[b] | 8.25 | 8.08[b] |
| SEM | 0.043 | 0.182 | 0.112 | 0.079 | 0.081 | 0.062 | 0.074 | 0.062 |
| P-value | 0.0089 | 0.9127 | 0.5059 | 0.0325 | 0.0032 | 0.0003 | 0.2773 | 0.0318 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.48 | 8.47 | 8.24[ab] | 8.05 | 8.11 | 8.09 | 8.40 | 8.36[a] |
| 2 | 8.46 | 8.04 | 8.02[b] | 7.85 | 7.74 | 7.95 | 8.29 | 8.06[c] |
| 3 | 8.48 | 8.01 | 7.99[b] | 7.88 | 7.94 | 7.96 | 8.24 | 8.13[bc] |
| 4 | 8.43 | 8.30 | 8.40[a] | 8.14 | 8.05 | 8.18 | 8.37 | 8.29[ab] |
| SEM | 0.064 | 0.199 | 0.115 | 0.096 | 0.110 | 0.099 | 0.089 | 0.069 |
| P-value | 0.9555 | 0.3347 | 0.0615 | 0.1485 | 0.1256 | 0.3333 | 0.5817 | 0.0222 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

Table 4. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler house and their effect on litter moisture levels (%) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 17.64 | 14.21 | 15.51 | 17.82 | 20.83 | 22.05 | 22.30 | 22.80 |
| PLT | 18.08 | 14.08 | 17.05 | 17.79 | 22.33 | 20.81 | 23.73 | 22.95 |
| SEM | 0.361 | 0.392 | 0.934 | 0.406 | 1.497 | 0.792 | 0.670 | 0.644 |
| P-value | 0.3971 | 0.8124 | 0.2585 | 0.9543 | 0.4863 | 0.2832 | 0.1472 | 0.8637 |
| House (H) | | | | | | | | |
| 1—LG | 17.22 | 14.57 | 17.50 | 17.70 | 25.25 | 21.27 | 21.25 | 24.62 |
| 2—PLT | 19.12 | 15.27 | 17.35 | 16.77 | 21.75 | 21.42 | 22.60 | 22.75 |
| 3—LG | 17.90 | 13.82 | 16.00 | 17.30 | 18.25 | 23.57 | 21.47 | 21.67 |
| 4—PLT | 17.72 | 13.95 | 17.27 | 18.72 | 22.00 | 20.90 | 23.92 | 22.80 |
| 5—LG | 17.80 | 14.25 | 13.05 | 18.47 | 19.00 | 21.30 | 24.20 | 22.10 |
| 6—PLT | 17.40 | 13.03 | 16.52 | 17.87 | 23.25 | 20.12 | 24.67 | 23.32 |
| SEM | 0.609 | 0.638 | 1.615 | 0.678 | 2.552 | 1.436 | 1.107 | 1.109 |
| P-value | 0.3462 | 0.2682 | 0.4008 | 0.3756 | 0.4193 | 0.6706 | 0.1776 | 0.5229 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 17.65 | 13.42[b] | 16.26 | 17.58 | 20.75 | 21.85 | 23.07 | 22.50 |
| 3 | 17.76 | 14.10[ab] | 15.16 | 18.60 | 20.50 | 21.10 | 24.06 | 22.45 |
| 6 | 18.17 | 14.92[a] | 17.42 | 17.23 | 23.50 | 21.35 | 21.92 | 23.68 |
| SEM | 0.452 | 0.434 | 1.154 | 0.460 | 1.828 | 1.013 | 0.818 | 0.779 |
| P-value | 0.6936 | 0.0722 | 0.3996 | 0.1193 | 0.4503 | 0.8686 | 0.2056 | 0.4593 |
| Location (L)[4] | | | | | | | | |
| 1 | 18.56 | 14.36 | 16.81 | 17.93 | 18.66 | 22.25 | 23.30 | 23.91 |
| 2 | 17.65 | 13.90 | 17.75 | 17.83 | 23.33 | 20.58 | 23.68 | 23.05 |
| 3 | 17.96 | 13.81 | 14.53 | 17.45 | 22.33 | 21.68 | 22.85 | 22.23 |
| 4 | 17.26 | 14.51 | 16.33 | 18.01 | 22.00 | 21.21 | 22.25 | 22.31 |
| SEM | 0.502 | 0.567 | 1.342 | 0.595 | 2.105 | 1.176 | 1.016 | 0.907 |
| P-value | 0.3356 | 0.7773 | 0.4730 | 0.9109 | 0.4467 | 0.7817 | 0.7772 | 0.5384 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

Table 5. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter water activity ($a_w$) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 0.798 | 0.674 | 0.827 | 0.784 | 0.838 | 0.876 | 0.902[b] | **** |
| PLT | 0.798 | 0.688 | 0.830 | 0.776 | 0.797 | 0.853 | 0.983[a] | **** |
| SEM | 0.020 | 0.015 | 0.0142 | 0.016 | 0.026 | 0.029 | 0.025 | **** |
| P-value | 0.9978 | 0.5023 | 0.8832 | 0.7302 | 0.2860 | 0.5952 | 0.0381 | **** |
| House (H) | | | | | | | | |
| 1—LG | 0.817[a] | 0.705 | 0.800 | 0.763 | 0.827 | 0.855 | 0.917[ab] | **** |
| 2—PLT | 0.857[a] | 0.723 | 0.813 | 0.722 | 0.804 | 0.879 | 0.962[b] | **** |
| 3—LG | 0.843[a] | 0.660 | 0.808 | 0.776 | 0.815 | 0.883 | 0.964[b] | **** |
| 4—PLT | 0.821[a] | 0.645 | 0.843 | 0.793 | 0.755 | 0.763 | 0.990[b] | **** |
| 5—LG | 0.733[b] | 0.656 | 0.872 | 0.813 | 0.872 | 0.889 | 0.823[b] | **** |
| 6—PLT | 0.716[b] | 0.696 | 0.833 | 0.812 | 0.833 | 0.917 | 0.996[b] | **** |
| SEM | 0.025 | 0.023 | 0.023 | 0.026 | 0.047 | 0.049 | 0.043 | **** |
| P-value | 0.0029 | 0.1808 | 0.3084 | 0.1979 | 0.6633 | 0.3750 | 0.0958 | **** |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 0.780 | 0.678[ab] | 0.821[ab] | 0.794[a] | 0.824 | 0.900 | 0.980 | **** |
| 3 | 0.777 | 0.651[b] | 0.857[a] | 0.803[a] | 0.813 | 0.826 | 0.907 | **** |
| 6 | 0.837 | 0.714[a] | 0.806[b] | 0.742[b] | 0.815 | 0.867 | 0.939 | **** |
| SEM | 0.023 | 0.016 | 0.015 | 0.018 | 0.033 | 0.035 | 0.034 | **** |
| P-value | 0.1590 | 0.0392 | 0.0912 | 0.0678 | 0.9728 | 0.3614 | 0.3323 | **** |
| Location (L)[4] | | | | | | | | |
| 1 | 0.820 | 0.683 | 0.844 | 0.784 | 0.805 | 0.857 | 0.982 | **** |
| 2 | 0.801 | 0.694 | 0.837 | 0.800 | 0.851 | 0.889 | 0.907 | **** |
| 3 | 0.791 | 0.671 | 0.826 | 0.737 | 0.785 | 0.838 | 0.917 | **** |
| 4 | 0.780 | 0.676 | 0.805 | 0.797 | 0.830 | 0.873 | 0.963 | **** |
| SEM | 0.030 | 0.022 | 0.020 | 0.022 | 0.038 | 0.043 | 0.040 | **** |
| P-value | 0.8165 | 0.8877 | 0.5662 | 0.2004 | 0.6515 | 0.8616 | 0.5116 | **** |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

****Equipment not operational.

SEM=Pooled Standard Error of Mean

Table 6. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total aerobic bacterial counts ($Log_{10}$ cfu/g) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 7.92 | 7.98 | 7.28 | 6.55 | 8.69 | 6.56 | 8.73[b] | 8.26 |
| PLT | 7.61 | 7.95 | 7.71 | 7.78 | 7.43 | 7.95 | 9.43[a] | 8.26 |
| SEM | 0.210 | 0.098 | 0.72 | 0.65 | 0.55 | 1.25 | 0.24 | 0.79 |
| P-value | 0.2169 | 0.8054 | 0.6753 | 0.1984 | 0.1263 | 0.4428 | 0.0556 | 0.9988 |
| House (H) | | | | | | | | |
| 1—LG | 8.09[ab] | 7.70 | 7.53 | 7.50 | 8.88 | 9.86[a] | 9.41[a] | 9.68 |
| 2—PLT | 8.07[ab] | 7.83 | 8.47 | 7.86 | 7.40 | 9.48[a] | 9.97[a] | 9.14 |
| 3—LG | 8.42[a] | 8.23 | 8.13 | 7.80 | 8.21 | 9.83[a] | 8.56[b] | 9.03 |
| 4—PLT | 7.97[ab] | 7.88 | 8.49 | 7.83 | 8.31 | 8.23[b] | 8.27[b] | 8.59 |
| 5—LG | 7.45[bc] | 8.03 | 8.24 | 8.06 | 8.97 | 8.22[b] | 8.22[b] | 8.19 |
| 6—PLT | 6.79[c] | 8.13 | 8.20 | 7.65 | 8.70 | 9.88[a] | 10.05[a] | 9.17 |
| SEM | 0.280 | 0.158 | 0.465 | 0.382 | 0.490 | 0.412 | 0.254 | 0.419 |
| P-value | 0.001 | 0.2213 | 0.7262 | 0.9337 | 0.2688 | 0.0152 | 0.0001 | 0.2371 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 7.61 | 8.18[a] | 8.17 | 7.72 | 8.46 | 9.86[a] | 9.30[a] | 9.10[ab] |
| 3 | 7.71 | 7.95[ab] | 8.36 | 7.95 | 8.64 | 8.22[b] | 8.24[b] | 8.39[b] |
| 6 | 8.08 | 7.76[a] | 8.00 | 7.68 | 8.14 | 9.67[a] | 9.69[a] | 9.41[a] |
| SEM | 0.261 | 0.106 | 0.323 | 0.254 | 0.370 | 0.273 | 0.240 | 0.284 |
| P-value | 0.4160 | 0.0402 | 0.7321 | 0.7382 | 0.6342 | 0.0006 | 0.0010 | 0.0539 |
| Location (L)[4] | | | | | | | | |
| 1 | 7.94 | 7.97 | 7.80 | 7.92 | 8.28[ab] | 9.27 | 9.33 | 9.35 |
| 2 | 7.54 | 7.93 | 8.51 | 7.90 | 7.67[b] | 9.02 | 9.13 | 8.64 |
| 3 | 8.02 | 7.95 | 8.50 | 7.88 | 9.26[a] | 9.28 | 9.08 | 9.06 |
| 4 | 7.69 | 8.01 | 7.91 | 7.45 | 8.44[ab] | 9.43 | 8.78 | 8.82 |
| SEM | 0.311 | 0.145 | 0.359 | 0.293 | 0.369 | 0.454 | 0.358 | 0.368 |
| P-value | 0.6789 | 0.9774 | 0.3649 | 0.6275 | 0.0474 | 0.9339 | 0.7900 | 0.5609 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

*Determined using Plate Count Agar (PCA).

cfu/g= colony forming units per gram of litter material

Table 7. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler house and their effect on total coliform counts* ($Log_{10}$ cfu/g) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.13 | 3.26 | 4.60 | 5.75 | 5.25 | 5.53 | 5.31 | 4.88 |
| PLT | 3.14 | 3.11 | 4.59 | 5.53 | 5.30 | 5.79 | 5.45 | 4.73 |
| SEM | 0.213 | 0.182 | 0.691 | 0.351 | 0.106 | 0.227 | 0.227 | 0.091 |
| P-value | 0.9948 | 0.5620 | 0.9894 | 0.6724 | 0.7343 | 0.4279 | 0.6647 | 0.2498 |
| House (H) | | | | | | | | |
| 1—LG | 3.74 | 3.03 | 3.48[bc] | 6.10 | 5.37 | 5.45 | 5.05[b] | 4.92 |
| 2—PLT | 2.91 | 3.35 | 2.00[c] | 5.50 | 5.21 | 5.89 | 5.69[ab] | 4.96 |
| 3—LG | 2.90 | 3.70 | 3.87[abc] | 5.98 | 5.36 | 5.79 | 4.78[b] | 4.87 |
| 4—PLT | 3.09 | 3.16 | 5.68[ab] | 5.11 | 5.21 | 5.99 | 5.02[b] | 4.44 |
| 5—LG | 2.77 | 3.07 | 6.47[a] | 5.17 | 5.03 | 5.38 | 6.11[a] | 4.87 |
| 6—PLT | 3.42 | 2.84 | 6.11[ab] | 6.00 | 5.49 | 5.51 | 5.65[ab] | 4.81 |
| SEM | 0.359 | 0.315 | 0.945 | 0.633 | 0.185 | 0.420 | 0.344 | 0.150 |
| P-value | 0.4099 | 0.4977 | 0.0228 | 0.7773 | 0.5864 | 0.8597 | 0.1001 | 0.2149 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 3.16 | 3.27 | 4.99[a] | 5.99 | 5.42 | 5.64 | 5.21 | 4.83 |
| 3 | 2.93 | 3.11 | 6.07[a] | 5.13 | 5.12 | 5.68 | 5.56 | 4.65 |
| 6 | 3.32 | 3.19 | 2.73[b] | 5.80 | 5.29 | 5.67 | 5.37 | 4.93 |
| SEM | 0.260 | 0.229 | 0.690 | 0.419 | 0.125 | 0.288 | 0.286 | 0.109 |
| P-value | 0.5650 | 0.8920 | 0.0083 | 0.3379 | 0.2504 | 0.9959 | 0.6773 | 0.1976 |
| Location (L)[4] | | | | | | | | |
| 1 | 3.48 | 3.21 | 3.74[ab] | 5.83 | 5.15 | 6.45 | 4.91 | 4.77 |
| 2 | 3.20 | 3.01 | 5.38[ab] | 5.26 | 5.14 | 5.16 | 5.74 | 4.96 |
| 3 | 2.76 | 3.40 | 6.02[a] | 6.06 | 5.34 | 5.56 | 5.72 | 4.90 |
| 4 | 3.10 | 3.12 | 3.25[b] | 5.41 | 5.48 | 5.50 | 5.14 | 4.59 |
| SEM | 0.295 | 0.266 | 0.891 | 0.503 | 0.144 | 0.266 | 0.297 | 0.124 |
| P-value | 0.4079 | 0.7680 | 0.1235 | 0.6578 | 0.3044 | 0.0175 | 0.1495 | 0.1968 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

*Determined using Eosin Methylene Blue (EMB) agar.

cfu/g= colony forming units per gram of litter material

Table 8. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *E.coli* levels* ($Log_{10}$ cfu/g) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 2.51 | 1.76 | 2.54 | 3.35 | 5.22 | 5.21 | 3.83 | 3.88 |
| PLT | 2.87 | 1.86 | 2.31 | 4.89 | 5.12 | 4.83 | 4.49 | 4.59 |
| SEM | 1.946 | 0.482 | 0.894 | 0.768 | 0.486 | 0.344 | 0.400 | 0.385 |
| P-value | 0.6272 | 0.8830 | 0.8579 | 0.1713 | 0.8809 | 0.4361 | 0.2505 | 0.2075 |
| House (H) | | | | | | | | |
| 1—LG | 2.54 | 0.00[c] | 2.59 | 2.73 | 5.71 | 5.22 | 4.45 | 3.37 |
| 2—PLT | 2.70 | 2.28[ab] | 1.14 | 5.62 | 5.45 | 5.06 | 4.37 | 4.78 |
| 3—LG | 2.52 | 3.22[a] | 1.88 | 4.51 | 5.59 | 5.20 | 3.39 | 3.50 |
| 4—PLT | 2.33 | 1.98[abc] | 0.00 | 2.99 | 4.13 | 5.29 | 4.28 | 4.25 |
| 5—LG | 2.47 | 2.06[ab] | 3.13 | 2.78 | 4.37 | 5.22 | 3.64 | 4.78 |
| 6—PLT | 3.59 | 0.84[bc] | 5.78 | 6.05 | 5.78 | 4.13 | 4.84 | 4.74 |
| SEM | 0.979 | 0.673 | 1.358 | 1.321 | 0.848 | 0.627 | 0.737 | 0.683 |
| P-value | 0.9513 | 0.0310 | 0.1092 | 0.3224 | 0.6077 | 0.7763 | 0.7433 | 0.4890 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 3.05 | 2.03 | 3.83 | 5.28 | 5.69 | 4.67 | 4.11 | 4.12 |
| 3 | 2.40 | 2.02 | 1.57 | 2.89 | 4.25 | 5.26 | 3.96 | 4.52 |
| 6 | 2.62 | 1.38 | 1.86 | 4.19 | 5.58 | 5.14 | 4.41 | 4.07 |
| SEM | 0.652 | 0.594 | 0.055 | 0.934 | 0.557 | 0.427 | 0.513 | 0.495 |
| P-value | 0.7743 | 0.6822 | 0.2786 | 0.2461 | 0.1517 | 0.5951 | 0.8175 | 0.7853 |
| Location (L)[4] | | | | | | | | |
| 1 | 3.83[a] | 2.07 | 2.23 | 5.67 | 5.43 | 5.64 | 4.49 | 4.46 |
| 2 | 2.77[ab] | 1.60 | 4.09 | 4.06 | 4.71 | 4.94 | 3.15 | 4.84 |
| 3 | 1.24[b] | 2.04 | 2.78 | 3.92 | 4.73 | 4.22 | 4.30 | 3.14 |
| 4 | 2.93[ab] | 1.54 | 0.58 | 2.84 | 5.82 | 5.27 | 4.70 | 4.51 |
| SEM | 0.660 | 0.708 | 1.202 | 1.099 | 0.690 | 0.462 | 0.551 | 0.517 |
| P-value | 0.0765 | 0.9226 | 0.2543 | 0.3611 | 0.6078 | 0.1992 | 0.2255 | 0.1295 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

*Determined using MacConkey (MAC) agar.

cfu/g= colony forming units per gram of litter material

Table 9. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on anaerobic bacterial levels* ($Log_{10}$ cfu/g) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 5.90 | 4.75 | 3.73[b] | 7.63[a] | 6.79 | 6.98 | 6.64 | 6.56 |
| PLT | 5.85 | 5.20 | 6.38[a] | 7.10[b] | 6.74 | 7.19 | 6.62 | 6.36 |
| SEM | 0.191 | 0.282 | 0.814 | 0.200 | 0.142 | 0.230 | 0.089 | 0.095 |
| P-value | 0.8542 | 0.2727 | 0.0312 | 0.0783 | 0.7824 | 0.5346 | 0.8866 | 0.1389 |
| House (H) | | | | | | | | |
| 1—LG | 5.44 | 3.86[b] | 6.06 | 7.69 | 7.03 | 6.90 | 6.55 | 6.64[a] |
| 2—PLT | 5.68 | 5.65[a] | 6.91 | 6.91 | 6.87 | 7.32 | 6.42 | 6.32[b] |
| 3—LG | 6.36 | 5.70[a] | 6.77 | 7.51 | 6.73 | 6.67 | 6.60 | 6.61[ab] |
| 4—PLT | 5.75 | 5.22[a] | 6.85 | 7.14 | 6.26 | 7.13 | 6.78 | 6.66[a] |
| 5—LG | 5.90 | 4.69[ab] | 7.20 | 7.69 | 6.62 | 7.37 | 6.76 | 6.44[ab] |
| 6—PLT | 6.11 | 4.73[ab] | 7.14 | 7.26 | 7.08 | 6.93 | 6.66 | 6.69[a] |
| SEM | 0.323 | 0.418 | 0.434 | 0.378 | 0.221 | 0.418 | 0.155 | 0.144 |
| P-value | 0.4377 | 0.0505 | 0.6315 | 0.6315 | 0.1512 | 0.7899 | 0.7590 | 0.0484 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 6.24 | 5.21 | 6.95 | 7.38 | 6.91[a] | 6.80 | 6.63 | 6.65[a] |
| 3 | 5.28 | 4.96 | 7.07 | 7.41 | 6.44[b] | 7.34 | 6.77 | 6.25[b] |
| 6 | 5.56 | 4.76 | 6.47 | 7.30 | 6.95[a] | 7.11 | 6.49 | 6.48[ab] |
| SEM | 0.259 | 0.357 | 0.305 | 0.270 | 0.155 | 0.279 | 0.103 | 0.109 |
| P-value | 0.1081 | 0.6690 | 0.3807 | 0.9550 | 0.0555 | 0.4026 | 0.5625 | 0.0537 |
| Location (L)[4] | | | | | | | | |
| 1 | 5.54 | 5.41 | 6.42 | 7.48 | 6.58 | 7.19 | 6.51 | 6.43 |
| 2 | 5.68 | 4.40 | 7.04 | 7.56 | 7.03 | 6.67 | 6.77 | 6.46 |
| 3 | 6.29 | 5.20 | 7.26 | 7.35 | 6.97 | 6.95 | 6.63 | 6.47 |
| 4 | 5.99 | 4.90 | 6.62 | 7.08 | 6.49 | 7.52 | 6.60 | 6.47 |
| SEM | 0.252 | 0.396 | 0.348 | 0.030 | 0.181 | 0.315 | 0.257 | 0.148 |
| P-value | 0.1900 | 0.3337 | 0.3279 | 0.7123 | 0.1077 | 0.3035 | 0.5625 | 0.9968 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

*Determined using Anaerobic Agar (AA).

cfu/g= colony forming units per gram of litter material

Table 10. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *Clostridium perfringens* counts* ($Log_{10}$ cfu/g) (Trial 1)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.613 | 3.996 | 3.569 | 2.432 | 3.911 | 3.869 | 3.625 | 3.538 |
| PLT | 3.729 | 3.603 | 3.186 | 2.604 | 4.122 | 3.841 | 3.801 | 3.876 |
| SEM | 0.436 | 0.263 | 0.526 | 0.592 | 0.138 | 0.602 | 0.249 | 0.245 |
| P-value | 0.7738 | 0.3033 | 0.6119 | 0.8392 | 0.2944 | 0.6813 | 0.6231 | 0.3401 |
| House (H) | | | | | | | | |
| 1—LG | 4.543[a] | 3.959 | 4.571[a] | 3.345 | 3.981[b] | 1.883 | 4.197 | 4.025 |
| 2—PLT | 4.530[a] | 4.325 | 1.225[b] | 1.040 | 4.767[a] | 3.006 | 3.927 | 4.141 |
| 3—LG | 1.959[b] | 3.812 | 2.089[b] | 0.938 | 3.769[b] | 3.955 | 3.106 | 2.877 |
| 4—PLT | 3.027[ab] | 3.048 | 4.173[a] | 3.037 | 3.880[b] | 4.922 | 3.781 | 3.535 |
| 5—LG | 4.335[a] | 4.217 | 4.046[a] | 3.014 | 3.983[b] | 4.621 | 3.573 | 3.713 |
| 6—PLT | 3.819[a] | 3.436 | 4.159[a] | 3.735 | 3.719[b] | 3.596 | 3.697 | 3.923 |
| SEM | 0.637 | 0.449 | 0.710 | 0.938 | 0.182 | 0.999 | 0.440 | 0.414 |
| P-value | 0.0605 | 0.3668 | 0.0173 | 0.1926 | 0.0088 | 0.3316 | 0.6346 | 0.3407 |
| Litter Age (LA)[3] | | | | | | | | |
| 2 | 2.889[a] | 3.624 | 3.124 | 2.336 | 3.744[b] | 3.775[ab] | 3.402 | 3.400 |
| 3 | 3.681[ab] | 3.632 | 4.109 | 3.026 | 3.932[b] | 4.771[a] | 3.677 | 3.639 |
| 6 | 4.537[a] | 4.142 | 2.898 | 2.193 | 4.374[a] | 2.445[b] | 4.062 | 4.083 |
| SEM | 0.485 | 0.325 | 0.633 | 0.730 | 0.148 | 0.667 | 0.297 | 0.295 |
| P-value | 0.0783 | 0.4503 | 0.3728 | 0.6943 | 0.0195 | 0.0683 | 0.3092 | 0.2730 |
| Location (L)[4] | | | | | | | | |
| 1 | 3.573 | 3.937 | 2.750 | 2.689 | 3.995 | 3.925 | 3.840 | 3.293 |
| 2 | 3.012 | 3.347 | 4.210 | 2.625 | 4.129 | 3.370 | 3.890 | 3.685 |
| 3 | 4.301 | 4.192 | 3.684 | 1.430 | 4.003 | 3.720 | 3.855 | 3.859 |
| 4 | 3.923 | 3.721 | 2.864 | 3.328 | 3.940 | 3.641 | 3.269 | 3.993 |
| SEM | 0.612 | 0.375 | 0.738 | 0.824 | 0.208 | 0.893 | 0.354 | 0.352 |
| P-value | 0.5085 | 0.4554 | 0.4664 | 0.4484 | 0.9150 | 0.9773 | 0.5607 | 0.5396 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM=Pooled Standard Error of Mean

*Determined using Tryptose Sulfite Cycloserine (TSC) agar.

cfu/g= colony forming units per gram of litter material

Table 11. Weekly mortality and culls in commercial broiler houses treated with Litter Guard (LG) and Poultry Litter Treatment (PLT) (Trial 1)[1]

| | Week | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment (T)[2] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| LG | 285 | 140 | 49 | 37 | 67 | 98 | 57 | 734 |
| PLT | 314 | 156 | 95 | 54 | 85 | 114 | 73 | 797 |
| SEM | 54 | 49 | 36 | 14 | 22 | 6 | 21 | 157 |
| P-value | 0.7124 | 0.6415 | 0.8707 | 0.8858 | 0.8000 | 0.9678 | 0.7862 | 0.7220 |

[1]Values are a weekly total expressed as number of birds per house as derived from 6 commercial broiler houses (3 per treatment level). Total represents cumulative mortality for the entire grow out period. Number of birds placed in each house was 28,000 head.
[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
SEM= Pooled Standard Error Mean

Table 12. Effect of Poultry Litter Treatment (PLT) and Litter Guard (LG) on foot pad dermatitis (Trial 1)

| | Score* | | |
|---|---|---|---|
| | Score 0 | Score 1 | Score 2 |
| Treatment[1] | | | |
| LG | 455.6 | 43.0 | 1.3 |
| PLT | 382.6 | 91.3 | 26.0 |
| SEM | 60.7 | 43.5 | 17.3 |
| P-value | 0.4436 | 0.4760 | 0.3714 |
| Litter Age[2] | | | |
| 2 | 452.5 | 45.0 | 2.5 |
| 3 | 473.0 | 27.0 | 0.0 |
| 6 | 332.0 | 129.5 | 38.5 |
| SEM | 69.3 | 48.7 | 21.0 |
| P-value | 0.4148 | 0.4001 | 0.4525 |
| House | | | |
| 1-LG | 452 | 46 | 2 |
| 2-PLT | 212 | 213 | 75 |
| 3-LG | 454 | 44 | 2 |
| 4-PLT | 485 | 15 | 0 |
| 5-LG | 461 | 39 | 0 |
| 6-PLT | 451 | 46 | 3 |

*Score 0 = no lesions on foot pad, Score 1= mild dermatitis lesions, Score 2 = severe dermatitis lesions. At processing, 500 paws were collected from each house and visually scored for quality (Values represent the number of paws for each score obtained).
[1]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.[2]Litter age indicates number of flocks reared prior to initiation of this trial.
SEM= Pooled Standard Error Mean

**Trial 2**

Litter treatments significantly *(P<0.10)* reduced ammonia levels on day1 and day 15 of sampling (Table 13). PLT reduced ammonia levels after application on day1 (20.7 ppm) compared to initial sampling (83.9 ppm) and even when compared to LG application (67.1 ppm). On the other hand, application of LG reduced ammonia emissions by day 15 *(P<0.10).* No significant differences were observed on other days of sampling when comparing either treatment.

Houses showed significant *(P<0.10)* differences in ammonia emission rates initially and on day 1, 8, 15 and 36 of sampling with no particular pattern (Table 13). Seven flock litter showed significantly *(P<0.10)* higher ammonia emission rates on day 8 and 15 as compared to 3 flock litter. Sampling locations did not have any effect on ammonia levels except on day 29 where location 4 had significantly higher ammonia levels (210 ppm) compared to sampling locations 2 and 3.

pH levels were significantly *(P<0.10)* affected by litter treatment on day 1 of sampling with PLT treated litter showing a significant lower pH compared to LG treated litter (Table 14). Houses had a significant effect on pH levels on initial day of sampling, day 1, 29, 36 and 45 and illustrated random fluctuations. Litter age had a significant *(P<0.10)* impact on pH levels only on initial day of sampling with 7 flock litter exhibiting the lowest (8.29) pH levels and 3 flock litter highest (8.53) pH levels. Sampling location exhibited a significant *(P<0.10)* difference on pH levels only on day 22 of sampling with location 4 exhibiting highest pH level (8.32) and location 2 the lowest (7.86).

Litter moisture levels were significantly *(P<0.10)* affected by litter treatment only on day 36 of the trial with PLT treated litter exhibiting significantly *(P<0.10)* lower moisture levels as compared to LG treated litter (Table 15). Houses exhibited a significant difference in moisture levels only on day 15 of sampling with house 2 treated with PLT showing the lowest moisture levels (24.45 %) and house 6 treated with PLT showing the highest moisture levels (26.35 %). Litter age showed a significant difference in moisture levels on day 15 and 36 with 3 flock litter exhibiting higher moisture levels for both sampling days. Sampling locations had a significant *(P<0.10)* effect on the moisture levels initially and on day 1 and 22 of sampling with sampling location 4 exhibiting the highest moisture levels for most of the sampling days.

Water activity ($a_w$) of litter was not affected by either of the litter treatments. Houses exhibited a significant difference in $a_w$ on day 29 and 36 of sampling. There were no consistent results with house, litter age or location on $a_w$ levels for the entire trial. Day 8 and 15 $a_w$ readings are unavailable due to non operational equipment.

Aerobic bacterial counts showed a significant *(P<0.10)* difference with litter treatments on day 22 and 45 of sampling (Table 17). Houses showed a significant *(P<0.10)* difference in aerobic bacterial count on day 1, 8, 22, 29 and 45 of sampling with no consistent results among any of the houses. Litter age showed significantly *(P<0.10)* different aerobic bacterial count on day 8, 22, 29 and 45 of sampling, without any consistent results among the three litter ages. Sampling location did not have any significant *(P>0.10)* effect on the aerobic bacterial count for the entire trial.

Total coliform count was significantly different on initial day of sampling with LG treated litter showing a significantly higher (4.56 cfu/gm) coliform counts compared

to PLT treated litter (4.03 cfu/gm) (Table 18). Day 29 showed a decrease in total coliform counts compared to day 22. Houses showed a significant *(P<0.10)* difference in total coliform count only on initial day of sampling. No consistent patterns were observed in total coliform counts with any of the houses throughout rest of the trial. Litter age showed a significant difference in total coliform count only on initial day of sampling where 3 and 7 flock litter exhibited highest bacterial count (4.69 and 4.44 cfu/gm respectively) and 4 flock litter with the lowest count (3.76 cfu/gm). No consistent results were noticed with different litter ages for the entire trial. Sampling locations did not show any significant *(P>0.10)* difference in total coliform counts except on day 36 *(P<0.10)* with location 2 exhibiting the highest count and location 1 the lowest count.

*E.coli* counts were significantly *(P<0.10)* affected by litter treatments on day 1 and 22 of sampling both showing LG treated litter with significantly higher *E.coli* counts compared to PLT treated litter (Table 19). There was a steep decrease in *E.coli* counts on day 1 thereafter showing a gradual increase in *E.coli* counts till day 22. Houses had a significant difference in *E.coli* counts on day 1 and 29 of sampling. Litter age showed a significant *(P<0.10)* difference in *E.coli* counts only on day 1 of sampling with 7 flock litter showing the highest (3.92 cfu/gm) *E.coli* count and 4 flock litter the lowest (3.45 cfu/gm) *E.coli* counts. Sampling location had a significant effect on *E.coli* counts on day 8 and 36 of sampling with location 1 showing significantly lower *E.coli* counts for both the sampling days.

Anaerobic bacterial counts were significantly *(P<0.10)* affected by litter treatments on day 15 of trial with PLT treated litter showing significantly *(P<0.10)* higher counts compared to LG treated litter (Table 20). Houses showed a significant

difference in anaerobic counts on day 8, 15, 22, 36 and 4 but there were no consistent results regarding the highest and lowest anaerobic counts among all houses. Litter age had a significant *(P<0.10)* affect on anaerobic bacterial count only on day 22 and 36 of trial. Sampling locations had no significant *(P>0.10)* effect on the anaerobic counts of litter.

*Cl.perfringens* counts were significantly affected by litter treatment application on initial day of sampling and on day 15 with similar results on both of these sampling days (Table 21). *Cl.perfringens* counts were significantly affected by houses on initial day, day 1, 8, 36 and 45 of sampling. House 6 treated with PLT showed highest *Cl.perfringens* counts for the entire trial except on last day of sampling on day 45. There was no consistent pattern regarding *Cl.perfringens* and its relation to different houses. Litter age significantly *(P<0.10)* affected the *Cl.perfringens* counts on initial day, day 1 and 8 of sampling. Three flock litter showed significantly *(P<0.10)* high *Cl.perfringens* levels for these three sampling days and 7 flock litter showed consistently lower *Cl.perfringens* levels. Sampling location had a significant *(P<0.10)* effect on *Cl.perfringens* levels only on day 29 with locations 1 and 2 showing highest count and location 4 the least count. There were no particular patterns regarding the effect of different sampling locations on *Cl.perfringens* counts for the entire trial.

Mortality data revealed that PLT treated litter houses had a slightly higher final mortality as compared to LG treated houses but there were no significant differences between the values (Table 22). Litter treatments did not show any effect on footpad dermatitis scores (Table 23). Litter age and different houses also did not show any effect on footpad dermatitis scores.

**Discussion**

Application of PLT decreased ammonia emission rates significantly *(P<0.10)* on day 1 of the trial due to its acidic nature. On the other hand, LG application significantly increased ammonia emission rates on day 1 due to the procedure followed after LG application; i.e. heating of the house and closing for 24 hours. This led to an accumulation of ammonia that was not dissipated on day 1 of the trial. Both litter treatments were ineffective in maintaining low ammonia levels after day 15. Terzich et al. (1998) observed similar effect of PLT in reducing ammonia and bacterial levels in poultry litter compared to control litter.

pH levels were significantly *(P<0.10)* decreased on application of PLT due to the acidic nature of PLT. Both litter treatments were ineffective after the first week of the trial as indicated by gradual increase in pH by day 8. Other litter treatments have also proved to be effective in reducing pH levels. Huff et al. (1984) found that ferrous sulfate as a litter acidifier is efficient in reducing litter pH for the first couple of weeks but there was a considerable increase in pH after 8 weeks of age. This confirms the fact that most of the acidic litter treatments are ineffective in maintaining pH levels after 3-4 weeks of application irrespective of their application rate.

Litter moisture was reduced on day 1 after PLT and LG application due to the heating of the house. There was a gradual increase in moisture levels after day 8 since as birds age they excrete increasing amounts of excreta containing large amounts of moisture. Increase in litter moisture levels were coupled with increasing ammonia emission rates for the first 3 weeks thereafter showing random fluctuations. Miles et al. (2011) noticed similar results while estimating the effect of moisture content of organic

and inorganic litter source on ammonia generation. They found that moisture levels in litter were directly proportional to the ammonia emission rates in poultry houses.

Aerobic bacterial counts were reduced after application of both litter treatments on day 1. There was a gradual increase in aerobic bacterial levels after day 8. Seven flock litter exhibited consistently higher aerobic bacterial counts for most of the readings, which was due to the reason that 7 flock litter contained much more organic matter than 3 or 4 flock litter. This higher organic microbial load favors microbial growth. Ruiz et al. (2008) conducted a trial with quicklime to determine its effect on aged litter and bacterial counts. It was noticed that used litter treated with 10% quicklime showed $1.6x10^6$ cfu/gm of aerobic counts and new litter treated with 15% quicklime had $1.0x10^3$ cfu/gm of aerobic bacteria. So, increase in litter age has a direct impact on increases in aerobic bacterial counts unless litter treatments are applied.

## References


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Table 13. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of ammonia volatilization (ppm) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T) | | | | | | | | |
| LG | 52.9[b] | 67.1[a] | 39.6 | 40.5[b] | 87.3 | 157.4 | 120.0 | 135.8 |
| PLT | 83.9[a] | 20.7[b] | 34.2 | 51.8[a] | 96.7 | 148.4 | 142.6 | 148.2 |
| SEM | 10.3 | 5.0 | 3.8 | 2.9 | 4.7 | 17.1 | 10.7 | 7.7 |
| P-value | 0.0457 | 0.0001 | 0.3246 | 0.0114 | 0.1697 | 0.7135 | 0.1498 | 0.2682 |
| House (H) | | | | | | | | |
| 1—LG | 44.8[ab] | 73.0[a] | 45.0[a] | 42.5[ab] | 78.8 | 116.0 | 82.3[b] | 127.5 |
| 2—PLT | 58.3[ab] | 25.4[bc] | 51.3[a] | 61.3[a] | 108.3 | 94.0 | 130.0[ab] | 140.5 |
| 3—LG | 30.3[b] | 60.0[ab] | 33.4[ab] | 38.1[b] | 90.0 | 183.0 | 145.3[ab] | 143.0 |
| 4—PLT | 88.5[ab] | 17.5[c] | 18.0[b] | 53.3[ab] | 91.0 | 174.3 | 166.5[a] | 174.5 |
| 5—LG | 83.8[ab] | 68.3[a] | 40.5[a] | 41.0[b] | 93.0 | 173.3 | 132.8[ab] | 137.0 |
| 6--PLT | 105.0[a] | 19.2[bc] | 33.4[ab] | 40.8[b] | 90.8 | 177.0 | 131.3[ab] | 129.5 |
| SEM | 15.7 | 9.2 | 4.2 | 4.2 | 7.9 | 26.1 | 15.7 | 12.2 |
| P-value | 0.0264 | 0.0004 | 0.0006 | 0.0070 | 0.2661 | 0.1110 | 0.0330 | 0.1343 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 67.7 | 39.6 | 33.4[b] | 39.4[b] | 90.4 | 180.0[a] | 138.3[a] | 136.3 |
| 4 | 86.1 | 42.9 | 29.3[b] | 47.1[ab] | 92.0 | 173.8[a] | 149.6[ab] | 155.8 |
| 7 | 51.6 | 49.2 | 48.1[a] | 51.9[a] | 93.5 | 105.0[b] | 106.1[b] | 134.0 |
| SEM | 13.2 | 10.7 | 3.8 | 3.7 | 6.1 | 17.3 | 12.2 | 9.2 |
| P-value | 0.2033 | 0.8132 | 0.0049 | 0.0786 | 0.9371 | 0.0098 | 0.0512 | 0.2079 |
| Location (L)[4] | | | | | | | | |
| 1 | 42.2 | 36.8 | 43.1 | 41.1 | 92.7 | 163.0[ab] | 150.0 | 150.7 |
| 2 | 64.7 | 44.9 | 33.2 | 49.8 | 86.7 | 116.2[b] | 125.2 | 138.7 |
| 3 | 93.2 | 46.0 | 29.8 | 44.8 | 86.8 | 122.5[b] | 103.7 | 121.8 |
| 4 | 73.7 | 47.8 | 41.6 | 48.8 | 101.7 | 210.0[a] | 146.5 | 156.8 |
| SEM | 14.7 | 12.6 | 5.2 | 4.7 | 6.7 | 19.1 | 14.4 | 10.1 |
| P-value | 0.1363 | 0.9291 | 0.2370 | 0.5457 | 0.3743 | 0.0086 | 0.1157 | 0.1043 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 14. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of litter pH levels (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.39 | 8.43[a] | 8.25 | 8.03 | 8.10 | 8.51[a] | 8.33 | 8.40 |
| PLT | 8.42 | 7.68[b] | 8.21 | 8.00 | 8.07 | 8.28[b] | 8.31 | 8.42 |
| SEM | 0.062 | 0.204 | 0.083 | 0.082 | 0.076 | 0.058 | 0.042 | 0.058 |
| P-value | 0.7386 | 0.0162 | 0.7220 | 0.8100 | 0.8085 | 0.0100 | 0.7138 | 0.8341 |
| House (H) | | | | | | | | |
| 1—LG | 8.31[bc] | 8.32[ab] | 8.44 | 7.89 | 8.06 | 8.36[bcd] | 8.36[a] | 8.17[b] |
| 2—PLT | 8.24[c] | 7.56[bc] | 8.33 | 7.97 | 7.91 | 8.24[cd] | 8.12[b] | 8.26[b] |
| 3—LG | 8.27[bc] | 8.42[a] | 8.12 | 8.03 | 8.06 | 8.71[a] | 8.41[a] | 8.49[a] |
| 4—PLT | 8.57[a] | 8.26[ab] | 8.14 | 8.26 | 8.22 | 8.42[bc] | 8.38[a] | 8.51[a] |
| 5—LG | 8.60[a] | 8.54[a] | 8.17 | 8.18 | 8.19 | 8.48[b] | 8.23[b] | 8.55[a] |
| 6—PLT | 8.47[ab] | 7.22[c] | 8.15 | 7.78 | 8.09 | 8.18[d] | 8.43[a] | 8.49[a] |
| SEM | 0.087 | 0.346 | 0.145 | 0.126 | 0.135 | 0.085 | 0.052 | 0.075 |
| P-value | 0.0303 | 0.0788 | 0.6056 | 0.1238 | 0.6541 | 0.0061 | 0.0036 | 0.0090 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 8.53[a] | 7.88 | 8.16 | 7.98 | 8.14 | 8.33 | 8.33 | 8.52 |
| 4 | 8.40[ab] | 7.91 | 8.24 | 8.11 | 8.07 | 8.33 | 8.25 | 8.39 |
| 7 | 8.29[b] | 8.37 | 8.29 | 7.96 | 8.06 | 8.53 | 8.39 | 8.33 |
| SEM | 0.069 | 0.280 | 0.102 | 0.100 | 0.095 | 0.077 | 0.049 | 0.066 |
| P-value | 0.0685 | 0.3923 | 0.6456 | 0.5022 | 0.8001 | 0.1245 | 0.1792 | 0.1372 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.49 | 8.15 | 8.33 | 8.03 | 8.23[a] | 8.48 | 8.28 | 8.34 |
| 2 | 8.42 | 7.51 | 8.35 | 8.01 | 7.86[b] | 8.43 | 8.33 | 8.41 |
| 3 | 8.27 | 8.01 | 8.19 | 7.88 | 7.94[b] | 8.22 | 8.27 | 8.46 |
| 4 | 8.46 | 8.55 | 8.05 | 8.15 | 8.32[a] | 8.45 | 8.42 | 8.44 |
| SEM | 0.085 | 0.304 | 0.111 | 0.114 | 0.075 | 0.090 | 0.057 | 0.084 |
| P-value | 0.2998 | 0.1540 | 0.2220 | 0.4427 | 0.0007 | 0.2023 | 0.2694 | 0.7488 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 15. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter moisture levels (%) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 23.31 | 18.46 | 17.54 | 25.19 | 21.56 | 23.52 | 27.20[a] | 23.90 |
| PLT | 23.62 | 18.58 | 17.88 | 25.62 | 21.44 | 25.40 | 25.60[b] | 23.73 |
| SEM | 0.818 | 0.499 | 0.827 | 0.255 | 0.512 | 1.602 | 0.525 | 0.629 |
| P-value | 0.7924 | 0.9535 | 0.7729 | 0.2426 | 0.8646 | 0.4148 | 0.0427 | 0.8460 |
| House (H) | | | | | | | | |
| 1—LG | 23.65 | 18.15 | 15.60 | 24.55[b] | 21.50 | 17.75 | 26.00 | 23.30 |
| 2—PLT | 22.37 | 17.97 | 16.62 | 24.45[b] | 21.07 | 24.15 | 25.05 | 24.20 |
| 3—LG | 23.30 | 19.42 | 18.47 | 24.77[b] | 21.32 | 27.45 | 27.37 | 24.50 |
| 4—PLT | 23.92 | 19.40 | 18.52 | 26.07[a] | 22.35 | 25.57 | 25.35 | 22.82 |
| 5—LG | 23.00 | 17.82 | 18.55 | 26.25[a] | 21.87 | 25.37 | 28.22 | 23.92 |
| 6—PLT | 24.57 | 18.15 | 18.50 | 26.35[a] | 20.90 | 26.50 | 26.40 | 24.17 |
| SEM | 1.517 | 0.875 | 1.435 | 0.163 | 0.940 | 2.521 | 0.904 | 1.159 |
| P-value | 0.9329 | 0.6383 | 0.5664 | 0.0001 | 0.8917 | 0.1450 | 0.1634 | 0.9076 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 23.78 | 17.98 | 18.52 | 26.30[a] | 21.38 | 25.93 | 27.31[a] | 24.05 |
| 4 | 23.15 | 18.68 | 17.52 | 25.66[b] | 21.71 | 24.86 | 25.20[b] | 23.51 |
| 7 | 23.47 | 18.78 | 17.03 | 24.66[c] | 21.41 | 22.60 | 26.68[ab] | 23.90 |
| SEM | 1.023 | 0.611 | 1.012 | 0.208 | 0.640 | 1.971 | 0.643 | 0.785 |
| P-value | 0.9079 | 0.6085 | 0.5831 | 0.0001 | 0.9236 | 0.4859 | 0.0806 | 0.8834 |
| Location (L)[4] | | | | | | | | |
| 1 | 23.46[ab] | 19.10[ab] | 16.65 | 25.25 | 22.16[a] | 22.80 | 25.81 | 23.36 |
| 2 | 23.43[ab] | 17.68[bc] | 16.48 | 25.45 | 19.75[b] | 25.88 | 26.50 | 23.50 |
| 3 | 21.43[b] | 17.38[c] | 18.21 | 25.41 | 20.83[b] | 23.78 | 25.80 | 24.21 |
| 4 | 25.50[a] | 19.78[a] | 19.50 | 25.51 | 23.21[a] | 25.40 | 27.48 | 24.20 |
| SEM | 1.027 | 0.593 | 1.098 | 0.388 | 0.486 | 2.349 | 0.8013 | 0.918 |
| P-value | 0.0746 | 0.0285 | 0.2027 | 0.9672 | 0.0004 | 0.7756 | 0.4229 | 0.8667 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 16. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter water activity ($a_w$) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 0.785 | 0.794 | **** | **** | 0.867 | 0.951 | 0.945 | 0.908 |
| PLT | 0.859 | 0.767 | **** | **** | 0.881 | 0.957 | 0.902 | 0.897 |
| SEM | 0.081 | 0.029 | **** | **** | 0.014 | 0.016 | 0.013 | 0.014 |
| P-value | 0.5271 | 0.5249 | **** | **** | 0.5135 | 0.7835 | 0.0316 | 0.5987 |
| House (H) | | | | | | | | |
| 1—LG | 0.933 | 0.802 | **** | **** | 0.864 | 0.882[b] | 0.913[bc] | 0.920 |
| 2—PLT | 0.959 | 0.789 | **** | **** | 0.843 | 0.946[a] | 0.916[b] | 0.867 |
| 3—LG | 0.945 | 0.865 | **** | **** | 0.859 | 0.999[a] | 0.981[a] | 0.924 |
| 4—PLT | 0.987 | 0.816 | **** | **** | 0.904 | 0.977[a] | 0.924[b] | 0.917 |
| 5—LG | **** | 0.715 | **** | **** | 0.877 | 0.972[a] | 0.942[ab] | 0.881 |
| 6—PLT | **** | 0.697 | **** | **** | 0.895 | 0.949[a] | 0.866[c] | 0.908 |
| SEM | 0.023 | 0.045 | **** | **** | 0.025 | 0.022 | 0.020 | 0.025 |
| P-value | 0.5604 | 0.1356 | **** | **** | 0.5660 | 0.0332 | 0.0235 | 0.5344 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | **** | 0.706[b] | **** | **** | 0.886 | 0.961 | 0.904 | 0.895 |
| 4 | 0.973 | 0.802[a] | **** | **** | 0.873 | 0.961 | 0.920 | 0.892 |
| 7 | 0.939 | 0.833[a] | **** | **** | 0.861 | 0.940 | 0.947 | 0.922 |
| SEM | 0.035 | 0.030 | **** | **** | 0.018 | 0.020 | 0.017 | 0.017 |
| P-value | 0.621 | 0.0212 | **** | **** | 0.6376 | 0.7075 | 0.2327 | 0.4328 |
| Location (L)[4] | | | | | | | | |
| 1 | 0.921 | 0.805 | **** | **** | 0.915[a] | 0.981 | 0.929 | 0.887 |
| 2 | 0.946 | 0.748 | **** | **** | 0.834[b] | 0.942 | 0.933 | 0.879 |
| 3 | 0.956 | 0.785 | **** | **** | 0.840[b] | 0.961 | 0.909 | 0.942 |
| 4 | 0.925 | 0.783 | **** | **** | 0.905[a] | 0.934 | 0.922 | 0.903 |
| SEM | 0.025 | 0.042 | **** | **** | 0.0148 | 0.022 | 0.021 | 0.018 |
| P-value | 0.5610 | 0.8177 | **** | **** | 0.0010 | 0.4882 | 0.8657 | 0.1186 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

****Equipment not operational.

SEM= Pooled Standard Error Mean

Table 17. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total aerobic bacterial counts* ($Log_{10}$ cfu/g) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.42 | 7.76 | 7.69 | 8.94 | 9.52[a] | 9.36 | 8.78 | 6.70[b] |
| PLT | 8.46 | 8.12 | 7.70 | 9.23 | 8.78[b] | 9.27 | 8.72 | 7.65[a] |
| SEM | 0.207 | 0.223 | 0.264 | 0.122 | 0.224 | 0.234 | 0.347 | 0.323 |
| P-value | 0.8681 | 0.2666 | 0.9793 | 0.1116 | 0.0284 | 0.7940 | 0.9048 | 0.0499 |
| House (H) | | | | | | | | |
| 1—LG | 8.80 | 7.60[cd] | 8.16[a] | 8.65 | 9.53[b] | 9.63[ab] | 8.35 | 6.28[b] |
| 2—PLT | 8.93 | 7.99[bc] | 8.40[a] | 8.99 | 9.63[ab] | 10.07[a] | 9.99 | 6.62[b] |
| 3—LG | 8.32 | 8.45[ab] | 7.32[a] | 9.09 | 10.2[a] | 10.02[a] | 9.34 | 5.97[b] |
| 4—PLT | 8.17 | 7.41[cd] | 7.73[ab] | 9.27 | 8.26[c] | 8.43[c] | 8.58 | 7.74[a] |
| 5—LG | 8.13 | 7.23[d] | 6.59[c] | 9.09 | 8.80[c] | 8.42[c] | 8.65 | 7.86[a] |
| 6—PLT | 8.30 | 8.96[a] | 6.97[bc] | 9.42 | 8.44[c] | 9.31[b] | 7.89 | 8.59[a] |
| SEM | 0.355 | 0.268 | 0.312 | 0.206 | 0.258 | 0.223 | 0.568 | 0.403 |
| P-value | 0.4929 | 0.0018 | 0.0022 | 0.1988 | 0.0002 | 0.0001 | 0.2922 | 0.0012 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 8.21 | 8.09 | 6.78[b] | 9.26 | 8.62[b] | 8.87[a] | 8.27 | 8.22[a] |
| 4 | 8.55 | 7.70 | 8.07[a] | 9.13 | 8.94[b] | 9.25[ab] | 9.13 | 7.18[b] |
| 7 | 8.56 | 8.03 | 8.24[a] | 8.87 | 9.88[a] | 9.83[a] | 8.84 | 6.12[c] |
| SEM | 0.253 | 0.281 | 0.221 | 0.151 | 0.241 | 0.253 | 0.413 | 0.303 |
| P-value | 0.5551 | 0.5834 | 0.0002 | 0.2031 | 0.0038 | 0.0443 | 0.3386 | 0.0003 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.50 | 7.84 | 8.05 | 9.08 | 9.05 | 8.99 | 8.75 | 7.37 |
| 2 | 8.70 | 7.66 | 7.47 | 9.16 | 9.24 | 9.15 | 8.68 | 7.04 |
| 3 | 8.14 | 8.19 | 7.99 | 8.81 | 9.18 | 9.47 | 9.00 | 7.49 |
| 4 | 8.43 | 8.07 | 7.273 | 9.285 | 9.12 | 9.38 | 8.565 | 6.804 |
| SEM | 0.294 | 0.359 | 0.362 | 0.176 | 0.371 | 0.338 | 0.510 | 0.510 |
| P-value | 0.6004 | 0.6683 | 0.3649 | 0.3125 | 0.9844 | 0.7485 | 0.9416 | 0.7721 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Plate Count Agar (PCA).

cfu/g= colony forming units per gram of litter material

Table 18. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total coliform counts* ($Log_{10}$ cfu/g) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 4.56[a] | 4.01 | 5.41 | 5.72 | 5.61 | 4.59 | 5.53 | 4.61 |
| PLT | 4.03[b] | 3.69 | 5.31 | 5.82 | 5.51 | 4.66 | 5.38 | 4.64 |
| SEM | 0.158 | 0.174 | 0.413 | 0.252 | 0.268 | 0.303 | 0.254 | 0.126 |
| P-value | 0.0273 | 0.1940 | 0.8590 | 0.7899 | 0.7840 | 0.8856 | 0.6828 | 0.8439 |
| House (H) | | | | | | | | |
| 1—LG | 4.51[a] | 3.66 | 4.75 | 5.10 | 5.20 | 5.05 | 5.56 | 4.72 |
| 2—PLT | 3.89[bc] | 3.89 | 4.45 | 5.80 | 5.27 | 5.75 | 6.08 | 4.75 |
| 3—LG | 4.36[ab] | 4.52 | 5.84 | 5.99 | 5.83 | 4.67 | 6.01 | 4.54 |
| 4—PLT | 3.63[c] | 3.31 | 6.73 | 6.20 | 5.78 | 3.98 | 4.63 | 4.68 |
| 5—LG | 4.80[a] | 3.87 | 5.64 | 6.07 | 5.80 | 4.04 | 5.02 | 4.56 |
| 6—PLT | 4.57[a] | 3.86 | 4.74 | 5.45 | 5.47 | 4.23 | 5.44 | 4.50 |
| SEM | 0.246 | 0.279 | 0.645 | 0.430 | 0.492 | 0.478 | 0.389 | 0.235 |
| P-value | 0.0277 | 0.1277 | 0.1607 | 0.4784 | 0.8865 | 0.1170 | 0.1123 | 0.9575 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 4.69[a] | 3.86 | 5.19 | 5.76 | 5.64 | 4.13 | 5.23 | 4.53 |
| 4 | 3.76[b] | 3.60 | 5.59 | 6.00 | 5.53 | 4.87 | 5.35 | 4.72 |
| 7 | 4.44[a] | 4.09 | 5.30 | 5.55 | 5.52 | 4.86 | 5.79 | 4.63 |
| SEM | 0.166 | 0.214 | 0.514 | 0.309 | 0.336 | 0.370 | 0.307 | 0.155 |
| P-value | 0.0022 | 0.2925 | 0.8524 | 0.5991 | 0.9615 | 0.2932 | 0.4182 | 0.6999 |
| Location (L)[4] | | | | | | | | |
| 1 | 4.51 | 4.26 | 4.66 | 5.38 | 5.83 | 4.09 | 4.70[c] | 4.92 |
| 2 | 4.11 | 3.65 | 5.62 | 5.92 | 5.62 | 4.77 | 6.13[a] | 4.56 |
| 3 | 4.49 | 3.60 | 6.37 | 5.83 | 5.76 | 5.17 | 5.29[bc] | 4.35 |
| 4 | 4.06 | 3.88 | 4.80 | 5.94 | 5.04 | 4.45 | 5.71[ab] | 4.67 |
| SEM | 0.247 | 0.242 | 0.530 | 0.3608 | 0.3736 | 0.429 | 0.297 | 0.163 |
| P-value | 0.4441 | 0.2303 | 0.1138 | 0.6660 | 0.4486 | 0.3540 | 0.0189 | 0.1345 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Eosin Methylene Blue (EMB) agar.

cfu/g= colony forming units per gram of litter material

Table 19. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *E.coli* levels * ($Log_{10}$ cfu/g) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 4.32 | 3.89[a] | 4.89 | 5.18 | 5.50[a] | 4.75 | 5.39 | 4.36 |
| PLT | 3.90 | 3.53[b] | 4.52 | 5.39 | 4.91[b] | 5.05 | 5.17 | 4.21 |
| SEM | 0.223 | 0.116 | 0.307 | 0.200 | 0.168 | 0.292 | 0.234 | 0.153 |
| P-value | 0.1976 | 0.0408 | 0.4120 | 0.4614 | 0.0206 | 0.4825 | 0.5113 | 0.4934 |
| House (H) | | | | | | | | |
| 1—LG | 4.17 | 3.48[bc] | 4.08 | 5.00 | 5.64 | 4.34[c] | 5.48 | 4.46 |
| 2—PLT | 3.90 | 3.48[bc] | 4.28 | 5.18 | 4.58 | 6.10[a] | 5.57 | 4.46 |
| 3—LG | 4.21 | 4.36[a] | 5.70 | 5.66 | 5.29 | 5.54[ab] | 5.62 | 4.35 |
| 4—PLT | 3.48 | 3.43[c] | 5.21 | 5.25 | 5.18 | 4.14[c] | 5.27 | 4.15 |
| 5—LG | 4.56 | 3.83[b] | 4.88 | 4.88 | 5.58 | 4.38[c] | 5.07 | 4.27 |
| 6—PLT | 4.32 | 3.69[bc] | 4.08 | 5.76 | 4.97 | 4.91[bc] | 4.67 | 4.01 |
| SEM | 0.397 | 0.158 | 0.483 | 0.342 | 0.299 | 0.392 | 0.411 | 0.281 |
| P-value | 0.5047 | 0.0049 | 0.1420 | 0.4170 | 0.1776 | 0.0140 | 0.5750 | 0.8434 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 4.44 | 3.76[ab] | 4.48 | 5.32 | 5.27 | 4.64 | 4.87 | 4.14 |
| 4 | 3.69 | 3.45[b] | 4.75 | 5.21 | 4.88 | 5.12 | 5.42 | 4.31 |
| 7 | 4.19 | 3.92[a] | 4.89 | 5.33 | 5.47 | 4.94 | 5.55 | 4.40 |
| SEM | 0.265 | 0.142 | 0.386 | 0.254 | 0.220 | 0.363 | 0.275 | 0.189 |
| P-value | 0.1493 | 0.0853 | 0.7507 | 0.9370 | 0.1825 | 0.6461 | 0.2022 | 0.6261 |
| Location (L)[4] | | | | | | | | |
| 1 | 4.32 | 3.77 | 3.75[b] | 5.10 | 5.13 | 4.37 | 4.55[b] | 4.40 |
| 2 | 3.89 | 3.77 | 5.07[a] | 5.28 | 5.19 | 5.32 | 5.86[a] | 4.34 |
| 3 | 4.47 | 3.65 | 5.36[a] | 5.23 | 5.08 | 5.36 | 5.42[a] | 4.02 |
| 4 | 3.74 | 3.65 | 4.64[ab] | 5.58 | 5.418 | 4.553 | 5.29[a] | 4.38 |
| SEM | 0.317 | 0.187 | 0.375 | 0.290 | 0.276 | 0.391 | 0.281 | 0.218 |
| P-value | 0.3478 | 0.9386 | 0.0351 | 0.6823 | 0.8315 | 0.1905 | 0.0277 | 0.5752 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using MacConkey (MAC) agar.

cfu/g= colony forming units per gram of litter material

Table 20. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on anaerobic bacterial counts*($Log_{10}$ cfu/g) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 5.92 | 5.56 | 6.70 | 7.03[b] | 7.17 | 7.19 | 6.93 | 6.72 |
| PLT | 6.10 | 5.43 | 6.61 | 7.68[a] | 6.74 | 7.41 | 6.77 | 6.82 |
| SEM | 0.143 | 0.115 | 0.306 | 0.180 | 0.112 | 0.185 | 0.072 | 0.065 |
| P-value | 0.3932 | 0.4472 | 0.8266 | 0.0178 | 0.0130 | 0.4082 | 0.1284 | 0.3009 |
| House (H) | | | | | | | | |
| 1—LG | 5.88 | 5.27 | 6.55[a] | 6.89[c] | 7.09[ab] | 7.34 | 7.05[a] | 6.78[b] |
| 2—PLT | 6.48 | 5.21 | 5.41[b] | 7.23[bc] | 6.75[bc] | 8.04 | 7.01[a] | 6.67[b] |
| 3—LG | 5.92 | 5.71 | 6.63[a] | 7.12[bc] | 7.44[a] | 6.84 | 7.02[a] | 6.79[b] |
| 4—PLT | 5.827 | 5.42 | 7.56[a] | 7.66[ab] | 6.59[c] | 7.23 | 6.64[b] | 7.08[a] |
| 5—LG | 5.98 | 5.70 | 6.93[a] | 7.07[bc] | 6.98[abc] | 7.39 | 6.72[b] | 6.60[b] |
| 6—PLT | 5.95 | 5.66 | 6.86[a] | 8.16[a] | 6.86[bc] | 6.96 | 6.65[b] | 6.70[b] |
| SEM | 0.250 | 0.189 | 0.453 | 0.306 | 0.194 | 0.284 | 0.102 | 0.094 |
| P-value | 0.5164 | 0.2650 | 0.0748 | 0.0825 | 0.0920 | 0.1023 | 0.0180 | 0.0333 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 5.96 | 5.68 | 6.89 | 7.61 | 6.92[b] | 7.18 | 6.69[a] | 6.65 |
| 4 | 6.18 | 5.32 | 6.48 | 7.44 | 6.67[b] | 7.64 | 6.82[b] | 6.87 |
| 7 | 5.90 | 5.49 | 6.59 | 7.01 | 7.26[a] | 7.09 | 7.03[b] | 6.78 |
| SEM | 0.177 | 0.135 | 0.378 | 0.239 | 0.134 | 0.217 | 0.078 | 0.076 |
| P-value | 0.5130 | 0.1899 | 0.7285 | 0.2064 | 0.0194 | 0.1884 | 0.0174 | 0.1365 |
| Location (L)[4] | | | | | | | | |
| 1 | 6.26 | 5.61 | 6.15 | 6.94 | 6.88 | 7.42 | 6.72 | 6.68 |
| 2 | 6.03 | 5.41 | 6.69 | 7.52 | 6.84 | 7.04 | 7.01 | 6.79 |
| 3 | 5.83 | 5.36 | 7.19 | 7.50 | 6.83 | 7.48 | 6.84 | 6.77 |
| 4 | 5.93 | 5.60 | 6.58 | 7.46 | 7.23 | 7.27 | 6.82 | 6.83 |
| SEM | 0.204 | 0.165 | 0.423 | 0.286 | 0.178 | 0.268 | 0.103 | 0.096 |
| P-value | 0.4974 | 0.6120 | 0.4095 | 0.4446 | 0.3940 | 0.6691 | 0.2936 | 0.6995 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Anaerobic Agar (AA)

cfu/g= colony forming units per gram of litter material

Table 21. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *Clostridium perfringens* counts *($Log_{10}$ cfu/g) (Trial 2)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 45 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.81[b] | 3.75 | 3.86 | 3.73[a] | 3.99 | 3.91 | 3.61 | 3.65 |
| PLT | 3.99[a] | 3.77 | 3.94 | 3.99[b] | 3.94 | 3.89 | 3.73 | 3.87 |
| SEM | 0.070 | 0.123 | 0.115 | 0.094 | 0.087 | 0.085 | 0.067 | 0.100 |
| P-value | 0.0887 | 0.9143 | 0.6160 | 0.0583 | 0.9796 | 0.8762 | 0.2091 | 0.1406 |
| House (H) | | | | | | | | |
| 1—LG | 3.96[ab] | 3.48[b] | 3.56[c] | 3.69 | 3.88 | 3.97 | 3.75[ab] | 3.66[bc] |
| 2—PLT | 3.86[b] | 3.48[b] | 3.80[c] | 3.79 | 4.04 | 3.82 | 3.55[b] | 3.57[bc] |
| 3—LG | 3.52[c] | 3.48[b] | 3.82[bc] | 3.79 | 4.06 | 3.98 | 3.51[b] | 3.82[b] |
| 4—PLT | 3.93[b] | 3.48[b] | 3.72[c] | 4.09 | 3.84 | 3.72 | 3.37[ab] | 4.31[a] |
| 5—LG | 3.95[b] | 4.29[a] | 4.20[ab] | 3.71 | 4.04 | 3.79 | 3.56[b] | 3.48[c] |
| 6—PLT | 4.18[a] | 4.34[a] | 4.31[a] | 4.11 | 4.11 | 4.14 | 3.93[a] | 3.73[bc] |
| SEM | 0.093 | 0.062 | 0.162 | 0.169 | 0.157 | 0.142 | 0.104 | 0.130 |
| P-value | 0.0044 | 0.0001 | 0.0295 | 0.3347 | 0.7894 | 0.3530 | 0.0882 | 0.0045 |
| Litter Age (LA)[3] | | | | | | | | |
| 3 | 4.06[a] | 4.31[a] | 4.25[a] | 3.91 | 4.07 | 3.96 | 3.76 | 3.60 |
| 4 | 3.90[ab] | 3.48[b] | 3.76[b] | 3.94 | 3.94 | 3.77 | 3.64 | 3.94 |
| 7 | 3.75[b] | 3.48[b] | 3.69[b] | 3.74 | 3.97 | 3.98 | 3.63 | 3.74 |
| SEM | 0.081 | 0.041 | 0.111 | 0.124 | 0.107 | 0.101 | 0.085 | 0.121 |
| P-value | 0.0385 | 0.0001 | 0.0031 | 0.4904 | 0.4410 | 0.2932 | 0.5734 | 0.1705 |
| Location (L)[4] | | | | | | | | |
| 1 | 3.95 | 3.66 | 3.94 | 3.94 | 4.08 | 4.06[a] | 3.70 | 3.66 |
| 2 | 3.87 | 3.81 | 3.83 | 3.62 | 4.08 | 4.07[a] | 3.62 | 3.77 |
| 3 | 3.97 | 3.81 | 3.90 | 3.83 | 3.92 | 3.84[ab] | 3.78 | 3.82 |
| 4 | 3.82 | 3.75 | 3.93 | 4.06 | 3.89 | 3.64[b] | 3.58 | 3.80 |
| SEM | 0.109 | 0.181 | 0.171 | 0.134 | 0.123 | 0.098 | 0.097 | 0.153 |
| P-value | 0.7565 | 0.9329 | 0.9683 | 0.1630 | 0.5725 | 0.0144 | 0.4818 | 0.8755 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.
[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
[3]Litter age indicates number of flocks reared prior to initiation of this trial.
[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.
[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.
SEM= Pooled Standard Error Mean
*Determined using Tryptose Sulfite Cycloserine (TSC) agar.
cfu/g= colony forming units per gram of litter material

Table 22. Weekly mortality and culls in commercial broiler houses treated with Litter Guard (LG) and Poultry Litter Treatment (PLT) (Trial 2)[1]

| | Week | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment (T)[2] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| LG | 753 | 455 | 76 | 52 | 104 | 144 | 129 | 1714 |
| PLT | 594 | 593 | 123 | 62 | 112 | 125 | 160 | 1769 |
| SEM | 428 | 207 | 83 | 29 | 48 | 58 | 52 | 707 |
| P-value | 0.3370 | 0.7677 | 0.7274 | 0.6515 | 0.5730 | 0.3584 | 0.7441 | 0.5359 |

[1]Values are a weekly total expressed as number of birds per house as derived from 6 commercial broiler houses (3 per treatment level). Total represents cumulative mortality for the entire grow out period. Number of birds placed in each house was 28,000 head.
[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
SEM= Pooled Standard Error Mean

Table 23. Effect of Poultry Litter Treatment (PLT) and Litter Guard (LG) on foot pad dermatitis (Trial 2)

| | Score* | | |
|---|---|---|---|
| | Score 0 | Score 1 | Score 2 |
| Treatment[1] | | | |
| LG | 439.6 | 68.6 | 1.3 |
| PLT | 323.6 | 163.6 | 26.0 |
| SEM | 59.9 | 49.3 | 17.3 |
| P-value | 0.2431 | 0.2457 | 0.3714 |
| Litter Age[2] | | | |
| 3 | 322.0 | 165.5 | 2.5 |
| 4 | 440.0 | 78.0 | 0.0 |
| 7 | 382.5 | 105.0 | 38.5 |
| SEM | 90.8 | 76.1 | 21.0 |
| P-value | 0.6914 | 0.7325 | 0.4525 |
| House | | | |
| 1-LG | 406 | 94 | 2 |
| 2-PLT | 359 | 116 | 27 |
| 3-LG | 478 | 34 | 0 |
| 4-PLT | 445 | 78 | 3 |
| 5-LG | 435 | 78 | 8 |
| 6-PLT | 167 | 297 | 45 |

*Score 0 = no lesions on foot pad, Score 1 = mild dermatitis lesions, Score 2 = severe dermatitis lesions. At processing, 500 paws were collected from each house and visually scored for quality (Values represent the number of paws for each score obtained).
[1]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
[2]Litter age indicates number of flocks reared prior to initiation of this trial.
SEM= Pooled Standard Error Mean

**Trial 3**

Ammonia levels were significantly lower *(P<0.10)* (Table 24) in LG treated houses on initial day of sampling, day 11, 18 and 39 (Table 24). All houses showed significant *(P<0.10)* variation in ammonia emission on initial day, day 11, 18, 25 and 39. Eight flock litter showed a significantly *(P<0.10)* high ammonia emission rates only on day 11 compared to four and five flock litter. Eight flock litter showed lower ammonia levels as compared to 4 and 5 flock litter on day 25. Different locations showed significant differences in ammonia levels on numerous sampling days and exhibit no consistent relationship.

pH levels were significantly affected by PLT treatment on day 4, 32 and 39 of the trial (Trial 25). Different houses had a significant *(P<0.10)* effect on pH levels on initial day of sampling, day 11 and 32 of trial. No particular patterns were observed between other houses and pH levels. Litter age had a significant impact on pH levels on initial day and day 11 of the trial with 5 flock litter showing significantly high readings for both samplings. No particular patterns were observed between different litter ages and pH levels for the entire trial. Sampling location resulted in a significant *(P<0.10)* difference with pH levels on day 4, 11, 18 and 32 of the trial but exhibited no specific trends.

Litter moisture was not significantly *(P>0.10)* affected by litter treatment on any of the sampling days except on day 18 *(P<0.10).* On that day PLT treated litter had a significantly *(P<0.10)* high reading (20.10%) compared to LG treated litter (17.85%) (Table 26). There was an increase in litter moisture level after application of PLT on day 4 compared to initial day moisture level (22.41 to 24.24%). Houses showed a significant *(P<0.10)* effect on moisture levels only on day 39 of sampling. Litter age significantly

affected moisture levels on day 25 and 39 of the trial. There was no relationship between the different litter ages and moisture levels for the entire trial. Sampling location had a significant impact on moisture levels on day 11, 25 and 46 of trial with no particular pattern among sampling locations.

Water activity was not significantly affected *(P>0.10)* for the entire trial except on day 46 where PLT treated litter had a higher $a_w$ (0.951) compared to LG treated litter (0.906) (Table 27). LG treated litter had marginally lower $a_w$ readings compared to PLT treated litter for the entire trial. Houses and litter age had no significant *(P>0.10)* impact on $a_w$ levels. Sampling locations showed a significant impact on $a_w$ readings only on day 18 and 25 with sampling location 1 exhibiting a high $a_w$ reading for both samples. No other sampling days had any relationship to $a_w$ readings. Day 39 $a_w$ readings are not available due to non operational equipment.

Litter treatment application has no significant *(P>0.10)* impact on aerobic bacterial counts for the entire trial (Table 28). Though there was a steep decline in aerobic bacterial count from the initial to day 4 followed by a gradual increase in readings till day 25. Houses had a significant impact on aerobic bacterial counts on day 4, 18, 32, 39 and 46 of the trial. Litter age showed a significant impact on aerobic bacterial count on days 4, 18, 32 and 46 of the trial. Eight flock litter had consistently high total aerobic counts compared to 4 and 5 flock litter after day 11. Sampling location had no significant impact on aerobic bacterial counts nor were there any relationship between different sampling locations and aerobic bacterial counts.

Total coliform counts were significantly affected by litter treatments on initial and day 18 of the trial (Table 29). Houses had a significant impact on total coliform levels on

day 11 and 18 of the trial with house 1-4 showing a significantly lower *(P<0.10)* count for both days. Litter age had no significant *(P>0.10)* impact on total coliform count for the entire trial, nor were there any consistent results with different litter ages. Sampling locations significantly *(P<0.10)* affected total coliform counts only on day 4 and 32 of the trial with location 1 and 4 showing a significantly *(P<0.10)* lower count for both sampling days.

*E.coli* counts were not significantly *(P>0.10)* affected with litter treatments for the entire trial except on day 18 of the trial. At that time LG treated litter had significantly *(P<0.10)* high *E.coli* counts (6.03 cfu/gm) compared to PLT treated litter (4.92 cfu/gm) (Table 30). Houses had a significant *(P<0.10)* impact on *E.coli* count on day 11 and 39 of the trial with house 6 having counts. Litter age had a significant *(P<0.10)* impact on *E.coli* counts only on day 11 and 39 of trial. Sampling location significantly *(P<0.10)* affected *E.coli* readings only on day 4 of sampling.

Anaerobic bacterial counts were not significantly *(P>0.10)* affected by litter treatment on any of the sampling days (Table 31). Houses had a significant impact on anaerobic counts on day 11, 32 and 39 of the trial. Different litter age had a significant *(P<0.10)* impact on anaerobic counts on initial day of sampling, day 11 and 32. Sampling locations showed a significant *(P<0.10)* difference in anaerobic counts only on day 4 of sampling. Sampling location 2 had higher anaerobic counts for most of sampling days without any significant difference in readings compared to other locations.

No significant *(P>0.10)* differences were observed with *Clostridium perfringens* counts due to the application of litter treatments (Table 32). Houses had a significant effect on *Cl.perfringens* counts only on day 4 and 11 of the trial. Four flock litter had a

significantly *(P<0.10)* higher *Cl.perfringens* counts on day 11 and 18 of the trial compared to 8 and 5 flock litter. Sampling locations did not show any significant impact on the *Cl.perfringens* counts for the entire trial nor was there any relationship between different sampling locations and *Cl.perfringens* counts.

Mortality of birds was significantly *(P<0.10)* affected by litter treatments in week 1 and 2 of the trial. LG treated houses had significantly *(P<0.10)* higher mortality rates compared to PLT treated houses (Table 33). Final total mortality at the end of the trial also showed a significant *(P<0.10)* difference with LG treated houses having higher mortality rates compared to PLT treated litter.

There was no effect of litter treatments, litter age and houses on footpad dermatitis scores (Table 33).

**Discussion**

PLT treatment showed consistently high ammonia levels for the entire trial as compared to LG. Johnson and Murphy (2000) found PLT to be effective in reducing ammonia levels upto 0 ppm after application in broiler houses. pH levels were significantly *(P<0.10)* decreased after application of PLT on day 4 of sampling compared to LG. PLT was more efficient in reducing litter pH. Choi and Moore noticed similar results in 2008, they found that PLT significantly *(P<0.05)* decreased the pH levels of poultry litter as compared to control litter, but liquid alum was the most effective litter acidifier in reducing litter pH levels.

Aerobic bacterial were not affected by either litter treatments and showed constant fluctuations. Ruiz et al. (2008) found that litter acidifiers showed reduced aerobic bacterial counts.

## References


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Johnson, T. M. and B. Murphy. 2000. Use of sodium bisulfate to reduce ammonia emissions from poultry and livestock housing.. Cited 20/09/2011. http://www.ag.iastate.edu/wastemgmt/Mitigation_Conference_proceedings/CD_proceedings/Animal_Housing_Amendments/Marsh-Johnson-Sodium_Bisulfate.pdf

Table 24. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for. the reduction of ammonia volatilization (ppm) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 64.4[b] | 72.5 | 61.0[b] | 41.2[b] | 95.3 | 146.1 | 99.0[b] | 58.3 |
| PLT | 90.2[a] | 73.9 | 70.5[a] | 50.6[a] | 103.2 | 153.9 | 133.5[a] | 60.0 |
| SEM | 5.3 | 4.3 | 2.5 | 2.5 | 11.3 | 10.9 | 6.2 | 8.1 |
| P-value | 0.0062 | 0.8321 | 0.0139 | 0.0144 | 0.6268 | 0.6229 | 0.0008 | 0.8866 |
| House (H) | | | | | | | | |
| 1—LG | 61.0[b] | 80.7 | 70.5[a] | 46.0[bc] | 76.2[bc] | 144.0 | 80.5[d] | 62.2 |
| 2—PLT | 82.5[a] | 74.2 | 77.0[a] | 56.5[a] | 65.0[c] | 155.2 | 129.7[ab] | 33.8 |
| 3—LG | 58.5[b] | 68.7 | 59.2[bc] | 38.7[c] | 76.2b[c] | 156.7 | 100.0[cd] | 63.5 |
| 4—PLT | 86.2[a] | 87.2 | 62.0[b] | 49.5[ab] | 99.0[b] | 158.2 | 128.7[ab] | 88.0 |
| 5—LG | 82.7[a] | 68.2 | 53.2[c] | 38.8[c] | 133.5[a] | 137.7 | 116.7[bc] | 49.2 |
| 6—PLT | 102.0[a] | 60.2 | 72.7[a] | 46.0[bc] | 145.7[a] | 148.2 | 142.0[a] | 58.2 |
| SEM | 8.5 | 6.7 | 2.9 | 4.2 | 12.9 | 20.7 | 10.1 | 12.4 |
| P-value | 0.0175 | 0.1154 | 0.0001 | 0.0702 | 0.0012 | 0.9761 | 0.0049 | 0.1191 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 80.2 | 64.5 | 66.0[b] | 42.3 | 111.0[a] | 152.5 | 121.0 | 60.8 |
| 5 | 84.5 | 77.7 | 57.6[c] | 44.1 | 116.2[a] | 148.0 | 122.7 | 68.6 |
| 8 | 71.7 | 77.5 | 73.7[a] | 51.2 | 70.6[b] | 149.6 | 105.1 | 48.0 |
| SEM | 7.7 | 4.9 | 2.6 | 3.3 | 12.0 | 13.8 | 9.7 | 9.7 |
| P-value | 0.5033 | 0.1245 | 0.0015 | 0.1623 | 0.0275 | 0.9733 | 0.3889 | 0.3380 |
| Location (L)[4] | | | | | | | | |
| 1 | 59.3[b] | 68.0 | 68.3 | 48.6 | 81.3 | 149.8[b] | 111.1 | 34.5[c] |
| 2 | 78.5[a] | 81.1 | 66.8 | 44.5 | 112.0 | 121.0[c] | 105.5 | 54.3[bc] |
| 3 | 87.0[a] | 78.5 | 62.8 | 41.7 | 104.1 | 130.1[bc] | 123.5 | 68.1[ab] |
| 4 | 90.5[a] | 65.3 | 65.1 | 48.8 | 99.6 | 199.1[a] | 125.0 | 79.6[a] |
| SEM | 7.7 | 5.7 | 4.2 | 4.08 | 16.1 | 9.2 | 11.5 | 9.5 |
| P-value | 0.0430 | 0.1807 | 0.8175 | 0.5567 | 0.5933 | 0.0001 | 0.5746 | 0.0189 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 25. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of litter pH levels (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.30 | 8.40[a] | 8.16 | 8.02 | 7.77 | 8.57[a] | 8.46[a] | 8.20 |
| PLT | 8.21 | 8.10[b] | 8.06 | 8.00 | 7.63 | 8.28[b] | 8.30[b] | 8.33 |
| SEM | 0.046 | 0.082 | 0.063 | 0.071 | 0.094 | 0.067 | 0.061 | 0.052 |
| P-value | 0.1550 | 0.0152 | 0.2793 | 0.8120 | 0.2858 | 0.0066 | 0.0837 | 0.1011 |
| House (H) | | | | | | | | |
| 1—LG | 8.22[b] | 8.27 | 8.00[b] | 8.03 | 7.88 | 8.50[ab] | 8.37 | 8.20 |
| 2—PLT | 8.05[a] | 8.06 | 8.01[b] | 7.98 | 7.76 | 8.22[b] | 8.33 | 8.40 |
| 3—LG | 8.25[b] | 8.42 | 8.08[b] | 7.94 | 7.81 | 8.65[a] | 8.49 | 8.23 |
| 4—PLT | 8.17[b] | 8.06 | 8.17[b] | 8.05 | 7.39 | 8.22[b] | 8.33 | 8.40 |
| 5—LG | 8.44[a] | 8.52 | 8.41[a] | 8.10 | 7.64 | 8.57[a] | 8.53 | 8.17 |
| 6—PLT | 8.40[a] | 8.16 | 8.01[b] | 7.98 | 7.74 | 8.42[ab] | 8.25 | 8.19 |
| SEM | 0.049 | 0.150 | 0.094 | 0.132 | 0.161 | 0.120 | 0.112 | 0.091 |
| P-value | 0.0002 | 0.2129 | 0.0479 | 0.9561 | 0.3833 | 0.0964 | 0.5350 | 0.2946 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 8.83[a] | 8.29 | 8.04[b] | 7.96 | 7.77 | 8.53 | 8.37 | 8.21 |
| 5 | 8.31[a] | 8.29 | 8.29[a] | 8.08 | 7.52 | 8.39 | 8.43 | 8.29 |
| 8 | 8.13[b] | 8.17 | 8.00[b] | 8.00 | 7.82 | 8.36 | 8.35 | 8.30 |
| SEM | 0.050 | 0.116 | 0.067 | 0.087 | 0.110 | 0.096 | 0.081 | 0.068 |
| P-value | 0.0239 | 0.6798 | 0.0146 | 0.6372 | 0.1375 | 0.4014 | 0.7798 | 0.6000 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.26 | 8.40[a] | 8.23[a] | 8.15[a] | 7.88 | 8.53[ab] | 8.25 | 8.23 |
| 2 | 8.23 | 8.02[b] | 8.05[ab] | 7.86[b] | 7.65 | 8.22[c] | 8.42 | 8.15 |
| 3 | 8.26 | 8.06[b] | 7.93[b] | 7.81[b] | 7.70 | 8.34[bc] | 8.33 | 8.21 |
| 4 | 8.27 | 8.53[a] | 8.24[a] | 8.23[a] | 7.58 | 8.62[a] | 8.50 | 8.38 |
| SEM | 0.071 | 0.100 | 0.078 | 0.068 | 0.134 | 0.095 | 0.089 | 0.072 |
| P-value | 0.9676 | 0.0037 | 0.0309 | 0.0005 | 0.4348 | 0.0291 | 0.3479 | 0.1352 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 26. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter moisture levels (%) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 21.19 | 21.02 | 17.50 | 17.85[b] | 18.65 | 25.94 | 24.28 | 21.40 |
| PLT | 22.41 | 24.24 | 18.65 | 20.10[a] | 18.56 | 24.87 | 23.37 | 22.19 |
| SEM | 0.609 | 1.693 | 0.920 | 0.748 | 0.781 | 0.891 | 0.546 | 1.102 |
| P-value | 0.1690 | 0.1928 | 0.3831 | 0.0443 | 0.9346 | 0.4068 | 0.2521 | 0.6203 |
| House (H) | | | | | | | | |
| 1—LG | 21.45 | 17.92 | 17.17 | 16.55 | 19.82 | 23.85 | 22.15[c] | 21.12 |
| 2—PLT | 20.65 | 23.22 | 18.07 | 20.35 | 20.35 | 23.00 | 23.12[bc] | 20.92 |
| 3—LG | 20.00 | 19.37 | 17.62 | 18.27 | 19.00 | 27.70 | 24.72[ab] | 21.72 |
| 4—PLT | 22.95 | 24.92 | 17.92 | 21.50 | 16.52 | 25.67 | 24.45[ab] | 23.05 |
| 5—LG | 22.12 | 25.77 | 17.70 | 18.72 | 17.15 | 26.27 | 25.97[a] | 21.37 |
| 6—PLT | 23.65 | 24.57 | 19.97 | 18.47 | 18.82 | 25.95 | 22.55[c] | 22.57 |
| SEM | 0.977 | 2.912 | 1.717 | 1.284 | 1.272 | 1.483 | 0.751 | 2.074 |
| P-value | 0.1281 | 0.3372 | 0.8918 | 0.1609 | 0.2774 | 0.2974 | 0.0159 | 0.9708 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 21.82 | 21.97 | 18.80 | 18.37 | 18.91[a] | 26.82 | 23.63[b] | 22.15 |
| 5 | 22.53 | 25.35 | 17.81 | 20.11 | 16.83[b] | 25.97 | 25.21[a] | 22.22 |
| 8 | 21.05 | 20.57 | 18.62 | 18.45 | 20.08[a] | 23.42 | 22.63[b] | 21.02 |
| SEM | 0.764 | 2.073 | 1.157 | 0.985 | 0.837 | 0.996 | 0.580 | 1.373 |
| P-value | 0.4035 | 0.2684 | 0.7460 | 0.3869 | 0.0374 | 0.0634 | 0.0168 | 0.7892 |
| Location (L)[4] | | | | | | | | |
| 1 | 21.45 | 20.80 | 21.06[a] | 19.06 | 17.95[bc] | 25.43 | 23.58 | 23.51[a] |
| 2 | 21.41 | 20.58 | 15.36[c] | 17.65 | 19.31[ab] | 23.68 | 23.06 | 18.10[b] |
| 3 | 22.18 | 23.20 | 16.98[bc] | 18.36 | 20.48[a] | 26.10 | 24.43 | 22.28[a] |
| 4 | 22.16 | 25.95 | 18.90[ab] | 20.83 | 16.70[c] | 26.41 | 24.23 | 23.30[a] |
| SEM | 0.929 | 2.424 | 1.011 | 1.099 | 0.968 | 1.258 | 0.799 | 1.321 |
| P-value | 0.8865 | 0.3839 | 0.0046 | 0.2347 | 0.0619 | 0.4392 | 0.6159 | 0.0302 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 27. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter water activity ($a_w$) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 0.753 | 0.760 | **** | 0.821 | 0.883 | 0.964 | **** | 0.906[b] |
| PLT | 0.843 | 0.747 | **** | 0.827 | 0.891 | 0.971 | **** | 0.951[a] |
| SEM | 0.037 | 0.024 | **** | 0.012 | 0.014 | 0.010 | **** | 0.015 |
| P-value | 0.1030 | 0.7043 | **** | 0.7240 | 0.6840 | 0.6082 | **** | 0.0469 |
| House (H) | | | | | | | | |
| 1—LG | 0.822[b] | 0.724 | **** | 0.819 | 0.895 | 0.950 | **** | 0.878 |
| 2—PLT | 0.765[c] | 0.747 | **** | 0.825 | 0.900 | 0.965 | **** | 0.981 |
| 3—LG | 0.803[b] | 0.782 | **** | 0.822 | 0.883 | 0.982 | **** | 0.920 |
| 4—PLT | 0.900[a] | 0.747 | **** | 0.856 | 0.875 | 0.985 | **** | 0.929 |
| 5—LG | **** | 0.773 | **** | 0.822 | 0.871 | 0.960 | **** | 0.921 |
| 6—PLT | 0.865[sb] | 0.747 | **** | 0.801 | 0.900 | 0.965 | **** | 0.943 |
| SEM | 0.0488 | 0.044 | **** | 0.022 | 0.0269 | 0.018 | **** | 0.026 |
| P-value | 0.3625 | 0.9483 | **** | 0.6893 | 0.9497 | 0.7502 | **** | 0.1989 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 0.834 | 0.764 | **** | 0.811 | 0.891 | 0.973 | **** | 0.932 |
| 5 | 0.767 | 0.760 | **** | 0.839 | 0.873 | 0.973 | **** | 0.925 |
| 8 | 0.793 | 0.735 | **** | 0.822 | 0.897 | 0.957 | **** | 0.929 |
| SEM | 0.048 | 0.020 | **** | 0.015 | 0.017 | 0.012 | **** | 0.020 |
| P-value | 0.6301 | 0.7614 | **** | 0.4630 | 0.6103 | 0.5985 | **** | 0.9719 |
| Location (L)[4] | | | | | | | | |
| 1 | 0.801 | 0.793 | **** | 0.852[a] | 0.943[a] | 0.976 | **** | 0.944 |
| 2 | 0.855 | 0.743 | **** | 0.795[b] | 0.865[bc] | 0.941 | **** | 0.890 |
| 3 | 0.838 | 0.701 | **** | 0.791[b] | 0.889[b] | 0.979 | **** | 0.941 |
| 4 | 0.829 | 0.776 | **** | 0.858[a] | 0.851[c] | 0.975 | **** | 0.939 |
| SEM | 0.0474 | 0.032 | **** | 0.012 | 0.014 | 0.013 | **** | 0.022 |
| P-value | 0.8760 | 0.2290 | **** | 0.0010 | 0.0014 | 0.1910 | **** | 0.2962 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

**** Equipment not operational.

SEM= Pooled Standard Error Mean

Table 28. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total aerobic bacterial counts* ($Log_{10}$ cfu/g) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.17 | 7.01 | 7.27 | 8.98 | 9.46 | 9.14 | 8.68 | 8.32 |
| PLT | 8.22 | 7.41 | 7.20 | 8.98 | 9.41 | 8.62 | 9.01 | 8.31 |
| SEM | 0.120 | 0.311 | 0.151 | 0.085 | 0.190 | 0.302 | 0.262 | 0.169 |
| P-value | 0.8320 | 0.3794 | 0.7673 | 0.9844 | 0.8777 | 0.2305 | 0.3884 | 0.9710 |
| House (H) | | | | | | | | |
| 1—LG | 8.37 | 5.99$^{c}$ | 7.78 | 9.10$^{ab}$ | 9.63 | 9.96$^{a}$ | 9.20$^{ab}$ | 8.52$^{a}$ |
| 2—PLT | 8.22 | 5.91$^{c}$ | 7.24 | 9.25$^{a}$ | 9.90 | 9.92$^{a}$ | 9.12$^{ab}$ | 8.87$^{a}$ |
| 3—LG | 8.37 | 7.32$^{b}$ | 6.94 | 9.10$^{ab}$ | 9.43 | 9.57$^{a}$ | 8.11$^{c}$ | 8.54$^{a}$ |
| 4—PLT | 8.37 | 8.33$^{a}$ | 7.11 | 8.85$^{bc}$ | 8.99 | 8.01$^{b}$ | 7.98$^{c}$ | 8.39$^{ab}$ |
| 5—LG | 7.80 | 7.74$^{ab}$ | 7.08 | 8.73$^{c}$ | 9.31 | 7.90$^{b}$ | 8.72$^{bc}$ | 7.89$^{bc}$ |
| 6—PLT | 8.07 | 7.98$^{a}$ | 7.26 | 8.84$^{bc}$ | 9.36 | 7.92$^{b}$ | 9.92$^{a}$ | 7.67$^{c}$ |
| SEM | 0.196 | 0.273 | 0.246 | 0.123 | 0.326 | 0.245 | 0.36 | 0.222 |
| P-value | 0.2800 | 0.0001 | 0.2765 | 0.0547 | 0.5074 | 0.0001 | 0.0063 | 0.0115 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 8.22 | 7.65$^{a}$ | 7.11 | 8.97$^{ab}$ | 9.39 | 8.74$^{b}$ | 9.02 | 8.10$^{b}$ |
| 5 | 8.09 | 8.03$^{a}$ | 7.10 | 8.79$^{b}$ | 9.15 | 7.95$^{c}$ | 8.35 | 8.14$^{b}$ |
| 8 | 8.30 | 5.95$^{b}$ | 7.51 | 9.18$^{a}$ | 9.77 | 9.94$^{a}$ | 9.16 | 8.70$^{a}$ |
| SEM | 0.147 | 0.203 | 0.175 | 0.088 | 0.218 | 0.241 | 0.306 | 0.186 |
| P-value | 0.5970 | 0.0001 | 0.1850 | 0.0180 | 0.1576 | 0.0001 | 0.1615 | 0.0618 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.03 | 7.18 | 7.25 | 8.86 | 9.40 | 8.76 | 8.54 | 8.11 |
| 2 | 8.33 | 6.82 | 7.30 | 9.10 | 9.53 | 9.25 | 8.75 | 8.17 |
| 3 | 8.19 | 7.43 | 7.28 | 9.00 | 9.52 | 8.69 | 9.00 | 8.67 |
| 4 | 8.25 | 7.43 | 7.12 | 8.95 | 9.30 | 8.82 | 9.08 | 8.31 |
| SEM | 0.171 | 0.457 | 0.222 | 0.120 | 0.279 | 0.453 | 0.385 | 0.232 |
| P-value | 0.6497 | 0.7530 | 0.9356 | 0.5762 | 0.9273 | 0.8180 | 0.7569 | 0.3457 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Plate Count Agar (PCA).

cfu/g= colony forming units per gram of litter material

Table 29. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total coliform counts* ($Log_{10}$ cfu/g) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.97[b] | 4.17 | 4.91 | 5.98[a] | 5.73 | 5.94 | 5.47 | 4.65 |
| PLT | 4.90[a] | 4.53 | 5.18 | 5.22[b] | 5.73 | 5.66 | 5.80 | 4.65 |
| SEM | 0.259 | 0.264 | 0.310 | 0.231 | 0.143 | 0.135 | 0.226 | 0.170 |
| P-value | 0.0193 | 0.3509 | 0.5388 | 0.0296 | 0.9936 | 0.1562 | 0.3158 | 0.9753 |
| House (H) | | | | | | | | |
| 1—LG | 3.66 | 4.29 | 4.85[b] | 5.41[b] | 5.72 | 6.19 | 4.89 | 4.02 |
| 2—PLT | 4.92 | 4.58 | 4.27[b] | 5.03[b] | 5.35 | 5.73 | 5.38 | 4.86 |
| 3—LG | 4.35 | 3.73 | 4.70[b] | 5.63[b] | 5.53 | 5.90 | 5.46 | 5.11 |
| 4—PLT | 4.66 | 4.73 | 8.82[b] | 5.05[b] | 5.93 | 5.58 | 5.79 | 4.65 |
| 5—LG | 3.90 | 4.50 | 5.17[b] | 6.89[a] | 5.93 | 5.73 | 6.06 | 4.83 |
| 6—PLT | 5.12 | 4.28 | 6.45[a] | 5.57[b] | 5.91 | 5.66 | 6.23 | 4.42 |
| SEM | 0.477 | 0.482 | 0.451 | 0.339 | 0.242 | 0.247 | 0.361 | 0.257 |
| P-value | 0.2567 | 0.7536 | 0.0509 | 0.0123 | 0.4429 | 0.5727 | 0.1556 | 0.1004 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 4.74 | 4.00 | 5.58 | 5.60 | 5.72 | 5.78 | 5.85 | 4.77 |
| 5 | 4.28 | 4.62 | 4.99 | 5.97 | 5.93 | 8.65 | 5.92 | 4.74 |
| 8 | 4.29 | 4.43 | 4.56 | 5.22 | 5.54 | 5.96 | 5.13 | 4.44 |
| SEM | 0.360 | 0.323 | 0.359 | 0.302 | 0.168 | 0.172 | 0.258 | 0.206 |
| P-value | 0.6034 | 0.4064 | 0.1571 | 0.2377 | 0.2756 | 0.4596 | 0.0819 | 0.4788 |
| Location (L)[4] | | | | | | | | |
| 1 | 4.45 | 3.59[b] | 5.03 | 5.63 | 5.89 | 5.56[b] | 6.01 | 4.85 |
| 2 | 4.52 | 4.83[a] | 5.54 | 5.38 | 5.78 | 6.33[a] | 5.62 | 4.53 |
| 3 | 4.63 | 4.95[a] | 4.83 | 5.81 | 5.65 | 5.59[b] | 5.63 | 4.44 |
| 4 | 4.14 | 4.04[b] | 4.79 | 5.58 | 5.60 | 5.72[b] | 5.28 | 4.70 |
| SEM | 0.429 | 0.311 | 0.445 | 0.376 | 0.205 | 0.158 | 0.324 | 0.241 |
| P-value | 0.8668 | 0.0168 | 0.6236 | 0.8807 | 0.7512 | 0.0086 | 0.4807 | 0.5865 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Eosin Methylene Blue (EMB) agar.

cfu/g= colony forming units per gram of litter material

Table 30. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *E.coli* levels* ($Log_{10}$ cfu/g) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.99 | 3.98 | 4.94 | 6.03[a] | 5.37 | 5.41 | 4.55 | 4.02 |
| PLT | 4.13 | 4.34 | 4.91 | 4.93[b] | 5.47 | 5.18 | 4.49 | 3.92 |
| SEM | 0.217 | 0.272 | 0.225 | 0.285 | 0.132 | 0.234 | 0.125 | 0.108 |
| P-value | 0.6677 | 0.3555 | 0.9469 | 0.0119 | 0.5931 | 0.4998 | 0.7472 | 0.4816 |
| House (H) | | | | | | | | |
| 1—LG | 4.31 | 3.90 | 4.15[d] | 5.59 | 5.17 | 5.79 | 4.71[ab] | 3.77 |
| 2—PLT | 3.99 | 4.25 | 4.79[bc] | 5.05 | 5.20 | 5.30 | 4.56[ab] | 3.90 |
| 3—LG | 3.97 | 3.67 | 5.00[b] | 6.00 | 5.47 | 5.73 | 4.45[b] | 4.27 |
| 4—PLT | 3.87 | 4.42 | 4.26[cd] | 5.49 | 5.61 | 5.22 | 3.98[c] | 3.83 |
| 5—LG | 3.71 | 4.36 | 5.65[a] | 6.51 | 5.47 | 4.72 | 4.48[b] | 4.02 |
| 6—PLT | 4.53 | 4.35 | 5.69[a] | 5.23 | 5.60 | 5.03 | 4.92[a] | 4.02 |
| SEM | 0.387 | 0.507 | 0.255 | 0.508 | 0.234 | 0.398 | 0.173 | 0.188 |
| P-value | 0.700 | 0.8720 | 0.0011 | 0.1313 | 0.6397 | 0.4174 | 0.0260 | 0.5218 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 4.25 | 4.01 | 5.35[a] | 5.62 | 5.62 | 5.38 | 4.69[a] | 4.15 |
| 5 | 3.79 | 4.39 | 4.46[ab] | 5.50 | 5.54 | 4.97 | 4.23[b] | 3.93 |
| 8 | 4.15 | 4.08 | 4.47[b] | 5.32 | 5.18 | 5.55 | 4.63[a] | 3.84 |
| SEM | 0.263 | 0.342 | 0.247 | 0.411 | 0.154 | 0.282 | 0.137 | 0.128 |
| P-value | 0.4504 | 0.7101 | 0.0628 | 0.8806 | 0.1959 | 0.3505 | 0.0543 | 0.2533 |
| Location (L)[4] | | | | | | | | |
| 1 | 3.79 | 3.53[c] | 5.09 | 5.97 | 5.57 | 5.29 | 4.21 | 3.89 |
| 2 | 4.31 | 4.38[ab] | 4.82 | 5.51 | 5.58 | 5.54 | 4.59 | 3.87 |
| 3 | 4.19 | 5.08[a] | 5.07 | 5.18 | 5.37 | 4.80 | 4.76 | 3.85 |
| 4 | 3.97 | 3.65[bc] | 4.72 | 5.26 | 5.16 | 5.57 | 4.50 | 4.27 |
| SEM | 0.311 | 0.304 | 0.326 | 0.470 | 0.182 | 0.323 | 0.164 | 0.142 |
| P-value | 0.6514 | 0.0061 | 0.8046 | 0.6441 | 0.3480 | 0.3373 | 0.1538 | 0.1450 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using MacConkey (MAC) agar.

cfu/g= colony forming units per gram of litter material

Table 31. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on anaerobic levels* ($Log_{10}$ cfu/g) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 6.04 | 6.18 | 6.48 | 7.49 | 6.92 | 7.08 | 6.54 | 6.50 |
| PLT | 5.99 | 6.38 | 6.72 | 7.19 | 9.81 | 6.68 | 6.80 | 6.37 |
| SEM | 0.092 | 0.275 | 0.222 | 0.217 | 0.148 | 0.180 | 0.228 | 0.072 |
| P-value | 0.7104 | 0.6203 | 0.4511 | 0.3324 | 0.6119 | 0.1327 | 0.4245 | 0.2292 |
| House (H) | | | | | | | | |
| 1—LG | 6.16 | 6.27 | 6.18$^{cd}$ | 7.11 | 7.33 | 7.92$^{a}$ | 6.93$^{ab}$ | 6.41 |
| 2—PLT | 6.25 | 6.22 | 5.93$^{d}$ | 6.93 | 6.73 | 6.87$^{b}$ | 6.30$^{bc}$ | 6.42 |
| 3—LG | 5.97 | 6.08 | 6.23$^{cd}$ | 7.49 | 6.57 | 6.73$^{b}$ | 6.11$^{c}$ | 6.74 |
| 4—PLT | 6.04 | 6.67 | 6.72$^{bc}$ | 7.03 | 6.86 | 6.53$^{b}$ | 6.42$^{bc}$ | 6.39 |
| 5—LG | 5.99 | 6.20 | 7.02$^{ab}$ | 7.87 | 6.86 | 6.58$^{b}$ | 6.58$^{bc}$ | 6.36 |
| 6—PLT | 5.68 | 6.25 | 7.51$^{a}$ | 7.60 | 6.84 | 6.64$^{b}$ | 7.70$^{a}$ | 6.32 |
| SEM | 0.144 | 0.520 | 0.294 | 0.378 | 0.252 | 0.234 | 0.324 | 0.119 |
| P-value | 0.1519 | 0.9778 | 0.0112 | 0.4671 | 0.4415 | 0.0047 | 0.0323 | 0.2140 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 5.82$^{b}$ | 6.16 | 6.87$^{a}$ | 7.54 | 6.71 | 6.69$^{b}$ | 6.90 | 6.53 |
| 5 | 6.02$^{ab}$ | 6.43 | 6.87$^{a}$ | 7.45 | 6.86 | 6.55$^{b}$ | 6.50 | 6.37 |
| 8 | 6.21$^{a}$ | 6.25 | 6.05$^{b}$ | 7.02 | 7.03 | 7.40$^{a}$ | 6.62 | 6.41 |
| SEM | 0.100 | 0.345 | 0.241 | 0.265 | 0.179 | 0.192 | 0.284 | 0.090 |
| P-value | 0.0434 | 0.8559 | 0.0395 | 03463 | 0.4550 | 0.0111 | 0.5920 | 0.4831 |
| Location (L)[4] | | | | | | | | |
| 1 | 6.11 | 5.50$^{b}$ | 6.52 | 7.33 | 6.85 | 6.55 | 6.43 | 6.43 |
| 2 | 6.08 | 7.16$^{a}$ | 6.48 | 7.67 | 7.02 | 7.16 | 6.79 | 6.37 |
| 3 | 6.05 | 7.14$^{a}$ | 6.74 | 7.12 | 6.79 | 6.82 | 6.68 | 6.52 |
| 4 | 5.82 | 5.32$^{b}$ | 6.65 | 7.24 | 6.80 | 6.98 | 6.79 | 6.43 |
| SEM | 0.128 | 0.131 | 0.330 | 0.316 | 0.216 | 0.264 | 0.338 | 0.108 |
| P-value | 0.3976 | 0.0001 | 0.9383 | 0.6446 | 0.8627 | 0.4323 | 0.8577 | 0.7757 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.
[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 ft2 (23.8 kg/100 m2) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
[3]Litter age indicates number of flocks reared prior to initiation of this trial.
[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.
[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.
SEM= Pooled Standard Error Mean
*Determined using Anaerobic Agar (AA).
cfu/g= colony forming units per gram of litter material

Table 32. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *Clostridium perfringens* counts* ($Log_{10}$ cfu/g) (Trial 3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 4 | 11 | 18 | 25 | 32 | 39 | 46 |
| Treatment (T)[2] | | | | | | | | |
| LG | 4.19 | 4.11 | 3.85 | 4.72 | 3.85 | 4.91 | 3.84 | 3.58 |
| PLT | 3.98 | 3.89 | 4.00 | 4.68 | 3.79 | 4.99 | 3.76 | 3.69 |
| SEM | 0.118 | 0.131 | 0.118 | 0.079 | 0.047 | 0.079 | 0.091 | 0.075 |
| P-value | 0.2234 | 0.2619 | 0.3782 | 0.6741 | 0.3692 | 0.4379 | 0.5385 | 0.3093 |
| House (H) | | | | | | | | |
| 1—LG | 4.35 | 4.48[a] | 3.72[b] | 4.51 | 3.74 | 5.04 | 3.94 | 3.51 |
| 2—PLT | 4.23 | 3.90[bc] | 3.48[b] | 4.56 | 3.73 | 4.85 | 3.75 | 3.50 |
| 3—LG | 4.02 | 4.14[ab] | 3.67[b] | 4.78 | 3.80 | 4.80 | 3.82 | 3.48 |
| 4—PLT | 4.02 | 4.31[a] | 4.21[a] | 4.58 | 3.79 | 5.21 | 3.69 | 3.76 |
| 5—LG | 4.19 | 3.70[cd] | 4.16[a] | 4.88 | 4.00 | 4.87 | 3.78 | 3.76 |
| 6—PLT | 3.68 | 3.48[d] | 4.31[a] | 4.89 | 3.83 | 4.93 | 3.86 | 3.82 |
| SEM | 0.200 | 0.164 | 0.143 | 0.123 | 0.077 | 0.131 | 0.171 | 0.121 |
| P-value | 0.2895 | 0.0038 | 0.0024 | 0.1391 | 0.2232 | 0.3020 | 0.9269 | 0.1875 |
| Litter Age (LA)[3] | | | | | | | | |
| 4 | 3.85 | 3.81 | 3.99[a] | 4.83[a] | 3.81 | 4.86 | 3.84 | 3.65 |
| 5 | 4.10 | 4.00 | 4.19[a] | 4.73[ab] | 3.90 | 5.04 | 3.73 | 3.76 |
| 8 | 4.29 | 4.19 | 3.60[b] | 4.54[b] | 3.74 | 4.95 | 3.85 | 3.50 |
| SEM | 0.138 | 0.158 | 0.120 | 0.279 | 0.055 | 0.097 | 0.114 | 0.088 |
| P-value | 0.1052 | 0.2671 | 0.0078 | 0.0754 | 0.1563 | 0.4633 | 0.7500 | 0.1430 |
| Location (L)[4] | | | | | | | | |
| 1 | 4.16 | 4.07 | 3.87 | 4.81 | 3.89 | 4.97 | 3.87 | 3.73 |
| 2 | 4.25 | 3.93 | 3.93 | 4.56 | 3.73 | 4.94 | 3.91 | 3.49 |
| 3 | 4.10 | 4.11 | 4.01 | 4.85 | 3.74 | 4.92 | 3.75 | 3.69 |
| 4 | 3.82 | 3.88 | 3.91 | 4.76 | 3.86 | 4.96 | 3.69 | 3.63 |
| SEM | 0.166 | 0.195 | 0.176 | 0.102 | 0.066 | 0.118 | 0.130 | 0.107 |
| P-value | 0.3197 | 0.8136 | 0.9155 | 0.1252 | 0.3715 | 0.9895 | 0.5809 | 0.4392 |

[1]Values are grand means derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of this trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Tryptose Sulfite Cycloserine (TSC) agar.

cfu/g= colony forming units per gram of litter material

Table 33. Weekly mortality and culls in commercial broiler houses treated with Litter Guard (LG) and Poultry Litter Treatment (PLT) (Trial 3)[1]

| | Week | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment (T)[2] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| LG | 568[a] | 602[a] | 125 | 71 | 83 | 126 | 112 | 1687[a] |
| PLT | 342[b] | 424[b] | 81 | 57 | 96 | 145 | 135 | 1279[b] |
| SEM | 49 | 41 | 66 | 20 | 38 | 62 | 43 | 257 |
| P-value | 0.0081 | 0.0100 | 0.2282 | 0.2271 | 0.6545 | 0.6354 | 0.7250 | 0.0645 |

[1]Values are a weekly total expressed as number of birds per house as derived from 6 commercial broiler houses (3 per treatment level). Total represents cumulative mortality for the entire grow out period. Number of birds placed in each house was 28,000 head.
[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
[ab]Numerical values for each variable column with different superscripts are significantly different at least where *P<0.10*.
SEM= Pooled Standard Error Mean

Table 34. Effect of Poultry Litter Treatment (PLT) and Litter Guard (LG) on foot pad dermatitis (Trial 3)

| | Score* | | |
|---|---|---|---|
| | Score 0 | Score 1 | Score 2 |
| Treatment[1] | | | |
| LG | 391.0 | 133.6 | 9.6 |
| PLT | 405.3 | 81.3 | 13.0 |
| SEM | 24.3 | 1.6 | 8.3 |
| P-value | 0.6983 | 0.3078 | 0.7920 |
| Litter Age[2] | | | |
| 3 | 399.5 | 148.0 | 5.0 |
| 4 | 369.0 | 103.0 | 25.5 |
| 7 | 426.0 | 71.5 | 3.5 |
| SEM | 26.3 | 41.3 | 6.4 |
| P-value | 0.4198 | 0.5050 | 0.1590 |
| House | | | |
| 1-LG | 388 | 102 | 6 |
| 2-PLT | 464 | 41 | 1 |
| 3-LG | 392 | 211 | 8 |
| 4-PLT | 345 | 118 | 36 |
| 5-LG | 393 | 88 | 15 |
| 6-PLT | 407 | 85 | 2 |

*Score 0 = no lesions on foot pad, Score 1 = mild dermatitis lesions, Score 2 = severe dermatitis lesions. At processing, 500 paws were collected from each house and visually scored for quality (Values represent the number of paws for each score obtained).
[1]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
[2]Litter age indicates number of flocks reared prior to initiation of this trial.
SEM= Pooled Standard Error Mean

**Pooled analysis for Trials 1, 2 and 3**

Ammonia emission rates were significantly *(P<0.10)* affected by litter treatments on initial day of sampling, day 1, 15 and 36 (Table 35). There was reduction in ammonia emission rates after the application of PLT to litter from 78.0 to 37.9 ppm on day 1. On the other hand, application of LG to litter increased ammonia emission rates from 54.5 to 59.4 ppm on day 1. Ammonia emission rates were significantly *(P<0.10)* affected by different litter ages on day 1, 8, 15, 29 and 36. Six to eight flock old litter showed a significantly *(P<0.10)* high ammonia emission rate till day 15 after which, 2-4 and 3-5 flock old litter showed significantly *(P<0.10)* higher ammonia rates. Highest ammonia rates were found on day 29 (131.3 ppm) with 2-4 flock old litter. Sampling locations showed a significant difference in ammonia emission rates only on initial day and day 29 of sampling.

pH levels were significantly affected by PLT litter treatment only on day 1 and 29 of the trials (Table 36). Houses had an impact on pH levels showing significant *(P<0.10)* differences on initial day of sampling, day 1, 15, 29 and 43. Litter age showed significant *(P<0.10)* differences in pH reading on initial day of sampling, day 15, 29, 36 and 43. No consistent patterns were observed with litter age. Sampling locations showed a significant difference on pH readings on day 1, 8, 15, 22, 29 and 43 of the trial.

Litter treatments had no significant *(P>0.10)* effect on litter moisture levels for the entire study (Table 37). Moisture levels were significantly *(P<0.10)* affected by house differences on day 29 and 36 of the study. There were no consistent patterns regarding the effect of different houses on moisture levels. Two-four and 3-5 flock litter exhibited

high moisture levels compared to 6-8 flock litter for most samplings. There were no consistent readings showing the effect of different sampling locations on moisture levels.

Litter treatments did not show any significant difference in water activity ($a_w$) readings (Table 38). Houses showed a significant *(P<0.10)* difference in $a_w$ reading only initial and on day 43 of the trial. No consistent patterns were observed regarding the effect of different houses on water activity throughout the trial. Litter age significantly *(P<0.10)* affected $a_w$ readings only on initial and day 43 of the treatment. No consistent readings were noticed regarding the effect different litter ages and sampling locations on $a_w$ readings.

Aerobic bacterial counts were significantly *(P<0.10)* affected by litter treatments only on day 22 of the study (Table 39). House had a significant *(P<0.10)* effect on aerobic bacterial counts only on initial day of sampling, day 1, 29 and 36. Litter ages showed a significant effect on aerobic bacterial counts on initial day of sampling, day 1, 29 and 36. Six-eight flock litter exhibited the highest aerobic bacterial counts for most of the samplings and 3-5 flock litter exhibited the least aerobic bacterial counts throughout most of the study. Sampling locations did not have any significant *(P>0.10)* effect on aerobic bacterial counts of litter.

Litter treatments did not show any significant *(P>0.10)* effect on total coliform counts of litter for the entire study (Table 40). Houses showed a significant *(P<0.10)* difference in total coliform counts only on day 8 of the trial. Litter ages showed a significant *(P<0.10)* effect of total coliform counts only on day 8 of the study. Sampling locations showed a significant *(P<0.10)* difference in total coliform counts only on day 8 of sampling.

Litter treatments had no significant *(P>0.10)* effect on *E.coli* counts for the entire trial (Table 41). There was an overall decrease in *E.coli* counts after application of litter treatments on day 1 of the study. After which there was a gradual increase until day 15. On that day the levels plateaued until day 36 which is when levels started to decrease. Houses had a significant *(P<0.10)* effect on *E.coli* counts only on day 8 and 29 of the study. Litter age showed a significant effect on *E.coli* counts only on day 8 and 29 of the study. There were no consistent results indicating the effect of different litter ages on *E.coli* counts throughout the study. Sampling locations showed a significant effect on *E.coli* counts only on day 8 and 36 of trials.

Anaerobic bacterial counts were significantly *(P<0.10)* affected by litter treatments only on day 22 of the study (Table 42). Houses had a significant *(P<0.10)* effect on anaerobic bacterial counts only on day 8 and 22 of the study. Litter age had a significant effect on anaerobic bacterial counts only on day 8 and 29 of the trial. No consistent results regarding the effect of litter age on anaerobic bacterial counts were measured. Sampling locations did not show any significant *(P>0.10)* effect on anaerobic bacterial counts throughout the trial.

Litter treatments showed a significant effect on *Cl.perfringens* counts only on day 43 of the study (Table 43). Houses showed a significant *(P<0.10)* effect on *Cl.perfringens* counts only on initial day of sampling. There were no consistent results regarding the effect of houses, different litter ages and sampling locations on *Cl.perfringens* counts.

Mortality rate was numerically higher in the houses treated with LG as compared to PLT treated houses, but there was no significant *(P>0.10)* difference between both these treatments regarding mortality rates throughout the study (Table 44). Paw quality of birds was not affected by litter treatments (Table 45).

**Discussion**

Ammonia levels were significantly *(P<0.10)* reduced on application of PLT, comparatively there was a significant *(P<0.10)* rise in ammonia emission rates on application of LG, this shows the efficiency of PLT in reducing ammonia levels within 24 hours of application. Whereas, LG was able to reduce ammonia levels two weeks after application. Terzich (1997) found that application of PLT significantly *(P<0.05)* reduced ammonia level to 5.1 ppm compared to 94.5 ppm of the control without any litter treatment. Similar results were observed by Terzich et al., 1998 who conducted a comparative field trial to notice the effect of PLT, alum, microbial treatment and a control on ammonia emission rates and production parameters. They found that PLT treated litter had the lowest ammonia emission rates after its application followed by alum, the microbial litter treatment and the untreated control area. They also observed that there was a gradual increase in ammonia levels after three weeks irrespective of litter treatment and application rate.

PLT application reduced pH levels significantly *(P<0.10)* compared to LG on day 1 due to its acidic nature. PLT was ineffective in maintaining lower pH level beyond the first week of the trial. Terzich (1996) conducted a field trial to assess the effect of PLT on

pH and other litter parameters. They found that PLT significantly *(P<0.05)* reduced pH levels to 1.5 as compared to 7.7 in control houses.

Aerobic bacterial counts showed random fluctuations throughout the study. Six-eight flock litter had a consistently high aerobic bacterial count compared to 2-4 and 3-5 flock litter. This shows the fact that old litter supports aerobic bacterial growth compared to new litter.

*E.coli* counts were reduced by both litter treatments until day 8, thereafter showing a gradual increase. Pope and Cherry (2000) found that PLT application significantly *(P<0.05)* reduced *E.coli* counts in litter. They found *E.coli* count of 0 cfu/gm of litter on application of PLT in first week and there was a gradual increase in *E.coli* count in week two (1.10E + 06 cfu/gm) and three (1.03E + 06 cfu/gm). They also observed a significant *(P<0.05)* decrease in *E.coli* counts from whole bird rinse collected from birds raised from PLT treated litter compared to control area birds.

## References


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Terzich, M., C. Quarles, M.A. Goodwin, and J. Brown. 1998. Effect of Poultry Litter Treatment (PLT) on the development of respiratory tract lesions in broilers. Avian Pathol. 27:566–569.

Table 35. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of ammonia volatilization (ppm) (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 54.5[b] | 59.4[a] | 39.8 | 34.2[b] | 63.7 | 114.8 | 100.4[b] | 104.1 |
| PLT | 78.0[a] | 37.9[b] | 41.8 | 41.4[a] | 70.3 | 118.0 | 120.3[a] | 109.4 |
| SEM | 4.5 | 4.6 | 3.6 | 2.4 | 7.9 | 10.9 | 6.3 | 8.0 |
| P-value | 0.0005 | 0.0017 | 0.7042 | 0.0390 | 0.5609 | 0.8387 | 0.0309 | 0.6407 |
| House (H) | | | | | | | | |
| 1—LG | 51.6[cd] | 75.3[a] | 46.5 | 38.1[bc] | 54.3 | 95.1 | 74.4[c] | 100.9 |
| 2—PLT | 65.8[bc] | 44.5[bc] | 53.7 | 48.5[a] | 61.5 | 91.4 | 105.8[b] | 99.0 |
| 3—LG | 38.1[d] | 49.1[b] | 34.3 | 30.0[c] | 57.2 | 129.5 | 122.1[ab] | 102.7 |
| 4—PLT | 77.7[ab] | 41.7[bc] | 32.2 | 41.1[ab] | 67.7 | 129.4 | 131.5[a] | 135.3 |
| 5—LG | 73.9[ab] | 53.9[b] | 38.5 | 34.7[bc] | 79.7 | 119.8 | 104.7[b] | 108.6 |
| 6—PLT | 90.4[a] | 27.7[c] | 39.4 | 34.7[bc] | 81.7 | 133.1 | 123.6[ab] | 93.9 |
| SEM | 7.1 | 7.7 | 6.2 | 4.0 | 13.8 | 18.8 | 10.3 | 13.7 |
| P-value | 0.0001 | 0.0026 | 0.1592 | 0.0398 | 0.6265 | 0.4459 | 0.0034 | 0.3366 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 64.2 | 38.4[a] | 36.9[b] | 32.2[b] | 69.5 | 131.3[a] | 122.8[a] | 98.3 |
| 3-5 | 75.8 | 47.8[ab] | 35.4[b] | 37.4[ab] | 73.7 | 124.6[a] | 118.1[a] | 122.0 |
| 6-8 | 58.7 | 59.9[a] | 50.1[a] | 43.3[a] | 57.9 | 93.2[b] | 90.1[b] | 99.9 |
| SEM | 5.9 | 5.8 | 4.3 | 2.9 | 9.7 | 13.0 | 7.5 | 9.6 |
| P-value | 0.1221 | 0.0403 | 0.0371 | 0.0352 | 0.4931 | 0.0958 | 0.0062 | 0.1603 |
| Location (L)[4] | | | | | | | | |
| 1 | 45.9[c] | 47.6 | 45.0 | 36.7 | 60.9 | 117.0[b] | 112.9 | 92.3 |
| 2 | 63.6[b] | 49.7 | 40.1 | 38.5 | 69.2 | 93.6[b] | 110.1 | 104.3 |
| 3 | 80.8[a] | 48.8 | 36.7 | 36.7 | 67.0 | 97.5[b] | 99.4 | 101.5 |
| 4 | 74.6[ab] | 48.6 | 41.2 | 39.5 | 70.9 | 157.5[a] | 119.0 | 128.7 |
| SEM | 6.3 | 7.1 | 5.2 | 3.5 | 11.3 | 14.4 | 9.3 | 11.0 |
| P-value | 0.0013 | 0.9977 | 0.7408 | 0.9260 | 0.9300 | 0.0098 | 0.5179 | 0.1247 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of first trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 36. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses for the reduction of litter pH levels (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.36 | 8.43$^{a}$ | 8.18 | 8.01 | 7.95 | 8.36$^{a}$ | 8.26 | 8.28 |
| PLT | 8.39 | 7.91$^{b}$ | 8.16 | 8.00 | 7.88 | 8.22$^{b}$ | 8.23 | 8.31 |
| SEM | 0.03 | 0.08 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.03 |
| P-value | 0.4701 | 0.0001 | 0.7261 | 0.9125 | 0.3433 | 0.0424 | 0.6132 | 0.4555 |
| House (H) | | | | | | | | |
| 1—LG | 8.28$^{b}$ | 8.32$^{ab}$ | 8.22 | 7.95$^{b}$ | 7.96 | 8.19$^{b}$ | 8.15 | 8.17$^{c}$ |
| 2—PLT | 8.24$^{b}$ | 7.92$^{cd}$ | 8.18 | 7.97$^{b}$ | 7.85 | 8.13$^{b}$ | 8.12 | 8.23$^{bc}$ |
| 3—LG | 8.28$^{b}$ | 8.44$^{a}$ | 8.10 | 7.93$^{b}$ | 7.88 | 8.47$^{a}$ | 8.32 | 8.30$^{abc}$ |
| 4—PLT | 8.47$^{a}$ | 8.08$^{bc}$ | 8.23 | 8.16$^{a}$ | 7.93 | 8.31$^{ab}$ | 8.34 | 8.40$^{a}$ |
| 5—LG | 8.51$^{a}$ | 8.52$^{a}$ | 8.21 | 8.14$^{a}$ | 8.02 | 8.42$^{a}$ | 8.32 | 8.37$^{a}$ |
| 6—PLT | 8.46$^{a}$ | 7.73$^{d}$ | 8.06 | 7.87$^{b}$ | 7.86 | 8.21$^{b}$ | 8.24 | 8.32$^{ab}$ |
| SEM | 0.04 | 0.14 | 0.08 | 0.06 | 0.09 | 0.08 | 0.07 | 0.05 |
| P-value | 0.001 | 0.0016 | 0.5673 | 0.0195 | 0.7993 | 0.0286 | 0.1550 | 0.0676 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 8.37$^{b}$ | 8.09 | 8.08 | 7.90$^{b}$ | 7.87 | 8.34$^{a}$ | 8.28$^{a}$ | 8.31$^{a}$ |
| 3-5 | 8.49$^{a}$ | 8.30 | 8.22 | 8.15$^{a}$ | 7.98 | 8.37$^{a}$ | 8.33$^{a}$ | 8.38$^{a}$ |
| 6-8 | 8.26$^{c}$ | 8.12 | 8.20 | 7.96$^{b}$ | 7.90 | 8.16$^{b}$ | 8.14$^{b}$ | 8.20$^{b}$ |
| SEM | 0.03 | 0.11 | 0.05 | 0.04 | 0.06 | 0.05 | 0.04 | 0.21 |
| P-value | 0.0001 | 0.3745 | 0.1682 | 0.0013 | 0.5348 | 0.0340 | 0.0232 | 0.0077 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.41 | 8.34$^{a}$ | 8.27$^{a}$ | 8.08$^{a}$ | 8.07$^{a}$ | 8.37$^{a}$ | 8.22 | 8.34$^{a}$ |
| 2 | 8.37 | 7.86$^{b}$ | 8.14$^{ab}$ | 7.91$^{b}$ | 7.75$^{c}$ | 8.20$^{b}$ | 8.23 | 8.21$^{b}$ |
| 3 | 8.34 | 8.02$^{b}$ | 8.04$^{b}$ | 7.86$^{b}$ | 7.83$^{bc}$ | 8.17$^{b}$ | 8.18 | 8.27$^{ab}$ |
| 4 | 8.39 | 8.46$^{a}$ | 8.23$^{a}$ | 8.17$^{a}$ | 7.98$^{ab}$ | 8.42$^{a}$ | 8.36 | 8.37$^{a}$ |
| SEM | 0.04 | 0.12 | 0.06 | 0.05 | 0.07 | 0.06 | 0.05 | 0.04 |
| P-value | 0.7150 | 0.0035 | 0.0568 | 0.0002 | 0.0170 | 0.0306 | 0.1572 | 0.0882 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 ft$^2$ (23.8 kg/100 m$^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to the initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 37. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter moisture levels (%) (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 20.1 | 17.9 | 16.8 | 20.2 | 20.3 | 23.8 | 24.5 | 22.7 |
| PLT | 21.3 | 18.9 | 17.8 | 21.1 | 20.7 | 23.7 | 24.2 | 22.9 |
| SEM | 0.53 | 0.83 | 0.52 | 0.63 | 0.62 | 0.71 | 0.42 | 0.48 |
| P-value | 0.3836 | 0.3842 | 0.1739 | 0.3305 | 0.6275 | 0.8915 | 0.5477 | 0.7092 |
| House (H) | | | | | | | | |
| 1—LG | 20.7 | 16.8 | 16.7 | 19.6 | 22.1 | 20.9[c] | 23.1[b] | 23.0 |
| 2—PLT | 20.7 | 18.8 | 17.3 | 20.5 | 21.0 | 22.8[bc] | 23.5[b] | 22.6 |
| 3—LG | 20.4 | 17.5 | 17.3 | 20.1 | 19.5 | 26.2[a] | 24.5[ab] | 22.6 |
| 4—PLT | 21.5 | 19.4 | 17.9 | 22.1 | 20.2 | 24.0[ab] | 24.5[ab] | 22.9 |
| 5—LG | 20.9 | 19.2 | 16.4 | 21.1 | 19.3 | 24.3[ab] | 26.1[a] | 22.4 |
| 6—PLT | 21.8 | 18.5 | 18.3 | 20.9 | 20.9 | 24.1[ab] | 24.5[ab] | 22.3 |
| SEM | 0.94 | 1.47 | 0.92 | 1.12 | 1.06 | 1.18 | 0.70 | 0.85 |
| P-value | 0.8830 | 0.8006 | 0.7133 | 0.7008 | 0.4239 | 0.0656 | 0.0678 | 0.9809 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 21.3 | 18.0 | 17.8 | 20.5 | 20.2 | 25.2[a] | 24.5[a] | 22.9 |
| 3-5 | 21.2 | 19.3 | 17.1 | 21.6 | 19.8 | 24.1[a] | 25.3[a] | 22.6 |
| 6-8 | 20.7 | 17.8 | 17.0 | 20.0 | 21.6 | 21.9[b] | 23.3[b] | 22.8 |
| SEM | 0.65 | 1.03 | 0.646 | 0.78 | 0.74 | 0.83 | 0.49 | 0.59 |
| P-value | 0.8489 | 0.5398 | 0.6446 | 0.3524 | 0.2133 | 0.0210 | 0.0207 | 0.9332 |
| Location (L)[4] | | | | | | | | |
| 1 | 21.1 | 18.0 | 18.1 | 20.7 | 19.5 | 23.4 | 24.2 | 23.6 |
| 2 | 20.8 | 17.3 | 16.4 | 20.3 | 20.8 | 23.3 | 24.4 | 21.5 |
| 3 | 20.5 | 18.1 | 16.5 | 20.4 | 21.2 | 23.8 | 24.3 | 22.9 |
| 4 | 21.6 | 20.0 | 18.2 | 21.4 | 20.6 | 24.3 | 24.6 | 23.2 |
| SEM | 0.75 | 1.08 | 0.72 | 0.91 | 0.88 | 1.02 | 0.60 | 0.66 |
| P-value | 0.7479 | 0.4188 | 0.1484 | 0.8119 | 0.6020 | 0.9108 | 0.9681 | 0.1511 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 38. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on litter water activity ($a_w$) (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 0.860 | 0.742 | **** | 0.769 | 0.862 | 0.930 | 0.828 | 0.836 |
| PLT | 0.881 | 0.734 | **** | 0.657 | 0.855 | 0.927 | 0.807 | 0.832 |
| SEM | 0.019 | 0.015 | **** | 0.028 | 0.012 | 0.013 | 0.038 | 0.030 |
| P-value | 0.4521 | 0.6939 | **** | 0.9081 | 0.6797 | 0.8835 | 0.6989 | 0.9268 |
| House (H) | | | | | | | | |
| 1—LG | 0.857[b] | 0.743 | **** | 0.770 | 0.862 | 0.895 | 0.780 | 0.933[a] |
| 2—PLT | 0.860[b] | 0.753 | **** | 0.678 | 0.849 | 0.930 | 0.787 | 0.942[a] |
| 3—LG | 0.864[b] | 0.769 | **** | 0.715 | 0.852 | 0.955 | 0.837 | 0.814[b] |
| 4—PLT | 0.903[a] | 0.736 | **** | 0.625 | 0.845 | 0.908 | 0.819 | 0.776[b] |
| 5—LG | **** | 0.715 | **** | 0.821 | 0.873 | 0.940 | 0.868 | 0.762[b] |
| 6—PLT | **** | 0.713 | **** | 0.670 | 0.873 | 0.943 | 0.815 | 0.777[b] |
| SEM | 0.041 | 0.026 | **** | 0.053 | 0.021 | 0.023 | 0.067 | 0.049 |
| P-value | 0.0001 | 0.6313 | **** | 0.1188 | 0.8923 | 0.4948 | 0.9506 | 0.0272 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 0.782 | 0.741 | **** | 0.692 | 0.862 | 0.949 | 0.826 | 0.796[b] |
| 3-5 | 0.740 | 0.725 | **** | 0.723 | 0.859 | 0.924 | 0.843 | 0.769[b] |
| 6-8 | 0.859 | 0.748 | **** | 0.724 | 0.855 | 0.913 | 0.784 | 0.937[a] |
| SEM | 0.035 | 0.018 | **** | 0.039 | 0.015 | 0.016 | 0.047 | 0.034 |
| P-value | 0.0687 | 0.6686 | **** | 0.8098 | 0.9458 | 0.3032 | 0.6567 | 0.0019 |
| Location (L)[4] | | | | | | | | |
| 1 | 0.869 | 0.760 | **** | 0.732 | 0.888 | 0.938 | 0.887 | 0.833 |
| 2 | 0.871 | 0.728 | **** | 0.701 | 0.850 | 0.924 | 0.743 | 0.816 |
| 3 | 0.871 | 0.719 | **** | 0.690 | 0.838 | 0.926 | 0.807 | 0.851 |
| 4 | 0.872 | 0.745 | **** | 0.729 | 0.860 | 0.927 | 0.834 | 0.836 |
| SEM | 0.0282 | 0.021 | **** | 0.045 | 0.016 | 0.019 | 0.053 | 0.043 |
| P-value | 0.9998 | 0.5311 | **** | 0.8929 | 0.2079 | 0.9587 | 0.2997 | 0.9557 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

Table 39. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total aerobic bacterial counts* ($Log_{10}$ cfu/g) (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 8.20 | 7.59 | 7.64 | 8.57 | 9.22[a] | 9.27 | 8.73 | 8.00 |
| PLT | 8.10 | 7.83 | 7.77 | 8.67 | 8.78[b] | 9.03 | 9.06 | 8.31 |
| SEM | 0.113 | 0.142 | 0.144 | 0.129 | 0.154 | 0.163 | 0.165 | 0.195 |
| P-value | 0.5473 | 0.2353 | 0.5504 | 0.6111 | 0.0451 | 0.2987 | 0.1731 | 0.2602 |
| House (H) | | | | | | | | |
| 1—LG | 8.43[a] | 7.10[d] | 7.82 | 8.42 | 9.35 | 9.82[a] | 8.99[abc] | 8.16 |
| 2—PLT | 8.41[a] | 7.25[cd] | 8.04 | 8.71 | 8.98 | 9.83[a] | 9.96[a] | 8.22 |
| 3—LG | 8.37[a] | 8.00[ab] | 7.80 | 8.67 | 9.29 | 9.81[a] | 8.67[bcd] | 7.85 |
| 4—PLT | 8.17[ab] | 7.88[ab] | 7.78 | 8.65 | 8.52 | 8.22[c] | 8.28[d] | 8.24 |
| 5—LG | 7.80[bc] | 7.67[bc] | 7.31 | 8.63 | 9.03 | 8.18[c] | 8.53[cd] | 7.98 |
| 6—PLT | 7.72[c] | 8.35[a] | 7.48 | 8.64 | 8.84 | 9.04[b] | 9.29[ab] | 8.48 |
| SEM | 0.183 | 0.220 | 0.248 | 0.229 | 0.270 | 0.196 | 0.266 | 0.347 |
| P-value | 0.0175 | 0.0011 | 0.3504 | 0.9640 | 0.2873 | 0.0001 | 0.0083 | 0.8492 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 8.05[b] | 8.18[a] | 7.64 | 8.65 | 9.07 | 9.42[b] | 8.98[a] | 8.16 |
| 3-5 | 7.98[b] | 7.77[b] | 7.54 | 8.64 | 8.77 | 8.20[c] | 8.41[b] | 8.11 |
| 6-8 | 8.42[a] | 7.17[c] | 7.93 | 8.56 | 9.16 | 9.82[a] | 9.29[a] | 8.19 |
| SEM | 0.134 | 0.154 | 0.175 | 0.159 | 0.193 | 0.143 | 0.192 | 0.243 |
| P-value | 0.0550 | 0.0001 | 0.2716 | 0.9121 | 0.3402 | 0.0001 | 0.0061 | 0.9742 |
| Location (L)[4] | | | | | | | | |
| 1 | 8.16 | 7.67 | 7.70 | 8.62 | 8.91 | 9.01 | 8.88 | 8.28 |
| 2 | 8.19 | 7.47 | 7.76 | 8.72 | 8.82 | 9.23 | 8.86 | 7.95 |
| 3 | 8.12 | 7.86 | 7.93 | 8.57 | 9.32 | 9.15 | 9.03 | 8.41 |
| 4 | 8.13 | 7.84 | 7.43 | 8.56 | 8.95 | 9.21 | 8.81 | 7.98 |
| SEM | 0.163 | 0.202 | 0.204 | 0.185 | 0.223 | 0.235 | 0.239 | 0.279 |
| P-value | 0.9884 | 0.4938 | 0.3963 | 0.9278 | 0.4089 | 0.9109 | 0.9259 | 0.5893 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Eosin Methylene Blue (EMB) agar.

cfu/g= colony forming units per gram of litter material

Table 40. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on total coliform counts ($Log_{10}$ cfu/g)* (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.90 | 3.82 | 4.98 | 5.82 | 5.53 | 5.36 | 5.44 | 4.72 |
| PLT | 4.02 | 3.78 | 5.03 | 5.53 | 5.52 | 5.37 | 5.55 | 4.68 |
| SEM | 0.163 | 0.145 | 0.284 | 0.161 | 0.109 | 0.161 | 0.134 | 0.076 |
| P-value | 0.5686 | 0.8371 | 0.8972 | 0.2059 | 0.9109 | 0.9516 | 0.5764 | 0.7016 |
| House (H) | | | | | | | | |
| 1—LG | 3.98 | 3.66 | 4.36[bc] | 5.54 | 5.43 | 5.57 | 5.17 | 4.56 |
| 2—PLT | 3.90 | 3.94 | 3.57[c] | 5.44 | 5.28 | 5.79 | 5.72 | 4.86 |
| 3—LG | 3.87 | 3.99 | 4.81[ab] | 5.87 | 5.58 | 5.46 | 5.42 | 4.84 |
| 4—PLT | 3.79 | 3.73 | 5.74[a] | 5.46 | 5.65 | 5.19 | 5.15 | 4.59 |
| 5—LG | 3.83 | 3.82 | 5.76[a] | 6.04 | 5.59 | 5.05 | 5.73 | 4.75 |
| 6—PLT | 4.37 | 3.66 | 5.77[a] | 5.68 | 5.63 | 5.13 | 5.77 | 4.58 |
| SEM | 0.286 | 0.256 | 0.440 | 0.284 | 0.190 | 0.276 | 0.227 | 0.131 |
| P-value | 0.7436 | 0.9117 | 0.0018 | 0.6089 | 0.7383 | 0.3701 | 0.1710 | 0.3651 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 4.12 | 3.82 | 5.29[a] | 5.77 | 5.60 | 5.29 | 5.60 | 4.71 |
| 3-5 | 3.81 | 3.78 | 5.75[a] | 5.75 | 5.62 | 5.12 | 5.44 | 4.61 |
| 6-8 | 3.94 | 3.80 | 3.97[b] | 5.49 | 5.36 | 5.68 | 5.44 | 4.71 |
| SEM | 0.200 | 0.179 | 0.313 | 0.200 | 0.132 | 0.192 | 0.166 | 0.094 |
| P-value | 0.5489 | 0.9828 | 0.0004 | 0.5490 | 0.3020 | 0.1152 | 0.7472 | 0.9524 |
| Location (L)[4] | | | | | | | | |
| 1 | 4.15 | 3.69 | 4.48[b] | 5.62 | 5.63 | 5.37 | 5.21 | 4.49 |
| 2 | 3.95 | 3.83 | 5.51[a] | 5.52 | 5.51 | 5.42 | 5.83 | 4.69 |
| 3 | 3.96 | 3.99 | 5.74[a] | 5.90 | 5.59 | 5.44 | 5.55 | 4.57 |
| 4 | 3.77 | 3.69 | 4.28[b] | 5.65 | 5.38 | 5.22 | 5.38 | 4.69 |
| SEM | 0.233 | 0.206 | 0.378 | 0.232 | 0.154 | 0.230 | 0.185 | 0.107 |
| P-value | 0.7221 | 0.7003 | 0.0154 | 0.6897 | 0.6859 | 0.9079 | 0.1165 | 0.3387 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Eosin Methylene Blue (EMB) agar.

cfu/g= colony forming units per gram of litter material

Table 41. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *E.coli* levels ($Log_{10}$ cfu/g)* (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.91 | 3.40 | 4.82 | 5.59 | 5.48 | 5.14 | 4.81 | 4.33 |
| PLT | 3.71 | 3.55 | 4.72 | 5.39 | 5.33 | 5.16 | 4.74 | 4.28 |
| SEM | 0.167 | 0.173 | 0.234 | 0.152 | 0.090 | 0.135 | 0.118 | 0.086 |
| P-value | 0.411 | 0.5576 | 0.7621 | 0.3654 | 0.2529 | 0.8846 | 0.6923 | 0.7054 |
| House (H) | | | | | | | | |
| 1—LG | 4.30 | 3.13 | 3.94$^{c}$ | 5.16 | 5.50 | 5.11$^{ab}$ | 4.88 | 4.33 |
| 2—PLT | 3.47 | 3.65 | 4.52$^{bc}$ | 5.37 | 5.13 | 5.54$^{a}$ | 4.89 | 4.33 |
| 3—LG | 3.67 | 3.50 | 4.90$^{ab}$ | 5.88 | 5.35 | 5.52$^{a}$ | 4.78 | 4.29 |
| 4—PLT | 3.52 | 3.70 | 4.46$^{bc}$ | 5.12 | 5.41 | 4.81$^{b}$ | 4.54 | 4.25 |
| 5—LG | 3.75 | 3.58 | 5.63$^{a}$ | 5.72 | 5.58 | 4.77$^{b}$ | 4.77 | 4.36 |
| 6—PLT | 4.14 | 3.29 | 5.18$^{ab}$ | 5.68 | 5.45 | 5.15$^{ab}$ | 4.81 | 4.26 |
| SEM | 0.285 | 0.303 | 0.384 | 0.260 | 0.157 | 0.223 | 0.208 | 0.153 |
| P-value | 0.2326 | 0.7418 | 0.0461 | 0.2086 | 0.4295 | 0.0656 | 0.8674 | 0.9955 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 3.91 | 3.40 | 5.04$^{a}$ | 5.78 | 5.40 | 5.34$^{a}$ | 4.77 | 4.27 |
| 3-5 | 3.63 | 3.64 | 5.05$^{a}$ | 5.42 | 5.50 | 4.79$^{b}$ | 4.65 | 4.31 |
| 6-8 | 3.88 | 3.39 | 4.23$^{b}$ | 5.27 | 5.32 | 5.32$^{a}$ | 4.88 | 4.33 |
| SEM | 0.206 | 0.212 | 0.277 | 0.184 | 0.111 | 0.158 | 0.144 | 0.106 |
| P-value | 0.5829 | 0.6338 | 0.0648 | 0.1358 | 0.5244 | 0.0250 | 0.5319 | 0.9368 |
| Location (L)[4] | | | | | | | | |
| 1 | 3.98 | 3.46 | 4.14$^{c}$ | 5.58 | 5.38 | 5.10 | 4.42$^{b}$ | 4.25 |
| 2 | 3.77 | 3.58 | 5.13$^{ab}$ | 5.41 | 5.41 | 5.27 | 5.03$^{a}$ | 4.35 |
| 3 | 3.69 | 3.70 | 5.43$^{a}$ | 5.44 | 5.36 | 5.10 | 4.83$^{a}$ | 4.22 |
| 4 | 3.79 | 3.17 | 4.40$^{bc}$ | 5.38 | 5.47 | 5.13 | 4.83$^{a}$ | 4.39 |
| SEM | 0.240 | 0.244 | 0.311 | 0.220 | 0.131 | 0.193 | 0.160 | 0.122 |
| P-value | 0.8573 | 0.4574 | 0.0143 | 0.9437 | 0.9340 | 0.9168 | 0.0616 | 0.7446 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using MacConkey (MAC) agar.

cfu/g= colony forming units per gram of litter material

Table 42. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on anaerobic bacterial counts ($Log_{10}$ cfu/g)* (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 5.95 | 5.50 | 6.63 | 7.38 | 6.96[a] | 7.08 | 6.70 | 6.59 |
| PLT | 5.98 | 5.67 | 6.76 | 7.32 | 6.76[b] | 7.09 | 6.73 | 6.52 |
| SEM | 0.084 | 0.162 | 0.148 | 0.120 | 0.078 | 0.118 | 0.085 | 0.052 |
| P-value | 0.8298 | 0.4533 | 0.5208 | 0.7325 | 0.0772 | 0.9545 | 0.8183 | 0.2920 |
| House (H) | | | | | | | | |
| 1—LG | 5.83 | 5.13 | 6.26[c] | 7.23 | 7.15[a] | 7.39 | 6.85 | 6.61 |
| 2—PLT | 6.14 | 5.69 | 6.08[c] | 7.02 | 6.79[bc] | 7.41 | 6.58 | 6.47 |
| 3—LG | 6.08 | 5.83 | 6.54[bc] | 7.37 | 6.91[ab] | 6.75 | 6.57 | 6.71 |
| 4—PLT | 5.89 | 5.77 | 7.04[ab] | 7.28 | 6.57[c] | 7.02 | 6.61 | 6.51 |
| 5—LG | 5.96 | 5.53 | 7.08[ab] | 7.54 | 6.82[bc] | 7.11 | 6.69 | 6.47 |
| 6—PLT | 5.91 | 5.55 | 7.17[a] | 7.67 | 6.93[ab] | 6.84 | 7.00 | 6.57 |
| SEM | 0.146 | 0.282 | 0.233 | 0.205 | 0.132 | 0.197 | 0.145 | 0.090 |
| P-value | 0.6559 | 0.5628 | 0.0034 | 0.2854 | 0.0823 | 0.1023 | 0.2229 | 0.3719 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 6.00 | 5.69 | 6.86[a] | 7.52 | 6.92 | 6.80[b] | 6.79 | 6.64 |
| 3-5 | 5.92 | 5.65 | 7.06[a] | 7.41 | 6.70 | 7.07[a] | 6.65 | 6.49 |
| 6-8 | 5.98 | 5.42 | 6.17[b] | 7.13 | 6.97 | 7.40[a] | 6.71 | 6.54 |
| SEM | 0.103 | 0.199 | 0.166 | 0.144 | 0.095 | 0.136 | 0.105 | 0.063 |
| P-value | 0.8646 | 0.5805 | 0.0009 | 0.1435 | 0.1078 | 0.0103 | 0.6436 | 0.2287 |
| Location (L)[4] | | | | | | | | |
| 1 | 5.97 | 5.51 | 6.36 | 7.25 | 6.77 | 7.05 | 6.56 | 6.51 |
| 2 | 5.93 | 5.66 | 6.73 | 7.58 | 6.97 | 6.96 | 6.86 | 6.54 |
| 3 | 6.05 | 5.90 | 7.06 | 7.32 | 6.87 | 7.08 | 6.71 | 6.59 |
| 4 | 5.91 | 5.27 | 6.62 | 7.26 | 6.84 | 7.26 | 6.74 | 6.58 |
| SEM | 0.120 | 0.227 | 0.205 | 0.169 | 0.113 | 0.167 | 0.120 | 0.075 |
| P-value | 0.8467 | 0.2681 | 0.1214 | 0.4672 | 0.6655 | 0.6489 | 0.3726 | 0.8718 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Anaerobic Agar (AA).

cfu/g= colony forming units per gram of litter material

Table 43. The use of Litter Guard (LG) and Poultry Litter Treatment (PLT) in commercial broiler houses and their effect on *Clostridium perfringens* counts ($Log_{10}$ cfu/g)* (Trials 1-3)[1]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment (T)[2] | | | | | | | | |
| LG | 3.98 | 3.95 | 4.01 | 4.25 | 3.92 | 4.43 | 3.75 | 3.65[b] |
| PLT | 3.98 | 3.88 | 4.09 | 4.26 | 3.97 | 4.45 | 3.77 | 3.81[a] |
| SEM | 0.094 | 0.074 | 0.069 | 0.078 | 0.058 | 0.131 | 0.061 | 0.062 |
| P-value | 0.9627 | 0.4870 | 0.4078 | 0.9584 | 0.5391 | 0.9272 | 0.8445 | 0.0646 |
| House (H) | | | | | | | | |
| 1—LG | 4.28[a] | 3.97 | 3.95 | 4.22 | 3.87 | 4.46 | 3.96 | 3.73 |
| 2—PLT | 4.21[ab] | 3.90 | 3.97 | 4.25 | 4.18 | 4.35 | 3.74 | 3.74 |
| 3—LG | 3.50[d] | 3.81 | 3.94 | 4.29 | 3.87 | 4.41 | 3.65 | 3.56 |
| 4—PLT | 3.83[cd] | 3.98 | 4.03 | 4.28 | 3.84 | 4.62 | 3.73 | 3.88 |
| 5—LG | 4.16[abc] | 4.07 | 4.13 | 4.24 | 4.01 | 4.42 | 3.64 | 3.65 |
| 6—PLT | 3.89[bc] | 3.75 | 4.26 | 4.24 | 3.89 | 4.39 | 3.83 | 3.82 |
| SEM | 0.147 | 0.129 | 0.120 | 0.140 | 0.097 | 0.232 | 0.103 | 0.110 |
| P-value | 0.0032 | 0.5449 | 0.3741 | 0.9996 | 0.1282 | 0.9750 | 0.2387 | 0.3678 |
| Litter Age (LA)[3] | | | | | | | | |
| 2-4 | 3.70[c] | 3.78 | 4.10 | 4.27 | 3.88 | 4.40 | 3.74 | 3.69 |
| 3-5 | 3.99[b] | 4.02 | 4.08 | 4.26 | 3.92 | 4.52 | 3.68 | 3.76 |
| 6-8 | 4.25[a] | 3.94 | 3.96 | 4.24 | 4.02 | 4.40 | 6.85 | 3.73 |
| SEM | 0.106 | 0.089 | 0.085 | 0.097 | 0.070 | 0.161 | 0.074 | 0.078 |
| P-value | 0.0024 | 0.1654 | 0.4682 | 0.9753 | 0.3403 | 0.8343 | 0.2611 | 0.8112 |
| Location (L)[4] | | | | | | | | |
| 1 | 4.01 | 3.89 | 4.02 | 4.31 | 3.99 | 4.43 | 3.80 | 3.67 |
| 2 | 3.93 | 3.94 | 3.99 | 4.10 | 4.00 | 4.68 | 3.81 | 3.65 |
| 3 | 4.12 | 4.04 | 4.11 | 4.37 | 3.89 | 4.21 | 3.80 | 3.79 |
| 4 | 3.86 | 3.79 | 4.07 | 4.24 | 3.90 | 4.38 | 3.62 | 3.81 |
| SEM | 0.133 | 0.104 | 0.100 | 0.110 | 0.082 | 0.184 | 0.085 | 0.090 |
| P-value | 0.5273 | 0.3863 | 0.8336 | 0.3616 | 0.6814 | 0.4581 | 0.3566 | 0.5005 |

[1]Values are grand means (N=72) derived from 6 commercial broiler houses (3 per treatment level) sampled at 4 specified locations within each house for 3 consecutive trials. The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.

[3]Litter age indicates number of flocks reared prior to initiation of each trial.

[4]Location refers to four equidistant sampling locations within the house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

SEM= Pooled Standard Error Mean

*Determined using Tryptose Sulfite Cycloserine (TSC) agar.

cfu/g= colony forming units per gram of litter material

Table 44. Weekly mortality and culls in commercial broiler houses treated with Litter Guard (LG) and Poultry Litter Treatment (PLT) (Trials 1-3)[1].

| | Week | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment (T)[2] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| LG | 536 | 399 | 84 | 53 | 85 | 123 | 99 | 1378 |
| PLT | 417 | 390 | 100 | 58 | 97 | 128 | 123 | 1313 |
| SEM | 277 | 226 | 62 | 21 | 35 | 46 | 50 | 581 |
| P-value | 0.1892 | 0.4693 | 0.7048 | 0.6589 | 0.7747 | 0.5921 | 0.8346 | 0.4073 |

[1]Values are a weekly total expressed as number of birds per house as derived from 6 commercial broiler houses (3 per treatment level). Total represents cumulative mortality for the entire grow out period. Number of birds placed in each house was 28,000 head.
[2]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
SEM= Pooled Standard Error Mean

Table 45. Effect of Poultry Litter Treatment (PLT) and Litter Guard (LG) on foot pad dermatitis (Trial 1-3)

| | Score* | | |
|---|---|---|---|
| | Score 0 | Score 1 | Score 2 |
| Treatment[1] | | | |
| LG | 1286.3 | 245.3 | 14.3 |
| PLT | 1111.6 | 336.3 | 64.0 |
| SEM | 59.9 | 48.9 | 14.3 |
| P-value | 0.1084 | 0.2592 | 0.0700 |
| Litter Age[2] | | | |
| 2-4 | 1174.5 | 358.5 | 30.0 |
| 3-5 | 1282.0 | 208.0 | 31.0 |
| 6-8 | 1140.5 | 306.0 | 56.5 |
| SEM | 105.7 | 54.5 | 29.5 |
| P-value | 0.6553 | 0.2856 | 0.7884 |
| House | | | |
| 1-LG | 1246 | 242 | 10 |
| 2-PLT | 1035 | 370 | 103 |
| 3-LG | 1324 | 289 | 10 |
| 4-PLT | 1275 | 211 | 39 |
| 5-LG | 1289 | 205 | 23 |
| 6-PLT | 1025 | 428 | 50 |

*Score 0 = no lesions on foot pad, Score 1 = mild dermatitis lesions, Score 2 = severe dermatitis lesions. At processing, 500 paws were collected from each house and visually scored for quality (Values represent the number of paws for each score obtained).
[1]The treatments comprised of Poultry Litter Treatment (PLT) applied to the brood area (1/2 house) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$) or Poultry Guard applied at a rate of 5.28 gallons (20 liter) diluted into 100 gallons (378.5 liter) of water prior to application.
[2]Litter age indicates number of flocks reared prior to initiation of each trial.
SEM= Pooled Standard Error Mean

**Effect of Poultry Litter Treatment (PLT) on environmental and microbiological parameters in commercial broiler facilities (Trials 1-3)**

The data obtained from the houses (2, 4 and 6) treated with Poultry Litter Treatment (PLT) was analyzed to determine the effect of PLT on environmental and microbiological parameters in a commercial broiler facility. PLT was applied to the central brooding area (Location 2 and 3) of three commercial houses as outlined in Section 1. The untreated area (Locations 1 and 4) served as control for this analysis.

**Pooled analysis for trials 1, 2 and 3**

The PLT treated area showed consistently low ammonia emission rates compared to control area until day 22 of sampling without any significant differences *(P>0.10)* (Table 46). Litter age had a significant effect *(P<0.10)* on ammonia emission rates only on day 8 of sampling with 2-4 flock litter showing the highest reading (53.7 ppm) and 3-5 flock the lowest (32.2 ppm).

Litter pH levels were similar prior to PLT application between the treatment areas (Table 47). On day 1 of sampling the PLT applied area showed a significant *(P<0.10)* decrease in pH levels compared to the control area with a reading of 7.48 vs. 8.34. The PLT treated area showed a significant *(P<0.10)* decrease in pH levels from day 1 of sampling until the end of the study except for day 36 compared to the control area. Litter age showed a significant impact *(P<0.10)* on pH levels on the initial day with 3-5 and 6-8 flock litter having the highest reading (8.47 and 8.46 respectively) and two flock litter with the lowest reading (8.24).

The PLT treated litter did not show any significant difference in moisture levels compared to control area throughout the study *(P>0.10)* (Table 48). Litter age and location failed to show any significant differences *(P>0.10)* in moisture levels throughout

the study. There were no significant differences *(P>0.10)* in water activity readings for the control and PLT treated areas (Table 49). Litter age and sampling location had no effect on water activity readings.

Aerobic bacterial counts were significantly higher *(P<0.10)* in PLT treated area compared to control area on day 8 of the study (Table 50). PLT treated area showed consistently higher aerobic bacterial counts compared to control area for the entire study without any significant differences *(P>0.10).* Aerobic bacterial counts were significantly affected by different litter age on initial day, day 1, 29 and 36 of the study.

Coliform counts were significantly affected *(P<0.10)* by PLT application on day 8 and 43 of the study (Table 51). Coliform count was significantly affected *(P<0.10)* by different litter age on day 8 with 2-4 flock litter having the lowest count (3.573 cfu/gm). All other sampling days and litter age did not show any significant differences in coliform counts.

PLT treated area showed a significantly higher *(P<0.10) E.coli* reading compared to control area on day 8 of sampling (Table 52). Litter age showed a significant difference *(P<0.10)* in *E.coli* levels only on day 29 of sampling. Anaerobic bacterial counts were significantly higher *(P<0.10)* in the PLT treated area compared to the control area on day 15 of sampling (Table 53). Litter age had a significant effect on anaerobic bacterial counts on day 8 and 22 of study. No other day showed any significant differences *(P>0.10)* in anaerobic bacterial counts.

PLT treatment did not show any significant difference *(P>0.10)* in *Clostridium perfringens* levels throughout the study (Table 54). Litter age and location had no major effect on *Clostridium perfringens* counts during the study.

**Discussion**

PLT treatment showed a significant *(P<0.10)* decrease in pH levels compared to the control area. Line conducted a field trial in 2002 to study the effect of PLT and aluminum bisulfate on litter pH. He observed that PLT at high application rates (4 lb/50 $ft^2$) was most effective in reducing pH levels of litter compared to aluminum sulfate at high levels (16 lb/50 $ft^2$). Pope and Cherry (2000) also observed similar results while using PLT as a litter treatment and observed a pH of 1.2 in the first week of application. Terzich obtained similar results in 1996 while conducting a field trial to notice the effect of PLT on litter parameters. He observed that PLT application reduced the pH of litter to 1.7 and there was a gradual increase to 4.7 eight days post treatment.

Coliform counts were significantly affected *(P<0.10)* by PLT application on day 8 and 43 of the trial. The PLT treated area showed higher coliform counts compared to the control area for all readings except for day 15 and 43 of sampling. Choi and Moore (2008) observed that acidification of poultry litter with alum decreases the coliform significantly *(P<0.05)* compared to control litter which is completely opposite of the results obtained in the current trial using PLT as a litter acidifier.

The PLT treatment exhibited lower *E.coli* counts on the initial day of sampling compared to the control area, but the readings were reversed on day 1 with PLT treated area showing higher *E.coli* readings compared to control area. PLT treated area showed a significantly higher *(P<0.10) E.coli* reading compared to control area on day 8 of sampling. On the other hand Pope and Cherry (2000) found that PLT application to poultry litter reduced the *E.coli* count of litter to 0 cfu/gm of litter compared to control area with 9.38E + 0.3 cfu/g of litter.

## References


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Pope, M.J. and T.E. Cherry. 2000. An evaluation of the presence of pathogens on broilers raised on poultry litter treatment-treated litter. Poult. Sci. 79:1351-1355.

Terzich, M. 1996. Poultry Litter Treatment (PLT) effect on broiler farm fuel cost and performance. Cited 04/16/2012. http://www.joneshamiltonag.com/jh/wp-content/uploads/2011/10/PLT-Effects-on-Fuel-Cost-and-Performance.pdf

Table 46. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses for the reduction of ammonia volatilization (ppm) (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 72.4 | 44.4 | 45.2 | 43.5 | 64.1 | 135.1 | 119.9 | 107.7 |
| PLT | 83.5 | 31.5 | 38.3 | 39.4 | 76.5 | 100.8 | 120.7 | 111.1 |
| SEM | 6.69 | 7.26 | 5.81 | 3.86 | 11.95 | 14.75 | 9.38 | 12.43 |
| P-value | 0.2490 | 0.2187 | 0.4107 | 0.4643 | 0.4671 | 0.1093 | 0.9496 | 0.8488 |
| Litter Age (LA)[4] | | | | | | | | |
| 2-4 | 65.8 | 44.5 | 53.7[a] | 48.5 | 61.5 | 91.4 | 105.8 | 99.0 |
| 3-5 | 77.7 | 41.7 | 32.2[b] | 41.1 | 67.7 | 129.4 | 131.5 | 135.3 |
| 6-8 | 90.4 | 27.7 | 39.4[ab] | 34.7 | 81.7 | 133.1 | 123.6 | 93.9 |
| SEM | 7.92 | 8.96 | 6.79 | 4.53 | 14.76 | 18.19 | 11.20 | 14.42 |
| P-value | 0.1064 | 0.3741 | 0.0922 | 0.1119 | 0.6168 | 0.2143 | 0.2650 | 0.1019 |

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 47. The use of Poultry Litter Treatment (PLT) [1] in commercial broiler houses for the reduction of litter pH levels (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 8.40 | 8.34[a] | 8.29[a] | 8.13[a] | 8.04[a] | 8.34[a] | 8.28 | 8.37[a] |
| PLT | 8.38 | 7.48[b] | 8.02[b] | 7.87[b] | 7.71[b] | 8.09[b] | 8.19 | 8.26[b] |
| SEM | 0.05 | 0.13 | 0.06 | 0.05 | 0.0 | 0.053 | 0.05 | 0.04 |
| P-value | 0.7759 | 0.0001 | 0.0046 | 0.0038 | 0.0057 | 0.0024 | 0.2039 | 0.0762 |
| Litter Age (LA)[4] | | | | | | | | |
| 2-4 | 8.24[b] | 7.92 | 8.18 | 7.97[b] | 7.85 | 8.13 | 8.12[b] | 8.23 |
| 3-5 | 8.47[a] | 8.08 | 8.23 | 8.16[a] | 7.93 | 8.31 | 8.34[a] | 8.40 |
| 6-8 | 8.46[a] | 7.73 | 8.06 | 7.87[b] | 7.86 | 8.21 | 8.24[b] | 8.32 |
| SEM | 0.05 | 0.20 | 0.08 | 0.07 | 0.10 | 0.07 | 0.06 | 0.05 |
| P-value | 0.0093 | 0.4901 | 0.3306 | 0.0265 | 0.8348 | 0.2035 | 0.0682 | 0.1017 |

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 48. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on litter moisture levels (%) (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 21.2 | 19.2 | 18.3 | 21.6 | 19.6 | 23.3 | 23.8 | 23.4 |
| PLT Treatment | 21.4 | 18.6 | 17.4 | 20.6 | 21.9 | 24.0 | 24.6 | 22.5 |
| SEM | 0.72 | 1.27 | 0.64 | 0.90 | 0.93 | 0.76 | 0.47 | 0.77 |
| P-value | 0.8265 | 0.7453 | 0.3421 | 0.4360 | 0.1002 | 0.5195 | 0.2630 | 0.4061 |
| Litter Age (LA)[4] | | | | | | | | |
| 2-4 | 20.7 | 18.8 | 17.3 | 20.5 | 21.0 | 22.8 | 23.5 | 22.6 |
| 3-5 | 21.5 | 19.4 | 17.9 | 22.1 | 20.2 | 24.0 | 24.5 | 22.9 |
| 6-8 | 21.8 | 18.5 | 18.3 | 20.9 | 20.9 | 24.1 | 24.5 | 22.3 |
| SEM | 0.89 | 1.57 | 0.79 | 1.11 | 1.20 | 0.93 | 0.58 | 0.96 |
| P-value | 0.6466 | 0.9277 | 0.6851 | 0.5844 | 0.8841 | 0.5468 | 0.4095 | 0.8647 |

* Significantly different P-value *(P>0.10)*

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 49. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on litter water activity (%) (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 0.830 | 0.750 | 0.683 | 0.675 | 0.859 | 0.944 | 0.806 | 0.826 |
| PLT | 0.812 | 0.718 | 0.637 | 0.640 | 0.852 | 0.910 | 0.809 | 0.838 |
| SEM | 0.042 | 0.018 | 0.042 | 0.055 | 0.018 | 0.022 | 0.056 | 0.046 |
| P-value | 0.7653 | 0.2253 | 0.4475 | 0.6520 | 0.8074 | 0.2868 | 0.9681 | 0.8499 |
| Litter Age (LA)[4] | | | | | | | | |
| 2-4 | 0.860[a] | 0.753 | 0.595 | 0.678 | 0.849 | 0.930 | 0.787 | 0.942[a] |
| 3-5 | 0.903[a] | 0.736 | 0.661 | 0.625 | 0.845 | 0.908 | 0.819 | 0.776[b] |
| 6-8 | 0.700[b] | 0.713 | 0.724 | 0.670 | 0.873 | 0.943 | 0.815 | 0.777[b] |
| SEM | 0.046 | 0.023 | 0.050 | 0.068 | 0.022 | 0.028 | 0.070 | 0.053 |
| P-value | 0.0103 | 0.4932 | 0.2103 | 0.8417 | 0.6474 | 0.6745 | 0.9407 | 0.0536 |

* Significantly different P-value *(P>0.10)*

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 50. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on total aerobic bacterial counts (cfu/g)* (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 8.107 | 7.829 | 7.448[b] | 8.602 | 8.625 | 8.995 | 8.835 | 8.309 |
| PLT | 8.096 | 7.829 | 8.087[a] | 8.729 | 8.931 | 9.064 | 9.274 | 8.315 |
| SEM | 0.190 | 0.203 | 0.210 | 0.202 | 0.236 | 0.229 | 0.247 | 0.250 |
| P-value | 0.9679 | 0.9989 | 0.0389 | 0.6604 | 0.3662 | 0.8331 | 0.2172 | 0.9865 |
| Litter Age (LA)[4] | | | | | | | | |
| 2-4 | 8.412[a] | 7.249[b] | 8.042 | 8.706 | 8.977 | 9.826[a] | 9.956[a] | 8.215 |
| 3-5 | 8.170[ab] | 7.879[a] | 7.780 | 8.651 | 8.520 | 8.224[c] | 8.279[b] | 8.243 |
| 6-8 | 7.722[b] | 8.350[a] | 7.481 | 8.639 | 8.837 | 9.039[b] | 9.288[a] | 8.478 |
| SEM | 0.219 | 0.212 | 0.269 | 0.252 | 0.291 | 0.206 | 0.264 | 0.309 |
| P-value | 0.0946 | 0.0031 | 0.3508 | 0.9799 | 0.5315 | 0.0001 | 0.0034 | 0.8055 |

* Significantly different P-value *(P>0.10)*

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 51. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on total coliform counts (cfu/g)* (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 4.026 | 3.580 | 4.466[b] | 5.542 | 5.517 | 5.326 | 5.394 | 4.820[a] |
| PLT | 4.022 | 3.975 | 5.592[a] | 5.509 | 5.518 | 5.414 | 5.698 | 4.531[b] |
| SEM | 0.266 | 0.218 | 0.419 | 0.214 | 0.127 | 0.252 | 0.196 | 0.096 |
| P-value | 0.9915 | 0.2110 | 0.0660 | 0.9137 | 0.9850 | 0.8076 | 0.2817 | 0.0403 |
| Litter Age (LA)[4] | | | | | | | | |
| 2-4 | 3.904 | 3.939 | 3.573[b] | 5.444 | 5.280 | 5.793 | 5.719 | 4.857 |
| 3-5 | 3.794 | 3.734 | 5.744[a] | 5.456 | 5.645 | 5.185 | 5.146 | 4.592 |
| 6-8 | 4.368 | 3.659 | 5.770[a] | 5.676 | 5.626 | 5.131 | 5.773 | 4.577 |
| SEM | 0.322 | 0.276 | 0.4517 | 0.264 | 0.150 | 0.300 | 0.233 | 0.121 |
| P-value | 0.4211 | 0.7610 | 0.0017 | 0.7846 | 0.1694 | 0.2385 | 0.1264 | 0.1989 |

* Significantly different P-value *(P>0.10)*

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 52. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on *E.coli* levels (cfu/g)* (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 3.814 | 3.357 | 4.134[b] | 5.423 | 5.374 | 4.984 | 4.553 | 4.298 |
| PLT | 3.603 | 3.739 | 5.311[a] | 5.356 | 5.282 | 5.343 | 4.935 | 4.259 |
| SEM | 0.233 | 0.255 | 0.300 | 0.204 | 0.1377 | 0.186 | 0.184 | 0.121 |
| P-value | 0.5251 | 0.2973 | 0.0090 | 0.8167 | 0.6393 | 0.1827 | 0.1517 | 0.8220 |
| Litter Age (LA)[4] | | | | | | | | |
| 2 | 3.466 | 3.651 | 4.522 | 5.370 | 5.125 | 5.535[a] | 4.885 | 4.327 |
| 3 | 3.516 | 3.703 | 4.463 | 5.118 | 5.413 | 4.806[b] | 4.539 | 4.252 |
| 6 | 4.143 | 3.291 | 5.182 | 5.681 | 5.447 | 5.150[ab] | 4.809 | 4.257 |
| SEM | 0.276 | 0.317 | 0.401 | 0.244 | 0.166 | 0.220 | 0.231 | 0.151 |
| P-value | 0.1716 | 0.6120 | 0.3830 | 0.2783 | 0.3332 | 0.0797 | 0.5463 | 0.9266 |

* Significantly different P-value *(P>0.10)*

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 53. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on anaerobic bacterial counts (cfu/g)* (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 6.047 | 5.509 | 6.622 | 7.016[b] | 6.726 | 7.205 | 6.640 | 6.564 |
| PLT | 5.911 | 5.831 | 6.904 | 7.631[a] | 6.799 | 6.980 | 6.820 | 6.467 |
| SEM | 0.107 | 0.222 | 0.221 | 0.168 | 0.086 | 0.166 | 0.129 | 0.081 |
| P-value | 0.3769 | 0.3132 | 0.3749 | 0.0143 | 0.5544 | 0.3461 | 0.3321 | 0.4051 |
| Litter Age (LA)[4] | | | | | | | | |
| 2 | 6.138 | 5.695 | 6.079[b] | 7.021 | 6.786[ab] | 7.410 | 6.575 | 6.469 |
| 3 | 5.888 | 5.769 | 7.040[a] | 7.278 | 6.573[b] | 7.024 | 6.611 | 6.508 |
| 6 | 5.912 | 5.546 | 7.170[a] | 7.672 | 6.929[a] | 6.843 | 7.004 | 6.570 |
| SEM | 0.131 | 0.279 | 0.237 | 0.214 | 0.098 | 0.197 | 0.152 | 0.107 |
| P-value | 0.3428 | 0.8489 | 0.0049 | 0.1124 | 0.0479 | 0.1325 | 0.1018 | 0.7773 |

* Significantly different P-value *(P>0.10)*

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[5]Location refers to four equidistant sampling locations within a 40' x 500' house beginning at the cooling pad end and progressing to the tunnel fan end of the house.

[ab]Numerical values for each variable column with different superscripts are significantly different at *P<0.10*.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

Table 54. The use of Poultry Litter Treatment (PLT)[1] in commercial broiler houses and its effect on *Clostridium perfringens* counts (cfu/g)* (Trials 1-3)[2]

| | | Age (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 1 | 8 | 15 | 22 | 29 | 36 | 43 |
| Treatment Area (TA)[3] | | | | | | | | |
| Control | 3.971 | 3.773 | 4.083 | 4.257 | 3.983 | 4.347 | 3.724 | 3.893 |
| PLT | 3.980 | 3.978 | 4.095 | 4.255 | 3.951 | 4.554 | 3.807 | 3.731 |
| SEM | 0.124 | 0.109 | 0.098 | 0.105 | 0.101 | 0.189 | 0.065 | 0.082 |
| P-value | 0.9583 | 0.1948 | 0.9309 | 0.9945 | 0.8296 | 0.4459 | 0.3738 | 0.1724 |
| Litter Age (LA)[4] | | | | | | | | |
| 2 | 4.207 | 3.899 | 3.974 | 4.248 | 4.180[a] | 4.346 | 3.742 | 3.736 |
| 3 | 3.826 | 3.976 | 4.034 | 4.275 | 3.837[b] | 4.617 | 3.730 | 3.877 |
| 6 | 3.893 | 3.752 | 4.259 | 4.244 | 3.885[b] | 4.389 | 3.825 | 3.824 |
| SEM | 0.146 | 0.136 | 116 | 0.130 | 0.117 | 0.235 | 0.081 | 0.103 |
| P-value | 0.1629 | 0.5074 | 0.2040 | 0.9836 | 0.0983 | 0.6849 | 0.6678 | 0.6301 |

[1]Poultry Litter Treatment (PLT) was applied to the brood area (1/2 house, location 2 and 3) at a rate of 50 lbs/1,000 $ft^2$ (23.8 kg/100 $m^2$). The days indicated are for Trial 1. Sampling days for Trial 2 and 3 were 1, 8, 15, 22, 29, 36 and 45 and 4, 11, 18, 25, 32, 39 and 46, respectively.

[2]Values are grand means (N=36) derived from 3 commercial broiler houses sampled at 4 specified locations within each house for three consecutive trials.

[3]Control area refers to location 1 and 4 without any treatment and PLT treated area is location 2 and 3 where PLT was applied.

[4]Litter age indicates number of flocks reared prior to initiation of first trial.

[ab]Numerical values for each variable column with different superscripts are significantly different at $P<0.10$.

cfu/g= colony forming units per gram of litter material

SEM= Pooled Standard Error Mean

## Conclusion

Maintaining poultry litter quality in poultry facilities continues to be of importance in terms of production parameters. Extensive research has been conducted to show the positive effect of chemical litter amendments in reducing ammonia emission rates and bacterial loads in poultry litter. Comparatively few studies have been conducted with biological litter amendments on poultry litter quality. The objective of the field trial described in the preceding manuscript was to determine the effect of Poultry Litter Treatment (PLT) and Litter Guard (LG) on litter characteristics for three consecutive trials.

The three field trials suggest both litter treatments were ineffective in maintaining low ammonia levels after second week of application. PLT was more effective in reducing litter pH compared to LG for all the three trials. Neither of the litter treatments was ineffective in reducing the bacterial counts of litter. Footpad dermatitis scores was unaffected.

Biological litter amendments are not common due to their low efficacy and the availability of highly effective chemical litter amendments. Combination of different bacterial species can be used to reduce bacteria specifically the ureolytic bacteria in poultry litter. This will ultimately help improve the litter condition. Thus, extensive research is needed in order to come up with different biological litter amendments for poultry litter that can be effective litter amendments.