Lehigh Valley Organic Growers,Inc

125 West Seventh Street
Wind Gap, Pennsylvania 18091 USA

Telephone: 610 863-6700
Facsimile: 610 863-4622
Email : agrisys1@aoil.com

April 21, 2014

Ms. Lisa M. Brines, Phd.
National List Manager
USDA/AMS/NOP Standards Division
1400 Independence Avenue S.W.
Room 2648 – So., Ag Stop 0268
Washington, D. C. 20250-0268

Dear Dr. Brines:

We are pleased to submit to you on behalf of our client, Jones-Hamilton, Co. two (2) copies of our Petition for Evaluation of the Substance- Sodium Bisulfate, labeled as Poultry Litter Treatment (PLT) for Inclusion on the National List of Substances Allowed in Organic Livestock Production.

Specifically, this petition request is to permit the use of Sodium Bisulfate (PLT), as follows:

. Category: Synthetic substance allowed for use in organic livestock production.

. NOP Reference: 205.603 - Synthetic substance allowed for use in organic livestock production

. NOP Sections: 205.603 as a new paragraph (8) As a litter treatment.

. Annotation Requested: To control ammonia in poultry houses for all species of domestic fowl in orders Galliformes and Anseriformes.

To the best of our knowledge, our petition is complete, accurate, and meets the petition requirements as published in the Notice of Guidelines and Call for National List Petitions, Federal Register Vol. 72, No11, January 18, 2007. 7CFR Part 205 (Docket No. AMS-TM-0223, TM-06-12).

If, you have any questions relative to this petition and/or if I can be of further assistance, please contact me.

Thank you very much for your professional assistance.

Sincerely yours always,

LVOG, Inc.

Thomas B. Harding, Jr.
President & CEO
Organic Program Consultant
Jones-Hamilton Co.

National Organic Standards Board (NOSB)

NATIONAL LIST PETITION

Sodium Bisulfate - PLT

JONES-HAMILTON CO.

Petitioner

Jones-Hamilton Co.
30354 Tracy Road
Walbridge, Ohio 43465-9792
419-666-9838

Submitted By:
LVOG, Inc.
125 West Seventh Street
Wind Gap, Pennsyvania 18091
Telephone: 610-863-6700
Facsimile: 610-863-4622
Email: agrisys1@aol.com

Materials Petition Contacts

. USDA/AMS/NOP Standards Division

Lisa M. Brines, PhD.
National List Manager
1400 Independence Ave. SW
Room 2648 - So., Ag Stop 0268
Washington , DC 20250-0268

. JONES-HAMILTON CO.

Carl Knueven
Director - Corporate Research & Development
30354 Tracy Road
Walbridge , Ohio 43465-9792
Ph. 419-662-5277
Fax. 419-666-1817
Email : cknueven@jones-hamilton.com

. LVOG,Inc.

Thomas B. Harding, Jr.
Organic Program Consultant
125 W. 7th. street
Wind Gap, PA. 18091
Ph. 610-863-6700 Fax: 610-863-4622
Cell : 610-392-5435
Email : agrisys1@aol.com

Item A
National List Category Being Petitioned

Category: Synthetic substance allowed for use in organic livestock production.

NOP Reference: §205.603 - Synthetic substance allowed for use in organic livestock production.

NOP Sections: §205.603 as new paragraph (g) As litter treatment.

Requested Annotation: To control ammonia in poultry houses for all species of domestic fowl in the orders Galliformes and Anseriformes.

Item B
Substance Information

1. ***Product's common name:***

   PLT – Poultry Litter Treatment

   Substance's common name:

   Sodium bisulfate CAS number 7681-38-1

   International Union of Pure and Applied Chemistry (IUPAC) name:

   Sodium hydrogen sulfate CAS number 7681-38-1

   Other names:

   Sodium acid sulfate CAS number 7681-38-1
   Bisulfate of soda CAS number 7681-38-1

2. ***Manufacturer's name address, and telephone number.***

   Jones-Hamilton Co.
   30354 Tracy Road
   Walbridge, Ohio 43465-9792
   Ph: 419-666-9838, 888-858-4425
   Fax: 419-666-1817
   aginfo@jones-hamilton.com

3. ***Intended use:***

Poultry litter treatment to control ammonia in poultry houses for all species of domestic fowl in the orders Galliformes and Anseriformes.

4. ***List of activities for which the substance will be used:***

PLT (Sodium bisulfate) will be used as a topical litter and dirt pad treatment to control ammonia in poultry houses. *PLT is not intended for use in feed, food, or drinking water.*

Mode of action:

Ammonia (NH_3) is formed through the microbial breakdown of uric acid and organic nitrogen (N) in bird excreta. Ammonia emissions depend on how much of the ammonia-nitrogen in solution reacts to form ammonia versus ionized ammonium (NH_4^+). The production and volatilization of ammonia is inhibited by litter pH below 7 because pH directly affects the equilibrium between ammonium (NH_4^+) and ammonia (NH_3).

PLT (Sodium bisulfate) is a safe medium strength dry mineral acid that breaks down into products naturally found in the environment.

When PLT is applied it breaks down into sodium, hydrogen and sulfate.

$$NaHSO_4 \rightarrow Na^+ + H^+ + SO_4^{=}$$

When PLT dissolves it releases hydrogen ions, causing the pH of the litter's surface to drop. In addition to lowering litter pH the hydrogen converts ammonia into ammonium. This ammonium then binds to the sulfate portion, forming ammonium sulfate ($(NH_4)_2SO_4$). The formation of the ammonium sulfate is non reversible; therefore the nitrogen in the litter is not released as the pH increases (Ullman, et al., 2004). The formation of ammonium sulfate prevents the release of ammonia as pH increases over time and keeps ammonia bound in the litter for the life of the flock. The ammonium sulfate that is formed is plant available and suitable for land application.

See Attachments 1 and 2.

5. ***Source of the substance and description of manufacturing procedures.***

Sodium bisulfate is an acid salt. It is a dry granular product that can be safely shipped and stored. The anhydrous (nonhydrated) form is hygroscopic (absorbs moisture from the air).

The petitioner, Jones-Hamilton Company, uses a sodium bisulfate production method which involves reacting sodium chloride (salt) and sulfuric acid at elevated temperatures to produce sodium bisulfate and hydrogen chloride gas.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$$

The liquid sodium bisulfate is sprayed and cooled so that it forms a solid bead. The hydrogen chloride gas is dissolved in water to produce hydrochloric acid as a useful co-product of the reaction.

6. ***Previous reviews by State or private certification programs or other organizations.***

No available data.

7. ***Information regarding EPA, FDA, and State regulatory authority registrations.***

PLT is an Environmental Protection Agency (EPA) registered pesticide and carries EPA Registration Number 33907-3. It has been continuously registered since July 12, 2001. *See Attachments 3, 4, and 5.*

8. ***Chemical Abstract Service (CAS) number or other product numbers.***

Substance's common name:

Sodium bisulfate	CAS number 7681-38-1

International Union of Pure and Applied Chemistry (IUPAC) name:

Sodium hydrogen sulfate	CAS number 7681-38-1

Other names:

Sodium acid sulfate	CAS number 7681-38-1
Bisulfate of soda	CAS number 7681-38-1

Product label: *See Attachment 6.*

Product Data Sheets for Broilers, Broiler Breeders, and Turkeys. *See Attachment 7.*

9. ***Substance's physical properties and chemical mode of action.***

PLT (Sodium bisulfate) is a medium strength dry mineral acid that breaks down into products naturally found in the environment. It is a dry granular product that can be safely shipped and stored.

(a) <u>Chemical interactions with other substances, especially substances used in organic production.</u>

PLT is not used in conjunction with other substances.

PLT is stable. It may decompose upon exposure to moist air or water. It is reactive or incompatible with oxidizing materials, acids and alkalis. Not to be mixed with concentrated solutions of chlorine bleach, ammonia cleaners or similar products.

It is incompatible with sodium carbonate and sodium hypochlorite; two National Organic Program, National List allowed substances. PLT is not used in association with either of these substances. Sodium carbonate and sodium hypochlorite are approved substances for use in organic production. Sodium carbonate is a § 205.605(a) non-synthetic allowed substance. Sodium hypochlorite is a § 205.601(a)(2) synthetic allowed as an algaecide, disinfectant, and sanitizer. Sodium hypochlorite is also a § 205.603(a)(7) synthetic allowed for disinfecting and sanitizing facilities and equipment.

(b) Toxicity and environmental persistence.

Toxicity

PLT is likely to be acutely harmful to aquatic life. Accordingly precautions have to be taken to prevent spilled material from entering waterways, drains and sewers. PLT readily dissolves in water to form a weak acid solution. A 0.05 percent or greater (by weight) solution of this product will likely be acutely harmful to aquatic life. There are no other known significant effects or critical hazards.

According to Scorecard, a pollution information guide part of the Good Guide, sodium bisulfate does not rank very high with regard to concerns about ecological toxicity and persistence, but does have some concerns nonetheless. Those concerns involve aquatic life which could be adversely impacted should the water pH of their habitat be lowered to critical levels.

Environmental persistence

There is no environmental persistence to PLT ($NaHSO_4$). Once it makes contact with moisture it breaks down into sodium (Na^+), hydrogen (H^+) and sulfate ($SO_4^=$), products naturally found in the environment.

Gonzalex-Matute and Rinker (2005) found that poultry litter treated with PLT did not affect mushroom productivity or quality and may offer a subtle positive influence on yield. *See Attachments 8 and 9.*

Beyer and Rhodes (1999) found that PLT applied to poultry manure at the recommended rates does not have any adverse influence on mushroom composting, spawn growth, or yields. *See Attachments 10.*

Poultry litter samples taken from poultry houses treated with PLT four times (once per flock for 4 flocks) was tested to determine the sodium level. The level was determined to be 0.89 percent or 35.6 pounds per two tons of litter with PLT. Dr. J. Michael Moore, Extension Agronomist, University of Georgia, Cooperative Extension, found this amount to be within the range of application for production of flue-cured tobacco, including use in tobacco seedbeds. *See Attachment 7.*

When PLT dissolves it releases hydrogen ions, causing the pH of the litter's surface to drop. In addition to lowering litter pH the hydrogen converts ammonia into ammonium. This ammonium then binds to the sulfate portion, forming ammonium sulfate ($(NH_4)_2SO_4$), a fertilizer. The formation of ammonium sulfate prevents the release of ammonia as pH increases over time and keeps ammonia bound in the litter for the life of the flock. This ammonium sulfate is a plant available nitrogen suitable for land application of treated litter.

(c) <u>Environmental impacts from its use or manufacture.</u>

PLT is used inside of poultry houses. It is not used in the outside environment in fields. Thus, PLT has no negative environmental impact on outside soil organisms, or crops. The use of PLT reduces ammonia emission from poultry houses and reduces fuel usage both of which have a positive environmental impact.

Gonzalex-Matute and Rinker (2005) found that poultry litter treated with PLT did not affect mushroom productivity or quality and may offer a subtle positive influence on yield. *See Attachments 8 and 9.*

Beyer and Rhodes (1999) found that PLT applied to poultry manure at the recommended rates does not have any adverse influence on mushroom composting, spawn growth, or yields. *See Attachments 10.*

Poultry litter samples taken from poultry houses treated with PLT four times (once per flock for 4 flocks) was tested to determine the sodium level. The level was determined to be 0.89 percent or 35.6 pounds per two tons of litter with PLT. Dr. J. Michael Moore, Extension Agronomist, University of Georgia, Cooperative Extension, found this amount to be within the range of application for production of flue-cured tobacco, including use in tobacco seedbeds. *See Attachment 11.*

As noted in (b) above there is no environmental persistence to PLT ($NaHSO_4$). Once it once it makes contact with moisture it breaks down into sodium (Na^+), hydrogen (H^+) and sulfate (SO_4^-); products naturally found in the environment.

PLT (Sodium bisulfate) is a medium strength dry acid that meets FTC Green ingredient guidelines[1] and can be classified as:

- Biodegradable
- Non-toxic and non-hazardous (Based on FDA guidelines.)
- Ozone friendly

[1] http://www.ftc.gov/bcp/grnrule/guides980427.html

- Environmentally friendly

The PLT production process follows the Green Chemistry[2] [3] principles. *See Attachment 12.*

PLT is designed to be fully effective while minimizing the potential for accidents such as explosions, fires and releases to the environment. It also degrades after use and breaks down into substances naturally found in the environment.

The production process involves reacting sodium chloride (salt) and sulfuric acid at elevated temperatures to produce sodium bisulfate and hydrogen chloride gas.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$$

The liquid sodium bisulfate is sprayed and cooled so that it forms a solid bead. The hydrogen chloride gas is dissolved in water to produce hydrochloric acid as a useful co-product of the reaction. There are no left over reactants requiring disposal.

Real time analysis during the production process prevents pollution, ensuring that all starting materials are contained in the final product so no waste is generated.

PLT is a mineral based phosphate-free compound produced in the United States. It is produced without the use of crude oil and it contains no chlorine, fluorine or organic compounds. If spilled, it can be easily swept up.

(d) <u>Effects on human health.</u>

PLT is safe when used according to the label and when all safety precautions are followed.

When mishandled, there is a risk of serious damage to eyes. Prolonged skin exposure may cause skin irritation. Inhalation of dust may irritate nose, throat and/or lungs. Safety advice includes: 1) avoid contact with skin and eyes, 2) in case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

<u>Potential acute health effects</u> *See Attachment 13.*

Inhalation: Inhalation of dust may irritate nose, throat and/or lungs.

Ingestion: Small amounts (tablespoonful) swallowed are not likely to cause injury; however, swallowing large amounts may irritate or burn digestive tract.

Skin: Prolonged exposure may cause skin irritation.

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[2] EPA: http://www.epa.gov/greenchemistry/pubs/principles.html

[3] California Department of Toxic Substances Control: http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/index.cfm

Eyes: Causes serious eye irritation.

Potential chronic health effects *See Attachment 13.*

Chronic effects: Contains material that may cause target organ damage, based on animal data.

Carcinogenicity: No known significant effects or critical hazards. Per the Pesticide Action Network (PAN) Pesticides Database – Chemicals, there is no available weight-of-the-evidence summary assessment. *See Attachment 14.*

Mutagenicity: No known significant effects or critical hazards.

Teratogenicity: No known significant effects or critical hazards.

Developmental effects: No known significant effects or critical hazards.

Fertility effects: No known significant effects or critical hazards.

Target organs: Contains material that may cause damage to the following organs: mucous membranes, skin, and eyes.

Per the PAN Product Information for PLT, there is no available weight-of-the-evidence summary assessment on whether PLT is a developmental or reproductive toxin or whether it is an endocrine disruptor. PAN has determined that PLT is not a cholinesterase inhibitor. *See Attachment 14.*

(e) Effects on soil organisms, crops, or livestock.

PLT is used inside of poultry houses. It is not used in the outside environment. Thus, PLT has no negative impact on soil organisms, or crops.

Toxicity research has proven that PLT has no adverse affects on poultry including bird weight, feed efficiency, abnormal behavior, skin pigmentation or feathering and mortality rates. This holds true even when used at application rates of up to 10 times the recommended rate. *See Attachment 15.*

In a PLT Field Research Trial there was a 25 percent lower incidence of breast blisters and abscesses among the birds maintained in pens treated with PLT than those maintained in untreated pens. Further, there was no negative effect on bird performance and foot pads appeared to be in good condition. *See Attachment 16.*

PLT can be safely applied in the presence of animals (Johnson, et al., Purswell, et al.). *See Attachment 17 and 18 respectively.*

10. ***Safety information including Material Safety Data Sheet (MSDS) and substance report from the National Institute of Environmental Health Studies (NIEHS).***

MSDS: Please see Material Safety Data Sheet, PLT/Poultry Litter Treatment at *Attachment 13.*

NIEHS: A search of sodium bisulfate in the NIEHS data base generated no information deemed applicable to where and how PLT is used. See attached search results documents at *Attachment 19.*

DOT: Sodium bisulfate is not regulated by the U.S. Department of Transportation (DOT). It does not have a hazardous or corrosive DOT rating. *Attachment 12.*

OSHA: Sodium bisulfate is classified as a mild irritant by OSHA. *Attachment 12.*

NFPA: Sodium bisulfate has earned a very safe 1-0-1 hazard rating from the National Fire Protection Association. *Attachment 12.*

11. ***Research information; substance reviews and research bibliographies including those which include contrasting positions presented by the petitioner.***

The following research papers are attached:

Atapattu, N. S. B. M., and K. P. Wickramasinghe. The Use of Refused Tea as Litter Mazterial for Broiler Chickens. Poultry Science, 2007, 86: 968-972. *See Attachment 20.*

Atapattu, N. S., and U. D. Belpagodagamage. Comparison of ammonia emission rates from three types of broiler litters. Poultry Science, 2008, 87(12): 2436-40. *See Attachment 21.*

Beyer, David M., and Tom Rhodes. 1999. PLT treated poultry manure used as a Phase I substrate supplement and its influence on mushroom composting and yield. PennState University, Cooperative Extension. *See Attachment 10.*

Blake, J. P., J. B. Hess, and K. S. Maccklin. 2008. Effectiveness of Litter Treatments for Reduction of Ammonia Volatilization in Broiler Production. In: Proceedings of Mitigating Air Emissions from Animal Feeding Operations Conference, 19-21 May 2008, Des Moines, Iowa. pp. 64-67. *See Attachment 22.*

Gonzalex-Matute, R., and D. L. Rinker. 2005. Effect of ammonia suppressants Used in Poultry Litter on Composting and Mushroom Production. In: Proceedings of Science and Cultivation of Edible and Medicinal Fungi, 14-17 March 2004, Miami, Florida. pp. 203-212. *See Attachment 8.*

Gonzalex-Matute, Ramiro, and Danny Lee Rinker. 2005. Compatibility of ammonia suppressants used in poultry litter with mushroom compost preparation and production. *Bioscience Technology* 97, pp. 1679-1686. *See Attachment 9.*

Johnson, T. Marsh, and Bernard Murphy. 2008. Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing. In: Proceedings of Mitigating Air Emissions from Animal Feeding Operations Conference, 19-21 May 2008, Des Moines, Iowa. pp. 74-78. *See Attachment 2.*

Johnson, Trisha Marsh, Brian Fairchild, and Casey W. Ritz. The Use of Sodium Bisulfate as a Best Management Practice for Reducing Ammonia Emissions from Poultry Manures. *See Attachment 17.*

Li, Hong, Hongwei Xin, Robert T. Burns, and Yi Liang. 2006. Reduction of Ammonia Emission from Stored Poultry Manure Using Additives: Zeolite, AL+ clear, Ferix-3 and PLT. ASABE Paper No. 064188. St. Joseph, Mich.: ASABE. *See Attachment 23.*

Macklin, K. S., J. P. Blake, J. B. Hess, and R. A. Norton. 2007. Effects of Poultry Litter Treatment (PLT) and Aluminum Sulfate (Alum) on Ammonia and Bacterial Levels in Poultry Litter. In: Proceedings of the Fifty-Sixth Western Poultry Disease Conference, 26-29 March 2007, Las Vegas, Nevada. pp. 132-134. *See Attachment 24.*

Moore, P. A. Jr., D. Miles, R. Burns, D. Pote, K. Berg, and I. H. Choi. Ammonia emission factors from broiler litter in barns, in storage, and after land application. J. Environ. Qual., 2011, Sep-Oct; 40(5): 1395-404. *See Attachment 25.*

Oviedo-Rondon, E. O., S. B. Shah, J. L. Grimes, P. W. Westerman, and D. Campeau. 2013. Live performance of roasters raised in houses receiving different acidifier application rates. J. Appl. Poult. Res. 22: 922-928. See Attachment 26.

PLT Research Trial JHL-2-98 Final Report, 1998. *See Attachment 15.*

Poultry Litter Treatment PLT Effect of Breast Blisters and Downgrading of Turkey Carcasses. Field Research Trial. *See Attachment 16.*

Purswell, J. L., J. D. Davis, A. S. Kiess, and C. D. Coufal. Effects of frequency of multiple applications of litter amendments on litter ammonia and live performance in a shared airspace. 2013. J. Appl. Poult. Res. 22: 469-473. *See Attachment 18.*

Romero, C., M. E. Abdallh, W. Powers, R.Angel, and A. J. Applegate. Effect of dietary adipic acid and corn dried distillers grains with soluble on laying hen performance and nitrogen loss from stored excreta with or without sodium bisulfate. Poultry Science, 2012, 91: 1149-1157. *See Attachment 27.*

Shah, Sanjay, Philip Westerman, and James Parsons. 2006. Poultry Litter Amendments. North Carolina State University, North Carolina Cooperative Extension Service. *See Attachment 28.*

Shah, S. B., P. W. Westerman, J. L. Grimes, E. O. Oviedo-Rondon, and D. Campeau. 2013. Ancillary effects of different acidifier application rates in roaster houses. J. Appl. Poult. Res. 22: 565-573. *See Attachment 29.*

Shah, S. B., J. L. Grimes, E. O. Oviedo-Rondon, P. W. Westerman, and D. Campeau. 2013. Nitrogen mass balance in commercial roaster houses receiving different acidifier application rates. J. Appl. Poult. Res. 22: 539-550. *See Attachment 30.*

Shishir, S. R., H. M. Murshed, B. Dey, and M. Al-Mamun. 2013. Effect of Dry Neem Leaves (DNL) in the Reduction of Ammonia Level of Poultry Litter Compared to Biochemicals Amendment. J. Anim. Sci. Adv., 2013, 3(7): 345-353. *See Attachment 31.*

Terzich, M. 1997. Effects of Sodium Bisulfate on poultry house ammonia, litter pH, litter pathogens, and insects, and bird performance. In: Proceedings of the Forty-Sixth Western Poultry Disease Conference, Sacramento, Ca. pp. 71-74. *See Attachment 32.*

Terzich, Mac, Carey Quarles, Mark A. Goodwin, and John Brown. 1998. Effect of Poultry Litter Treatment (PLT) on Death Due to Ascites in Broilers. *Avian Dis.* April-June 42(2): 385-87. *See Attachment 33.*

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 Pathology 27, 566-569. See Attachment 34.*

Wheeler, E. F., K. D. Casey, R. S. Gates, H. Xin, P. A. Topper, and Y. Liang. 2008. Ammonia Emissions from USA Broiler Chicken Barns Managed with New Bedding, Built-up Litter, or Acid-Treated Litter. ASABE Paper No. 701P0408. St. Joseph, Mich.: ASABE. *See Attachment 35.*

12. ***Petition Justification Statement.***

Inclusion of a Synthetic on the National List § 205.603

Explain why the synthetic substance is necessary for the production of an organic product.

Bird health and productivity benefits from an improved poultry house environment and improved in-house air quality. Litter treatment with sodium bisulfate is a proven way to improve the poultry house environment and improved in-house air quality.

Ammonia excretion in manure is a normal physiologic process of the avian kidney resulting in ammonia in the production environment. The standard reference values for nitrogen (ammonia) excretion are an average of 1.97 g/N/day for a 7-week old bird and 2.61 g/N/day for a 9-week old bird (National Research Council. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. pp 210-213.). Ammonia volatilization from poultry litter often causes high levels of atmospheric ammonia in poultry houses. Ammonia is corrosive to equipment and detrimental to the health of the birds and farmers. Ammonia emissions from houses also aggravate environmental problems, such as acid rain and particulate matter formation, and result in a loss of fertilizer nitrogen.

Ammonia levels above 25 PPM in poultry houses can result in profit loss due to damage to the bird's respiratory system which allows infectious agents to become established. This leads to a decline in flock health, reduced weights and higher feed to body weight conversion.

Sodium bisulfate can be used to reduce ammonia levels in poultry houses below 25 PPM thereby creating an environment more conducive to bird health and productivity. Sodium bisulfate controls ammonia by a simple acid-base reaction. Sodium bisulfate is an acid, when applied to litter it breaks down into sodium, hydrogen and sulfate ($NaSO_4 \rightarrow Na_+ + H_+ + SO_{4=}$). When it dissolves, it lowers pH and converts ammonia into ammonium by donating hydrogen ions to ammonia (NH_3) to produce ammonium (NH_4). The ammonium further reacts with the sulfate ions to form ammonium sulfate $(NH_4)_2SO_4$. Ammonium sulfate is a water-soluble fertilizer.

These acid-based reactions keep ammonia bound in the litter for the life of the flock. Ammonia (NH_3) is a noxious gas, ammonium (NH_4) is non-volatile solid, and therefore the nitrogen stays in the litter and is not released as a gas.

Ammonia is lost in the house, during storage, and after land application. Moore et al. (2011) found the loss to be 45.6 g NH_3 per bird marketed. *See in Attachment 25.*

Describe any non-synthetic substances, synthetic substances on the National List or alternative cultural methods that could be used in place of the petitioned synthetic substance.

<u>Non-synthetic substances</u>

We are unaware of any non-synthetic substances that could be used in place of sodium bisulfate.

Neem (*Azadirachta indica*) is a large evergreen fast growing perennial tree found in South Asia. Shishir et al. (2013) found that dried, stem free, ground neem leaves, when applied to poultry litter, were effective in reducing the ammonia level of the litter. They found the optimum rate may be 50 grams per 16 sq. ft. of litter. A higher rate of application was found to be harmful to the birds. They also report that a lower rate cannot remove the level of ammonia expected. To the authors' knowledge dried neem leaves had never previously been tested for their effect on the ammonia level of broiler litter. *See Attachment 31.*

The use of dried neem leaves in poultry production in South Asia may be economical, sustainable, and environmentally friendly. It is doubtful that the same would be true for export to the United States for use in U.S. poultry houses.

Synthetic substances on the National List

There are no synthetics currently on the list that can be used.

Hydrated lime is on the list in § 205.603(b) as an external pest control, not permitted to cauterize physical alterations or deodorize animal wastes. Hydrated lime has been shown to initially elevate litter pH and failed to support any reduction in ammonia volatilization (Blake et al., 2008). *See Attachment 22.*

Humic acids are listed in § 205.601(j)(3) as plant or soil amendments. The annotation requires that the Humic acids be naturally occurring deposits, water and alkali extracts only. Litter Life is a product that contains Fulvic acid, 11% Humic acid, Lignin and 25 microorganisms. No other specific ingredient information was found for this liquid product that claims a microbiology that takes over the litter bed. Per the manufacturer Litter Life causes a rapid natural release of ammonia prior to placement of the birds. There is no information regarding how long after treatment before the birds are placed in the house. In commercial use it has actually increased ammonia levels while birds are in the house. The manufacturer claims that the product's beneficial biology breaks down litter into ammonium and binds the ammonium with nitrogen to make Ammonium Nitrate.

We were unable to find any studies of Litter Life published in scientific journals. Further, the rapid natural release of ammonia and venting into the environment degrades air quality. *See Litter Life company internet documents at Attachment 36.*

Cultural methods

Cleaning out all litter after every flock is a cultural method that could be used. This method of ammonia emission suppression requires removal and disposal of litter and replacement of shavings or other litter materials.

This method of ammonia suppression has the following drawbacks:

- Availability of bedding has become an issue. Dry shavings are difficult to obtain and are becoming increasingly expensive.
- Increased cost of operation to: remove bedding after each flock, dispose of the litter, and replace litter.
- More litter volume to apply to the land due to the lack of litter break down.
- Increased chance of nutrient or pathogen contamination to waterways.

- Bird intestinal health is impaired when raised on new litter as compared to old litter that contains normal poultry intestinal microflora.
- New litter does not provide the insulation needed to maintain bird comfort at brooding.
- Not recycling litter within the house requires a large forestry input that reduces environmental sustainability.
- New litter does not provide good moisture control and increases paw lesions in birds.
- Poultry houses with dirt floors absorb ammonia and it is not uncommon for ammonia levels to be above 25 PPM even with new litter.

Wheeler et al. (2008) discusses three litter management strategies. *See Attachment 35.*

In a study that compared refused tea to paddy husk, Atapattu and Wickramasinghe (2007) found that refused tea could be successfully used as an alternative litter material for broilers. This despite the fact that litter cake formation in the refused tea based litter was higher than that in paddy husk based litter. The higher cake formation required frequent raking to minimize the cake formation. In this study the Nitrogen content of the refused tea increased. This lead the researches to assume that it may be possible that refused tea binds some ammonia, preventing volatilization. In a study comparing emission of NH_3 from refused tea, sawdust, and paddy husk, Atapattu et al. (2008) concluded that NH_3 emission could be reduced substantially by using refused tea as a litter material. *See Attachments 20 and 21 respectively.*

Describe the beneficial effects to the environment, human health, or farm ecosystem from use of the synthetic substance that support its use instead of the use of a non-synthetic substance or alternative cultural methods.

Sodium bisulfate effectively reduces ammonia volatilization from poultry house litter. This means:

1. Lower ammonia levels in the poultry house;
2. Healthier living environment for the birds;
3. Healthier working environment for the farmer;
4. Greater litter fertilizer value due to sequestration of nitrogen in the litter;
5. Lower ammonia gas emissions to the outside environment, thereby lowering the operations adverse impact on outside air quality;
6. Ability to recycle litter increasing environmental sustainability through smaller forestry inputs;
7. Reduced fossil fuel usage by allowing proper ventilation rather than over-ventilation for ammonia control; and
8. Better temperature control during brooding enhancing bird comfort and welfare.

When used in poultry houses, sodium bisulfate reduces ammonia levels by converting the ammonia to ammonium. By converting the ammonia to ammonium it reduces the release of ammonia from the litter, thereby improving air quality within the house and preventing release to the outside environment.

The ammonium then binds to the sulfate portion, forming ammonium sulfate ($(NH_4)_2SO_4$). The formation of ammonium sulfate prevents the release of ammonia as pH increases over time and keeps ammonia bound in the litter. This in turn binds the nitrogen in the litter providing for a more appropriate agronomic fertilizer by providing a better nitrogen to phosphorus ratio. Research documenting retention of nitrogen in the litter include Romero et al. (2012) and Shah & Grimes et al. (2013). *See attachments 27 and 30 respectively.*

Re-using litter can be beneficial and economical, if managed properly. There is less litter to dispose of or apply to the land over a specified time period. This reduces the chance of nutrient or pathogen contamination to waterways. (Environmental benefit)

Recycling litter reduces forestry inputs thereby enhancing carbon sequestration. (Environmental benefit)

Sodium bisulfate is recommended by the US-EPA and the USDA-NRCS as a best management practice for improving water and air quality (EPA Watershed Implementation Plan for Federal Lands in the Chesapeake Bay regions &NRCS Practice Standard 591). (Environmental benefit)

Re-use allows producers to reduce their costs associated with removal, disposal, and replacement. (Economic benefit)

Reusing litter and treating with PLT allows the use of a more economical minimum ventilation rate. (Economic and environmental benefit)

Terzich (1997) reported a fuel use reduction of 43% in poultry houses treated with PLT in the winter of 1996 in Delaware and Maryland. This was due to shorter fan times and reduced venting of heat. *See Attachment 32*. (Economic and Environmental benefit)

See Jones-Hamilton Company LITTER forum and Technical Update documents attached as Attachment 37.

13. ***Commercial Confidential Information Statement.***

We are not claiming any Confidential Business Information (CBI) at this time.

PLT contains 93.2% sodium bisulfate as the active ingredient. It also contains 6.8% sodium sulfate, identified on the label as other ingredients. Sodium bisulfate and sodium sulfate are the only substances in PLT.

References:

National Research Council. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. Washington, DC: The National Academies Press, 2003.

Ullman, J. L., S. Mukhtar, R. E. Lacey, and J. B. Carey. 2004. A review of literature concerning odors, ammonia, and dust from broiler production facilities: 4. Remedial Management Practices. *J. Appl. Poult.* Res. 13: 521-31.

List of Attachments

TAB 1

4. ***List of activities for which the substance will be used:***

1. PLT Product Chemistry.

2. Johnson, T. Marsh, and Bernard Murphy. 2008. Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing. In: Proceedings of Mitigating Air Emissions from Animal Feeding Operations Conference, 19-21 May 2008, Des Moines, Iowa. pp. 74-78.

TAB 2

7. ***Information regarding EPA, FDA, and State regulatory authority registrations.***

3. Notice of Pesticide Registration, July 12, 2001.

4. July 21, 2001 Amendment, PLT, EPA Registration 33907-3, dated October 22, 2001.

5. EPA Pesticide Product Label System product Status Report (2 pages)

TAB 3

8. ***Chemical Abstract Service (CAS) number or other product numbers.***

6. Product label.

7. Product Data Sheets for Broilers, Broiler Breeders, and Turkeys.

TAB 4

9. ***Substance's physical properties and chemical mode of action.***

8. Gonzalex-Matute, R., and D. L. Rinker. 2005. Effect of ammonia suppressants Used in Poultry Litter on Composting and Mushroom Production. In: Proceedings of Science and Cultivation of Edible and Medicinal Fungi, 14-17 March 2004, Miami, Florida. pp. 203-212.

9. Gonzalex-Matute, Ramiro, and Danny Lee Rinker. 2005. Compatibility of ammonia suppressants used in poultry litter with mushroom compost preparation and production. *Bioscience Technology* 97, pp. 1679-1686.

10. Beyer, David M., and Tom Rhodes. 1999. PLT treated poultry manure used as a Phase I substrate supplement and its influence on mushroom composting and yield. PennState University, Cooperative Extension.

11. Letter dated May 12, 1994, from Dr. J. Michael Moore, UGA Cooperative Extension Service, to David R. Morgan, Jones-Hamilton Company.

12. Environmental Chemistry.

13. Material Safety Data Sheet, PLT/Poultry Litter Treatment.

14. PAN Pesticides Database – Pesticide Products, Product Name: PLT.

15. PLT Research Trial JHL-2-98 Final Report, 1998.

16. Poultry Litter Treatment PLT Effect of Breast Blisters and Downgrading of Turkey Carcasses. Field Research Trial.

17 Johnson, Trisha Marsh, Brian Fairchild, and Casey W. Ritz. The Use of Sodium Bisulfate as a Best Management Practice for Reducing Ammonia Emissions from Poultry Manures.

18. Purswell, J. L., J. D. Davis, A. S. Kiess, and C. D. Coufal. Effects of frequency of multiple applications of litter amendments on litter ammonia and live performance in a shared airspace. 2013. J. Appl. Poult. Res. 22: 469-473.

TAB 5

10. ***Safety information including Material Safety Data Sheet (MSDS) and substance report from the National Institute of Environmental Health Studies (NIEHS).***

13. Material Safety Data Sheet, PLT/Poultry Litter Treatment. ***See TAB 4 for copy.***

19. NIEHS data base search results documents.

TAB 6

11. ***Research information; substance reviews and research bibliographies including those which include contrasting positions presented by the petitioner.***

2. Johnson, T. Marsh, and Bernard Murphy. 2008. Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing. In: Proceedings of Mitigating

Air Emissions from Animal Feeding Operations Conference, 19-21 May 2008, Des Moines, Iowa. pp. 74-78. ***See TAB 1 for copy.***

8. Gonzalex-Matute, R., and D. L. Rinker. 2005. Effect of ammonia suppressants Used in Poultry Litter on Composting and Mushroom Production. In: Proceedings of Science and Cultivation of Edible and Medicinal Fungi, 14-17 March 2004, Miami, Florida. pp. 203-212. ***See TAB 4 for copy.***

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20. Atapattu, N. S. B. M., and K. P. Wickramasinghe. The Use of Refused Tea as Litter Mazterial for Broiler Chickens. Poultry Science, 2007, 86: 968-972.

21. Atapattu, N. S., and U. D. Belpagodagamage. Comparison of ammonia emission rates from three types of broiler litters. Poultry Science, 2008, 87(12): 2436-40.

22. Blake, J. P., J. B. Hess, and K. S. Maccklin. 2008. Effectiveness of Litter Treatments for Reduction of Ammonia Volatilization in Broiler Production. In: Proceedings of Mitigating Air Emissions from Animal Feeding Operations Conference, 19-21 May 2008, Des Moines, Iowa. pp. 64-67.

23. Li, Hong, Hongwei Xin, Robert T. Burns, and Yi Liang. 2006. Reduction of Ammonia Emission from Stored Poultry Manure Using Additives: Zeolite, AL+ clear, Ferix-3 and PLT. ASABE Paper No. 064188. St. Joseph, Mich.: ASABE.

24. Macklin, K. S., J. P. Blake, J. B. Hess, and R. A. Norton. 2007. Effects of Poultry Litter Treatment (PLT) and Aluminum Sulfate (Alum) on Ammonia and Bacterial Levels

in Poultry Litter. In: Proceedings of the Fifty-Sixth Western Poultry Disease Conference, 26-29 March 2007, Las Vegas, Nevada. pp. 132-134.

25. Moore, P. A. Jr., D. Miles, R. Burns, D. Pote, K. Berg, and I. H. Choi. Ammonia emission factors from broiler litter in barns, in storage, and after land application. J. Environ. Qual., 2011, Sep-Oct; 40(5): 1395-404.

26. Oviedo-Rondon, E. O., S. B. Shah, J. L. Grimes, P. W. Westerman, and D. Campeau. 2013. Live performance of roasters raised in houses receiving different acidifier application rates. J. Appl. Poult. Res. 22: 922-928.

27. Romero, C., M. E. Abdallh, W. Powers, R.Angel, and A. J. Applegate. Effect of dietary adipic acid and corn dried distillers grains with soluble on laying hen performance and nitrogen loss from stored excreta with or without sodium bisulfate. Poultry Science, 2012, 91: 1149-1157.

28. Shah, Sanjay, Philip Westerman, and James Parsons. 2006. Poultry Litter Amendments. North Carolina State University, North Carolina Cooperative Extension Service.

29. Shah, S. B., P. W. Westerman, J. L. Grimes, E. O. Oviedo-Rondon, and D. Campeau. 2013. Ancillary effects of different acidifier application rates in roaster houses. J. Appl. Poult. Res. 22: 565-573.

30. Shah, S. B., J. L. Grimes, E. O. Oviedo-Rondon, P. W. Westerman, and D. Campeau. 2013. Nitrogen mass balance in commercial roaster houses receiving different acidifier application rates. J. Appl. Poult. Res. 22: 539-550.

31. Shishir, S. R., H. M. Murshed, B. Dey, and M. Al-Mamun. 2013. Effect of Dry Neem Leaves (DNL) in the Reduction of Ammonia Level of Poultry Litter Compared to Biochemicals Amendment. J. Anim. Sci. Adv., 2013, 3(7): 345-353.

32. Terzich, M. 1997. Effects of Sodium Bisulfate on poultry house ammonia, litter pH, litter pathogens, and insects, and bird performance. In: Proceedings of the Forty-Sixth Western Poultry Disease Conference, Sacramento, Ca. pp. 71-74.

33. Terzich, Mac, Carey Quarles, Mark A. Goodwin, and John Brown. 1998. Effect of Poultry Litter Treatment (PLT) on Death Due to Ascites in Broilers. *Avian Dis.* April-June 42(2): 385-87.

34. 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 Pathology 27, 566-569.*

35. Wheeler, E. F., K. D. Casey, R. S. Gates, H. Xin, P. A. Topper, and Y. Liang. 2008. Ammonia Emissions from USA Broiler Chicken Barns Managed with New Bedding,

Built-up Litter, or Acid-Treated Litter. ASABE Paper No. 701P0408. St. Joseph, Mich.: ASABE.

TAB 7

12. ***Petition Justification Statement.***

20. Atapattu, N. S. B. M., and K. P. Wickramasinghe. The Use of Refused Tea as Litter Mazterial for Broiler Chickens. Poultry Science, 2007, 86: 968-972. ***See TAB 6 for copy.***

21. Atapattu, N. S., and U. D. Belpagodagamage. Comparison of ammonia emission rates from three types of broiler litters. Poultry Science, 2008, 87(12): 2436-40. ***See TAB 6 for copy.***

22. Blake, J. P., J. B. Hess, and K. S. Maccklin. 2008. Effectiveness of Litter Treatments for Reduction of Ammonia Volatilization in Broiler Production. In: Proceedings of Mitigating Air Emissions from Animal Feeding Operations Conference, 19-21 May 2008, Des Moines, Iowa. pp. 64-67. ***See TAB 6 for copy.***

25. Moore, P. A. Jr., D. Miles, R. Burns, D. Pote, K. Berg, and I. H. Choi. Ammonia emission factors from broiler litter in barns, in storage, and after land application. J. Environ. Qual., 2011, Sep-Oct; 40(5): 1395-404. ***See TAB 6 for copy.***

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32. Terzich, M. 1997. Effects of Sodium Bisulfate on poultry house ammonia, litter pH, litter pathogens, and insects, and bird performance. In: Proceedings of the Forty-Sixth Western Poultry Disease Conference, Sacramento, Ca. pp. 71-74. ***See TAB 6 for copy.***

36. Litter Life company internet documents.

37. Jones-Hamilton Company LITTER forum and Technical Update documents.

Jones-Hamilton Co.

National List Petition Sodium Bisulfate-PLT

TAB 1

4. List of activities for which the substance will be used .

TAB 2

6. Previous reviews by State, Federal, and International

TAB 3

7. Information for EPA,FDA, and State Autorities

TAB 4

9. Substance's Physical Properties and Mode of Action

TAB 5

10. Safety Information, Substance Report , NEIHS

TAB 6

11. Research Information, Substance Reviews, Citations

TAB 7

Petition Justification , Other Relevant Support Documents

Substance's Common Name: PLT - Poultry Litter Treatment

Manufacturer Name, Address and Telephone:

United States

Jones-Hamilton Co.
30354 Tracy Road
Walbridge, OH 43465
419-666-9838

Intended and Current Use:

A topical litter treatment to control ammonia in poultry houses.

Mode of Action:

PLT (sodium hydrogen sulfate) is a dry acid. When spread on the litter it absorbs moisture out of the air and lowers the pH of the litter surface. When PLT is exposed to air it absorbs water out of the air and dissolves. When it dissolves it dissociates into sodium ions, hydrogen ions and sulfate ions. (see following)

$$\underset{\text{(PLT)}}{NaHSO_4} \xrightarrow[H_2O]{} Na^+ + \mathbf{H^+} + SO_4^{2-}$$

When PLT dissolves it releases hydrogen ions, causing the pH of the litter's surface to drop.

PLT controls ammonia by a simple acid-base reaction. PLT is an acid, when applied to litter it will donate hydrogen ions to ammonia (NH_3) to produce ammonium (NH_4). Ammonia (NH_3) is a noxious gas, ammonium (NH_4) is non-volatile, therefore the nitrogen stays in the litter and is not released as a gas.

Production Method

The raw materials for PLT are food grade salt and sulfuric acid.

The salt and sulfuric acid are heated to produce sodium hydrogen sulfate and hydrogen chloride.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$$

Sodium hydrogen sulfate is sprayed and cooled to form a solid bead. It is screened for consistent particle size then packaged into the appropriate container. The hydrogen chloride is dissolved in water and sold as hydrochloric acid.

There is no waste or byproducts produced from the production of sodium hydrogen sulfate. Sodium hydrogen sulfate meets FDA's definition of a natural product.

Sodium bisulfate follows the principles of "Green Chemistry" as described by the EPA[1] and the California Department of Toxic Substances Control [2]

- The production process generates no waste
- Sodium bisulfate is designed to be fully effective and has little toxicity
- The production process maximizes "atom economy" by containing all of the starting materials in the final products
- The production process uses no solvents
- Sodium bisulfate degrades after use: It breaks down to innocuous substances
- The production process is analyzed in real time to prevent pollution
- Sodium bisulfate is designed to minimize the potential for accidents including explosions, fires, and releases to the environment.

Other pertinent information on sodium bisulfate:

- Generally Recognized as Safe (GRAS) (FDA Response Letter GRAS Notice No. GRN 000003, June 5, 1998)
- Phosphate –free
- DOT classification – "Non-Regulated"
- OSHA classified - "Mild Irritant"
- National Fire Protection Agency (NFPA) Hazard rating 1-0-1
- If it is spilled, it can be safely swept up, which is not the case for liquid acids

1- http://www.epa.gov/greenchemistry/pubs/principles.html
2- http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryResources/index.cfm#What_is_green_chemistry

References Regulatory:

FDA food additive clearance at 21 CFR 170.36 Generally Recognized as Safe (GRAS) (FDA Response Letter GRAS Notice No. GRN 000003, June 5, 1998)

USDA/FSIS- Directive 7120.1-Safe and Suitable Ingredients Used in the Production of Meat and Poultry Products.

CAS Number, Other Product Codes, and Labels

Chemical Name:	CAS Number:
Sodium bisulfate	7681-38-1
Sodium Hydrogen Sulfate	

Physical Properties

Molecular Weight: 120
Molecular Formula: $NaHSO_4$
Appearance: Off-white granular material
Physical State: Anhydrous crystalline solid spherical shape beads
Bulk Density: 80-85 lbs/ft^3 (loose)
Solubility in Water: 1080 g/l @68^{0}F (20^{0}C)
Flammability (Solid): Material is non-combustible
Particle Size: $\pm$ 0.75 mm diameter
Melting Point: 350^{0}F (177^{0}C)
Mode of Action: lowers pH

Toxicity-

Animal Effects: Oral-LD_{50} Rat 2800 mg/kg
Skin Irritation: This material is neither corrosive nor destructive to the skin of New Zealand rabbits.

Environmental Impact-

Sodium bisulfate is biodegradable, and will decompose in soil.

Petition Justification Statement

PLT (Sodium bisulfate) is a unique dry granular acid with no organic equivalent. It is safe to handle and easy to spread on litter. It has a strong hygroscopic nature that enables it to absorb water from the air in a dry environment typical of poultry houses. There is no organic acid alternative that can do this. This attribute is very important because acids need to be dissolved in water to donate their hydrogen ions to ammonia and convert it to ammonium.

ALABAMA COOPERATIVE **Extension** SYSTEM

ANR-1208

ALABAMA A&M AND AUBURN UNIVERSITIES

Sodium Bisulfate (PLT) as a Litter Treatment

The detrimental effects of ammonia in poultry production have been known for years. Numerous laboratory and field studies have shown how ammonia affects bird health and performance. Continued exposure to ammonia levels in the poultry house as low as 10 parts per million (ppm) can damage the bird's respiratory system and allow infectious agents to become established, leading to declining flock health and performance. In addition, body weight, feed efficiency, and condemnation rate will be poorer in birds exposed to levels of ammonia that exceed 25 ppm.

The volatilization of ammonia has been attributed to microbial decomposition of nitrogenous compounds, principally uric acid, in poultry house litter. Litter pH plays an important role in ammonia volatilization. Once formed, free ammonia will be in one of two forms: as the uncharged form of NH_3 or the ammonium ion (NH_4), depending on the pH of the litter. Ammonia concentration tends to increase with increasing pH. Ammonia release remains small when litter pH is below 7, but can be substantial when litter pH is above 8. Uric acid decomposition is most favored under alkaline (pH>7) conditions. Uricase, the enzyme that catalyzes uric acid breakdown, has maximum activity at a pH of 9 with uric acid decreasing linearly for more acid or alkaline pH values. One principal ureolytic bacterium, *Bacillus pasteurii,* cannot grow at neutral pH, but thrives in litter above 8.5. Typically, litter pH in a broiler house ranges between 9 and 10. The combination of these factors contributes to ammonia formation and volatilization within the poultry house environment.

One primary question for poultry growers is "What is the best litter treatment?" Unfortunately, this most frequently asked question has no general answer, and the difficulties in addressing this question may be complicated and numerous. There has never been an experimental study evaluating the various litter treatment products under various management conditions. Litter moisture, brooding and lighting programs, ambient temperature, strain type, ventilation management, litter management, and disease challenge are only a few of the variables that can impact product selection, efficacy, and potential return on investment.

In the selection of a litter treatment product, one must identify the goals for application. Litter treatments may be cost-effective and justifiable under one or more of the following situations:

- High fuel prices
- Extremely cold weather
- Short layout periods
- Persistent disease challenges
- Severe vaccination reactions
- Reduced ammonia-related stress
- Prolonged litter reuse
- Increased bird density
- Needed marginal management or housing situations

Litter treatments may be used to enhance the composition of the litter as a fertilizer or as part of a best management practice to reduce food-borne pathogens. Ammonia-reducing litter treatments offer a potentially better in-house environment for both birds and growers. They may also play an increasing role in reducing ammonia and odor emissions from poultry facilities. In recent years, the reasons for using a litter treatment and any potential benefits from its use have expanded to include improvements in performance and environmental concerns. Although different litter treatments vary in their ability to control ammonia, each offers a unique set of characteristics that need to be considered in selecting the appropriate product to meet an individual's needs. The litter treatment that offers the best return on investment will depend on the user's ability to select the product that best meets the overall goals of his application.

Poultry Litter Treatment (PLT) is a dry granular additive used extensively by the poultry industry for poultry house ammonia control, litter acidification, on-farm HACCP programs for pathogen reduction, and in the prevention of many bacterial or stress-related poultry conditions. PLT is a unique blend of sodium bisulfate and other ingredients and is considered a nonhazardous and nontoxic substance classified as GRAS (Generally Regarded as Safe) and a food-grade substance. PLT eliminates ammonia by converting litter ammonium to ammonium sulfate, lowering litter pH to acidify litter, and providing potent ionic effects that enhance acidification. PLT was the first nonhazardous and nontoxic litter treatment used in an overall total litter management program.

Experiments and field tests using PLT resulted in the following:

- Decreased fuel usage
- Decreased house ammonia levels
- Decreased litter pH levels
- Improved performance
- Reduced bacterial populations of *Salmonella* and *Campylobacter*
- Lowered darkling beetle populations

Ammonia (NH_3) produced from poultry manure by the breakdown of uric acid can be inhibited if converted to NH_4^+ (ammonium), which can be accomplished by lowering litter pH. Sodium bisulfate, commonly referred to as PLT, is an acid that produces hydrogen ions (H^+) when it dissolves, and the hydrogen ions produced by this reaction will attach to ammonia to form ammonium, which further reacts with sulfate ions to form ammonium sulfate—$(NH_4)_2 SO_4$. Ammonium sulfate is simply a water-soluble fertilizer. Because of these reactions, the amount of ammonia emitted from the litter will be reduced, which will increase the nitrogen (N) content of the litter. The use of PLT in broiler litter management can impact performance and environmental concerns.

A rate of 50 pounds of PLT per 1,000 square feet of floor space is the typical recommendation for the treatment of broiler litter. For most broiler houses, this will equal 800 to 1,000 pounds of PLT per house for each grow-out. A rate of 50 pounds per 1,000 square feet will control ammonia production and reduce the growth of microorganisms in the litter. Rate selection for an individual's operation will be dependent on current management practices and needs, based on such factors as ventilation control and litter moisture levels. Higher rates may be recommended where high ammonia conditions prevail, due to increased litter age or short down times. PLT can also be safely applied with birds in the house to address specific disease or management issues that occur post-placement.

Before PLT application, the broiler house needs to be de-caked or rototilled. Afterward, PLT can be broadcast at the chosen level using a cyclone spreader. During application, gloves, a long-sleeved shirt, and long pants should be worn to prevent skin irritation and burns. Goggles should be worn for eye protection, and a dust mask should be worn to prevent dust inhalation.

Research has demonstrated cost savings to the poultry producer from the use of PLT. Cost savings can be realized due to a reduction in heating and ventilation costs and improvements in performance. PLT treatment of litter will increase the nitrogen content of the litter, creating a more valuable source of fertilizer.

Summary

- Using sodium bisulfate (PLT) as a litter amendment can effectively reduce in-house ammonia volatilization and improve performance.
- A rate of 50 pounds per 1,000 square feet will provide ammonia control and pathogen reduction.
- PLT does not negatively impact the fertilizer or feeding value of litter.
- Wear protective gloves, a long-sleeved shirt, long pants, goggles, and a mask when applying PLT.

John P. Blake, *Extension Poultry Scientist* and Professor, and **Joseph B. Hess,** *Extension Poultry Scientist* and Associate Professor, both in the Department of Poultry Science at Auburn University

Trade names are used **only** to give specific information. The Alabama Cooperative Extension System does not endorse or guarantee any product and does not recommend one product instead of another that might be similar.

For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.

ALABAMA COOPERATIVE Extension SYSTEM

ANR-1208

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ECP, 3M, **New May 2001,** ANR-1208

A2

Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing

T. Marsh Johnson[1] and Bernard Murphy[2]
Veterinary & Environmental Technical Solutions, PC[1]; Jones-Hamilton Co.[2]

Species: Poultry (broiler, layer & turkey), cattle, and horses
Use Area: Animal Housing
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Ammonia & Volatile Organic Carbons

Description:

Ammonia (NH_3), volatile organic compounds (VOCs) and greenhouse gases (GHG) of animal manure origin are produced by microbial activity on the nitrogen and carbon compounds not utilized by the animals for either maintenance or growth and excreted in the feces and /or urine (Carey, et al., 2004; Mutlu, et al. 2005). The release of ammonia from animal manure is dependent upon the amount of ammoniacal nitrogen present, pH, surface area, temperature, and the amount of urease present (Mutlu, et al., 2005; Gay and Knowlton, 2005). Therefore, for any emissions intervention to be effective, it must exploit at least one of these avenues to prevent NH_3 release into the atmosphere (Jongebreur and Monteny, 2001). VOCs are mostly derived from the bacterial degradation of manures soon after excretion (Mitloehner, 2005). Decreasing the bacterial activity in freshly excreted manures should then reduce the production & subsequent emissions of VOCs.

Ammonia emission from animal housing is calculated by multiplying ammonia concentration by airflow. Research and extensive commercial application show that the use of Sodium Bisulfate reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. The amount of emissions reduction can be tailored to a specific location by varying the rate, timing, and surface area of SBS application. Other documented benefits are as follow:

- Fuel savings through reduced ventilation
- Improved bird performance i.e. weight, feed conversion, and livability
- Improved animal welfare through better air quality and paw quality
- Reduced respiratory lesions
- Reduced Salmonella & campylobacter incidence of broilers
- Fly control in layer, equine, and calf housing
- Reduction in environmental mastitis
- Substantial return on investment.

Mitigation Mechanism:

Sodium bisulfate (SBS) is a dry, granular acid salt that has been used for many years as a pH reducer in a variety of agricultural, industrial, and food applications. The anti-bacterial properties of sodium bisulfate have been exploited in its application as a toilet-bowl sanitizer (i.e. EPA Reg. #1913-24-AA) and as a preservative in EPA method #5035 "Closed-System Purge-and-Trap & Extraction for Volatile Organics in Soil & Waste Samples," to prevent microbial activity leading to VOC release. These properties along with the safety and ease of use of SBS have led to its use for ammonia binding (Fig.1) and bacterial reduction in poultry, dairy, and equine manure and bedding materials (Ullman, et al., 2004; Blake and Hess, 2001; Sweeney, et al., 1996; Harper, 2002). The use of SBS reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. Sodium bisulfate is hygroscopic. As water is adsorbed into the SBS bead from the humidity in the air, the SBS is dissolved into its Na^+, H^+ and $SO_4^=$ constituents.

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

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

The hydrogen ion reduces the pH of the litter and protonates the ammonia molecule. The resulting ammonium is then bound by the sulfate component. This formation of ammonium sulfate is non reversible therefore the nitrogen in the litter is not released as the pH increases (Ullman, et al., 2004). The sodium and hydrogen ions of SBS exert negative pressure on the bacterial populations of the litter; decreasing total aerobic population counts 2-3 logs (Pope and Cherry, 2000). This may also serve to decrease urease concentration in the litter for additional ammonia reductions

Manufacturing Order

Order Quantity (Trays):

Order Number	Item Description	Item Code
	WAA BASE 24.30 X 120 8UP	AAS000419

Customer : ESSENTRA GREENSBORO INC

Machine	Tray Content	Std. Waste %	Trays per Hour	Trays Per Pallet	Cuts per Minute	Sampling Frequency
Machine 231	4675	4.00	32.09	52	2500	5

Test Specifications

	PD QTM mm		OVALITY mm		CIRQTM mm LASER		WGT QTM g		LENGTH mm		PZ g/100		TOW g/100		MENTHOL MX g/100		MENTHOL WT g/100				
Target	510.00	MM	0.45	MM	24.30	MM	1.370	G1	120.00	MM	4.45	G1	59.16	G1	64.000	GM	9.600	GM			
Control	487.05	532.95	0.00	0.53	24.22	24.38	1.315	1.425	119.80	120.20	3.78	5.14	62.12	56.20	57.600	70.400	8.640	10.560			
Reject	479.40	540.60	0.00	0.55	24.15	24.45	1.288	1.452	119.20	120.80	3.11	5.85	65.08	53.24	54.400	73.600	7.680	11.520			
Indv	443.70	576.30	0.00	0.65	24.08	24.52	1.233	1.507	119.00	121.00	3.11	5.85	53.24	65.08	54.400	73.600	7.680	11.520			
SD Control	30.600		0.080		0.080		0.027		0.300												
SD Reject	44.217		0.150		0.120		0.055		0.350												

Dimensions

Material Specifications

AD000088	HOTMELT - 34-716A AMGP	KG	0.0020	1 LAP	PA410051	STANDARD FILTRONA HARD LID
AD000090	32-475A-PVA AMGP	KG	0.0060	2 INTERNALS	PA410054	TRAY - 120MM
AT410065	3.0Y30 E-W LOT 109 TOW	KG	0.5916			
PW600074	26.5X6500 27.0G FY/33060 7.5C OLSAN	EA	0.0185			
PZ600006	PRIACETIN1578	KG	0.0445			
RM000222	MENTH SEP 15 X 30 - 15% ORGANIC MEN	KG	0.6400			

Packaging Instructions

42 X 42 wooden pallet with TP Inspection Logo.
Pack 13 layers of 4 trays each.
52 trays per pallet.
Hard lids on every tray.
Pallet cap every pallet.
Use BLUE tray labels.

Authorized By ____________________

3:37:48PM Wednesday, December 18, 2013

(Ullman, et al., 2004). Once the ammonia concentration at bird level has been reduced, the poultry houses can be minimally ventilated for relative humidity control as they were designed rather than over-ventilated for NH_3 removal (Czarick and Lacey, 1998). In an ongoing emissions study being conducted at North Carolina State University, the value of whole house application and higher rates of application of SBS on reducing emissions are being demonstrated. In houses using an industry standard rate of 75-lbs/1000 sqft, emissions from brood chamber only application totaled 32.52 kg-NH3 per house for the 14 day brooding period compared to 23.96 kg-NH3 for a whole house application at the same rate for the same time period. Houses receiving 150-lbs of SBS per 1000 sqft in a whole house application had an average total emission for the 14-day brooding period of only 4.9-kg of ammonia.

Applicability:

Sodium bisulfate is suited to a wide variety of animal housing types. SBS has been used successfully in commercial applications in dry litter in both broiler, turkey, and layer facilities, deep bedding of horses, swine, and cattle, and free-stall and dry lot dairy housing systems. Due to the safety of SBS, it can be broadcast in the presence of animals at any time during production unlike most other amendments. This flexibility allows for each operation to tailor SBS usage rate and application timing to meet its unique needs. Any application scheme of SBS will reduce interior ammonia and ventilation rates, thereby reducing ammonia emissions. Specific application rates and application timing are necessary for reduction of food-borne pathogens and fly control purposes.

Reduction of ambient ammonia levels in broiler housing has been demonstrated in a variety of studies. Ammonia levels were 90% lower post PLT application with an average of 6.2 PPM of NH_3 in the treated houses and 62.3 PPM in the control houses. Two weeks after application, the ammonia levels in the treated houses were still reduced by 50% compared to control houses. Two hundred commercial broiler houses were studied in Delaware and Maryland by Terzich (1997) with 100 houses treated with PLT® and 100 houses serving as control. Ammonia levels averaged 127 PPM pre-treatment and were all 0 PPM post-treatment (Table 1). Consequent to the improved air quality, bird performance was significantly improved in the treated houses with better mortality rates, average weights, average daily gain, and percentage of respiratory lesions at processing compared to controls. Fuel usage was also reported to be 43% less in the treated houses. At a cost of $120/house for the PLT® litter treatment, the resulting production increases and fuel savings provided the producer with a substantial return on investment that would support increased

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

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

PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998; Terzich et al, Apr 1998).

By converting ammonia into ammonium sulfate, the use of SBS increases fertilizer value of litter and displaces phosphorus resulting in improved nitrogen to phosphorus ratio. In a study at the University of Georgia, a linear increase is evident in both N and NH_4-N retained in the litter as the amount of PLT applied is increased (Fig. 3 & 4).

Similar results were observed in a commercial egg layer high-rise house where the higher rate of PLT showed the most consistent decrease in ammonia emissions (Patterson et al, 2006). As in the UGA study, manure ammonium (NH_4^+) nitrogen and P_2O_5 were positively altered by treatment group with the high-rate treatment group having the highest level of retained nitrogen and the lowest level of P_2O_5 (table 2).

Limitations:

Sodium bisulfate is only limited by the amount of product applied. Because of the hygroscopic nature of SBS, greater longevity of ammonia reductions will occur at interior housing humidity of 75% or less. This is consistent with the normal and proper ventilation of poultry houses for relative humidity control.

Manufacturing Order

Order Quantity (Trays):

Order Number	Item Description	Item Code
	WAA BASE 24.20 X 120 8UP	AAS000444

Customer : ESSENTRA GREENSBORO INC

Machine	Tray Content	Std. Waste %	Trays per Hour	Trays Per Pallet	Cuts per Minute	Sampling Frequency
Machine 231	4675	4.00	32.09	52	2500	5

Test Specifications

	PD QTM mm		OVALITY mm		CIRQTM mm LASER		WGT QTM g		LENGTH mm		PZ g/100		TOW g/100		MENTHOL MX g/100		MENTHOL WT g/100				
Target	300.00	MM	0.45	MM	24.20	MM	1.059	G1	120.00	MM	3.92	G1	52.09	G1	40.504	GM	4.050	GM			
Control	286.50	313.50	0.00	0.53	24.12	24.28	1.017	1.101	119.80	120.20	3.33	4.53	54.70	49.49	36.454	44.554	3.645	4.455			
Reject	282.00	318.00	0.00	0.55	24.05	24.35	0.995	1.123	119.20	120.80	2.74	5.15	57.30	46.88	34.428	46.580	3.240	4.860			
Indv	261.00	339.00	0.00	0.65	23.98	24.42	0.953	1.165	119.00	121.00	2.74	5.15	46.88	57.30	34.428	46.580	3.240	4.860			
SD Control	18.000		0.080		0.080		0.021		0.300												
SD Reject	26.010		0.150		0.120		0.042		0.350												

Dimensions

Material Specifications

AD000088	HOTMELT - 34-716A AMGP	KG	0.0020	1 LAP	
AD000090	32-475A-PVA AMGP	KG	0.0060	2 INTERNALS	
AT410029	3.9Y30 E-W LOT 129 TOW	KG	0.5209		
PW600074	26.5X6500 27.0G FY/33060 7.5C OLSAN	EA	0.0185		
PZ600006	PRIACETIN1578	KG	0.0392		
RM000221	MENTH SEP 15 X 30 - 10% ORGANIC MEN	KG	0.4050		

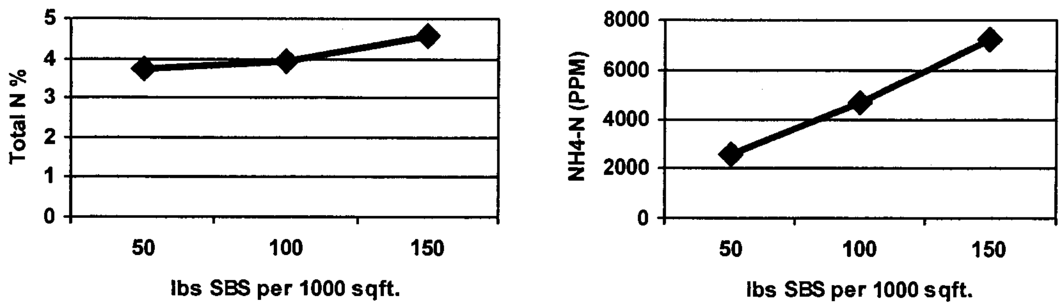
PA410051	STANDARD FILTRONA HARD LID
PA410054	TRAY - 120MM

Packaging Instructions

42 X 42 wooden pallet with TP Inspection Logo.
Pack 13 (thirteen) layers of 4 (four) trays each.
Hard lids on every tray.
Pallet cap every pallet.
52 trays per pallet.
Use BLUE tray labels.

Authorized By ____________________

3:36:06PM Wednesday, December 18, 2013



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

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

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

Cost:

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

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

Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial additional return on investment.

Manufacturing Order

Order Quantity (Trays):

Order Number	Item Description	Item Code
	WAA BASE 24.20 X 120 8UP	AAS000463

Customer : ESSENTRA GREENSBORO INC

Machine	Tray Content	Std. Waste %	Trays per Hour	Trays Per Pallet	Cuts per Minute	Sampling Frequency
Machine 231	4675	4.00	32.09	52	2500	5

Test Specifications

	PD QTM mm		OVALITY mm		CIRQTM mm LASER		WGT QTM g		LENGTH mm		PZ g/100		TOW g/100		MENTHOL MX g/100		MENTHOL WT g/100				
Target	532.00	MM	0.45	MM	24.20	MM	1.420	G1	120.00	MM	4.35	G1	57.85	G1	70.000	GM	14.000	GM			
Control	508.06	555.94	0.00	0.53	24.12	24.28	1.363	1.477	119.80	120.20	3.69	5.03	60.74	54.96	63.000	77.000	12.600	15.400			
Reject	500.08	563.92	0.00	0.55	24.05	24.35	1.335	1.505	119.20	120.80	3.05	5.72	63.64	52.07	59.500	80.500	11.200	16.800			
Indv	462.84	601.16	0.00	0.65	23.98	24.42	1.278	1.562	119.00	121.00	3.05	5.72	52.07	63.64	59.500	80.500	11.200	16.800			
SD Control	31.920		0.080		0.080		0.028		0.300												
SD Reject	46.124		0.150		0.120		0.057		0.350												

Dimensions

Material Specifications

AD000088	HOTMELT - 34-716A AMGP	KG	0.0020	1 LAP	PA410051	STANDARD FILTRONA HARD LID
AD000090	32-475A-PVA AMGP	KG	0.0060	2 INTERNALS	PA410054	TRAY - 120MM
AT600037	2.7Y32 E-W LOT 272 TOW	KG	0.5785			
PW600074	26.5X6500 27.0G FY/33060 7.5C OLSAN	EA	0.0185			
PZ600006	PRIACETIN1578	KG	0.0435			
RM000223	MENTH SEP 15 X 30 - 20% ORGANIC MEN	KG	0.7000			

Packaging Instructions

42 X 42 wooden pallet with TP Inspection Logo.
Pack 13 (thirteen) layers of 4 (four) trays each.
Hard lids on every tray.
Pallet cap top and bottom of every pallet.
52 trays per pallet.
Once finished, wrap pallet immediately!
Protective Sleeves & Mask must be worn.
Use BLUE tray labels.

Authorized By ____________________

3:38:19PM Wednesday, December 18, 2013

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

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

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

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

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

Implementation:

The rate and timing of SBS application are dependent upon the type of housing to be treated, the age of the bedding material in the house, and the age of the animals being housed. Application rates begin at 0.32 kg/m^2 (50-lbs/1000 sqft) for new bedding and litter up to 3-4 flocks old. As the bedding material ages or the manure load increases, the application rate is increased accordingly. Rates of 0.64-0.96 kg/m^2 (100-150-lbs/1000 sqft) are commonly used in commercial field applications. The two drivers of ammonia release from the litter or bedding material are temperature and surface area. Because there is no choice but to have the proper floor temperatures to brood chicks, surface area of the litter particles needs to be minimized to reduce ammonia release from the litter. The amount of SBS needed for a particular grow-out is dependent on the amount of ammonia in the litter and how readily that ammonia is released. The older the birds raised on a farm and the higher the number of flocks raised on the litter, the more fecal material that is present. In other words, 3 flock litter from a house of 45-day-old 1.8-kg birds will have much less ammonia in it than 3 flock litter from a house of 4.2-kg roasters. Also, litter that has been aggressively handled and has maximum surface area will release far more ammonia than litter that has been crusted correctly. Because the amount of amendment used has to be matched to the ammonia load in a particular location, it is important to follow the manufacturer's recommendations when deciding upon the correct rate to use for a specific location and animal type.

In poultry housing, SBS is routinely applied prior to bird placement using a broadcast spreader of some type. Both professional application with a truck mounted spreader and hand application with a push spreader are used depending on farmer preference. Applications in the presence of animals are often done for bacterial or fly control purposes. Because of the safety and efficacy of SBS, producers have maximum flexibility to meet their needs.

Technology Summary:

Sodium bisulfate reduces ammonia and VOC emissions from animal housing areas. SBS binds ammonia converting it to ammonium sulfate thereby retaining nitrogen and increasing fertilizer value of the litter. Total phosphorus is reduced through dilution. Fuel savings and increased animal performance and welfare are realized allowing the mitigation to pay for itself. Research and commercial field studies indicate a 60-90% reduction of ammonia flux form the bedding surface. Application rates vary from 0.32-1.95 kg/m2 depending on the litter age and concentration of manure in the bedding. Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial return on investment. Additional benefits include reduced incidence of food-borne pathogens, fewer respiratory lesions and ascites, and improved paw quality.

33907-3 7-12-2001 A3

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Pesticide Programs
Antimicrobials Division (7510C)
401 "M" St., S.W.
Washington, D.C. 20460

NOTICE OF PESTICIDE:
_x_ Registration
__ Reregistration

(under FIFRA, as amended)

EPA Reg. Number: 33907-3

Date of Issuance: July 12, 2001

Term of Issuance: Conditional

Name of Pesticide Product: PLT

Name and Address of Registrant (include ZIP Code):

Jones-Hamilton Company
30354 Tracy Road
Walbridge, OH 43465-9792

Note: Changes in labeling differing in substance from that accepted in connection with this registration must be submitted to and accepted by the Antimicrobials Division prior to the use of the label in commerce. In any correspondence on this product always refer to the above EPA regulation number.

On the basis of information furnished by the registrant, the above named pesticide is hereby registered/reregistered under the Federal Insecticide, Fungicide and Rodenticide Act.
Registration is in no way to be construed as an endorsement or recommendation of this product by the Agency. In order to protect health and the environment, the Administrator, on his motion, may at any time suspend or cancel the registration of a pesticide in accordance with the Act. The acceptance of any name in connection with the registration of a product under this Act is not to be construed as giving the registrant a right to exclusive use of the name or to its use if it has been covered by others

This product is conditionally registered in accordance with FIFRA sec. 3(c)(7)(A) provided that you:

1. Submit and/or cite all data required for registration/ reregistration of your product under FIFRA sec. 3(c)(5) when the Agency requires all registrants of similar products to submit such data; and submit acceptable responses required for reregistration of your product under FIFRA section

2. Submit one copy of the revised final printed label for the record.

3. Change the registration number on the label to read "EPA Reg. No. 33907-3".

4. The precautionary statements need to be on the front of the label and need to be revised to read:

"Corrosive. Causes irreversible eye damage. Causes skin burns Do not get in eyes or on clothing. Wear protective eyewear (goggles, face shield, or safety glasses). Wear protective clothing and rubber gloves. Wash thoroughly with soap and water after handling. Avoid breathing dust. Remove contaminated clothing and wash clothing before reuse."

5. Change the active ingredient on the label to "Sodium bisulfate". Although Sodium hydrogen sulfate is a synonym, Sodium bisulfate is the name generally used by the Agency. Add a third line to the ingredient statement, indicating " TOTAL.......100%".

Signature of Approving Official:

Robert S. Brennis
Product Manager 32

Date: 7/12/01

EPA Form 8570-6

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5. Revise the First Aid section to read:

"IF IN EYES: Hold eyelids open and flush with a steady, gentle stream of water for 15 minutes. Get medica attention.

IF ON SKIN: Wash with plenty of soap and water. Get medical attention.

IF SWALLOWED: Call a doctor or get medical attention. Do not induce vomiting or give anything by mouth to an unconscious person. Drink promptly a large quantity of milk, eggwhites gelatin solution, or if these are not available, drink large quantities of water. Avoid alcohol."

6. Add the following note to the end of the first aid section:

"Note to Physician: Probable mucosal damage may contraindicate the use of gastric lavage"

7. Remove all references on the label to Pasteurella. The term Pasteurella could include pathogens of publi health concern.

If these conditions are not complied with, the registration will be subject to cancellation in accordance wit FIFRA sec. 6(e). Your release for shipment of the product constitutes acceptance of these conditions.

A stamped copy of the label is enclosed for your records.

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FRONT PANEL

MARCH 18, 2001

PLT ®

EFFECTIVE MANAGEMENT IN REDUCING BACTERIA IN POULTRY LITTER

EFFECTIVE AMMONIA CONTROL

ACTIVE INGREDIENT Sodium bisulfate	
Sodium hydrogen sulfate [CAS# 7681-38-1]	93.2%
OTHER INGREDIENTS	6.8%
Total	100.0%

KEEP OUT OF REACH OF CHILDREN

DANGER

CAUSES EYE & SKIN DAMAGE (Replaced)
HARMFUL IF SWALLOWED

READ BACK PANEL PRECAUTIONARY STATEMENTS CAREFULLY

READ ALL DIRECTIONS BEFORE USING THIS PRODUCT

Manufactured by Jones-Hamilton Co.
Wallbridge, OH 43465

EPA Registration No. XXXXX-X 33907-3

EPA Establishment No. XXXXX-OH-1

To receive information concerning the proper use of the product and/or specific actions to be taken in case of emergencies, call
1-800-xxx-xxxx

ACCEPTED
with COMMENTS
in EPA Letter Dated:

JUL 12 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No. 33907-3

NET CONTENTS: 50 lbs

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BACK PANEL

MARCH 18, 2001

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS

DANGER

Causes eye and skin damage. Do not get in eyes or on skin, or on clothing. Wear goggles, or face shield and rubber gloves when handling. Harmful if swallowed, inhaled or absorbed through the skin. Avoid breathing dust. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash clothing before reuse.

FIRST AID

IF IN EYES:
- Hold eye open and rinse slowly and gently with water for 15 - 20 minutes.
- Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
- Call a poison control center or doctor for treatment advice.

Replaced

IF ON SKIN OR CLOTHING:
- Take off contaminated clothing
- Rinse skin immediately with plenty of water for 15 - 20 minutes.
- Call a poison control center or doctor for treatment advice.

IF SWALLOWED:
- Call a poison control center or doctor for treatment advice.
- Have person sip a glass of water if able to swallow.
- Do not induce vomiting unless told to do so by a poison control center or doctor.
- Do not give anything by mouth to an unconscious person

ENVIRONMENTAL HAZARDS

Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when cleaning equipment or disposing of equipment washwaters.

PHYSICAL & CHEMICAL HAZARDS

Never use with products containing chlorine. Never use or mix with other chemicals.

ACCEPTED
with COMMENTS
in EPA Letter Dated:

JUL 12 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No. 33907-3

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ACCEPTED
with COMMENTS
in EPA Letter Dated:
JUL 1 2 2001

BACK PANEL

MARCH 18, 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No. 33907-3

STORAGE AND DISPOSAL STATEMENTS

Do not contaminate water, food or feed by storage or disposal

PESTICIDE STORAGE:	Store in original container in a cool, dry area.
PESTICIDE DISPOSAL:	Pesticides are acutely hazardous. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal law. If these wastes cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste Representative at the nearest EPA Regional Office for guidance.
CONTAINER DISPOSAL:	Completely empty bag into application equipment. Then dispose of empty bag in a sanitary landfill or by incineration, or, if allowed by State and local authorities, by burning. If burned stay out of smoke

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling

FOR ALL APPLICATIONS

Apply PLT® evenly on top of the litter, do not mix PLT® into the litter. PLT® is activated by moisture. The ambient relative humidity of the poultry house must be maintained at greater than 30%. Bacterial reduction occurs with a 1 hour contact time.

AMMONIA CONTROL AND LITTER pH REDUCTION

FOR ALL BIRDS

Apply PLT® at rate of 5 - 8lbs/100 ft^2 floor, a minimum of 1 hour prior to bird placement. For litter older than 2 years, apply PLT® at a rate up to 10 lbs/100 ft^2. With new litter, PLT® may be applied at the same rate at any time during the flock for ammonia control. Off chambers should be applied at the same rate a minimum of 1 hour prior to bird migration.

BACTERIAL MANAGEMENT

BROILERS

Apply PLT® at rate of 8 - 12 lbs/100 ft^2 in the entire house a minimum of 1 hour before bird placement. Retreat the entire house at 10 lbs/100 ft^2 7-10 days before bird movement.

BROILER BREEDERS

Apply PLT® to scratch area at rate of 8 - 12 lbs/100 ft^2 a minimum of 1 hour prior to bird placement in the breeder house. Apply PLT® at the rate of 5 - 10 lbs/100 ft^2 when using

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BACK PANEL

MARCH 18, 2001

antibiotic therapy. Apply PLT® at the rate of 5 - 10 lbs/100 ft^2 one week prior to peak production or at any other times of stress. Retreat the entire house at10 lbs/100 ft^2 7-10 days before bird movement.

PULLETS

Apply PLT® to whole house at rate of 8 - 12 lbs/100 ft^2 a minimum of 1 hour prior to pullet placement

Apply PLT® at the rate of 5 - 10 lbs/100 ft^2 immediately prior to periods of stress, especially prior to vaccination or antibiotic therapy, or routinely apply PLT® at this rate every 3 weeks.

TURKEYS

Apply PLT® at rate of 8 - 12 lbs/100 ft^2 prior to bird placement in brood or grow out barn and at the rate of 5 - 10 lbs/100 ft^2 especially under feed and watering areas.

~~PASTEURELLA MANAGEMENT~~

BREEDERS

As part of a comprehensive ~~*Pasteurella*~~ control program, apply PLT® under slats and in scratch area at the rate of 5 - 10 lbs/100 ft^2. Re-apply at same rate during periods of bird stress or during antibiotic therapy for Fowl Cholera.

TURKEYS

Apply PLT® to the entire house at rate of 10 - 20 lbs/100 ft^2 at time of placement in grow-out barn. Apply 8 - 12 lbs/100 ft^2 to dirt floor at time of clean out.

WARRANTY

Jones-Hamilton Co., warrant that this product conforms to the chemical description on the label. Jones-Hamilton Co., neither makes nor authorizes any agent or representative to make any other warranty of fitness or of merchantability, guarantee or representation, express or implied, concerning this material. Jones-Hamilton Co.'s maximum liability for breach of this warranty shall not exceed the purchase price of this product. Buyer and user acknowledge and assume all risks and liabilities resulting from the handling, storage and use of this material.

ACCEPTED
with COMMENTS
in EPA Letter Dated:

JUL 1 2 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No. 33907-3

33907-3 10/22/2001 Page 1 of 6 A4

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

OCT 22 2001

OFFICE OF PREVENTION, PESTICIDES AND TOXIC SUBSTANCES

Iain Weatherston, Senior Regulatory Consultant
Jones-Hamilton Company
30354 Tracy Road
Walbridge, OH. 43465-9792

SUBJECT: July 21, 2001 Amendment
PLT
EPA Registration 33907-3

Dear Mr. Weatherston:

The following amendment, submitted in connection with registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, is acceptable with the following conditions:

- Add the statement "See side panels for additional precautionary statements" to the front panel.
- Add the Effluent Discharge Labeling Statement (NPDES) in accordance with PR Notice 95-1:

  Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to the discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance contact your State Water Board or Regional Office of the EPA.

  The NPDES statement should placed under the Environmental Hazards section since the possibility of this product being introduced into water treatment facilities does exist and is a 50 pound container.
- Remove date from label.
- Add Inhalation precaution to First Aid statement in accordance with PR Notice 2001-1. This should be listed under "If Swallowed":

If Inhaled	▪ Move person to fresh air. ▪ If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to mouth, if possible. ▪ Call a poison control center or doctor for further treatment advice.

In general, the following requested revisions have taken place:

- Original proposed label was revised as conditionally accepted.
- First Aid statement partially updated per PR 2001-1.

Submit three (3) copies of your final printed labeling before distributing or selling the product bearing the revised labeling. A stamped copy of the label is enclosed for your records. If you have any questions regarding this letter, please contact Tom Luminello of my staff at (703) 308-8075.

Sincerely yours,

Robert S. Brennis
Product Manager 32
Regulatory Management Branch II
Antimicrobial Division (7510-C)

3 7 6

FRONT PANEL

July 21, 2001

PLT ®

EFFECTIVE MANAGEMENT IN REDUCING BACTERIA IN POULTRY LITTER

EFFECTIVE AMMONIA CONTROL

ACTIVE INGREDIENT

Sodium bisulfate [CAS# 7681-38-1] 93.2%

OTHER INGREDIENTS 6.8%

Total 100.00%

KEEP OUT OF REACH OF CHILDREN

DANGER

CORROSIVE. CAUSES IRREVERSIBLE EYE DAMAGE. CAUSES SKIN BURNS
DO NOT GET IN EYES OR ON CLOTHING
WEAR PROTECTIVE EYEWEAR [GOGGLES, FACE SHIELD OR SAFETY GLASSES]
WEAR PROTECTIVE CLOTHING AND RUBBER GLOVES
WASH THOROUGHLY WITH SOAP AND WATER AFTER HANDLING. AVOID BREATHING DUST.
REMOVE CONTAMINATED CLOTHING AND WASH CLOTHING BEFORE REUSE

READ ALL DIRECTIONS BEFORE USING THIS PRODUCT

Manufactured by Jones-Hamilton Co.
Wallbridge, OH 43465

EPA Registration No.33907-3

EPA Establishment No. 33907-OH-1

To receive information concerning the proper use of the product and/or specific actions to be taken in case of emergencies, call
1-800-xxx-xxxx

NET CONTENTS: 50 lbs

ACCEPTED
with COMMENTS
in EPA Letter Dated:

OCT 22 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No.
33907-3

BACK PANEL July 21, 2000

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS

DANGER

FIRST AID

IF IN EYES:
- Hold eye open and rinse slowly and gently with water for 15 - 20 minutes.
- Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
- Call a poison control center or doctor for treatment advice.

IF ON SKIN OR CLOTHING:
- Take off contaminated clothing
- Rinse skin immediately with plenty of water for 15 - 20 minutes.
- Call a poison control center or doctor for treatment advice..

IF SWALLOWED:
- Call a poison control center or doctor for treatment advice.
- Have person sip a glass of water if able to swallow.
- Do not induce vomiting unless told to do so by a poison control center or doctor.
- Do not give anything by mouth to an unconscious person

NOTE TO PHYSICIAN: Probable mucosal damage may contraindicate the use of gastric lavage

---

ENVIRONMENTAL HAZARDS

Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when cleaning equipment or disposing of equipment washwaters.

PHYSICAL & CHEMICAL HAZARDS

Never use with products containing chlorine. Never use or mix with other chemicals.

ACCEPTED
with COMMENTS
In EPA Letter Dated:

OCT 22 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pes[illegible] registered under EP[illegible] [illegible]

33907-3

5 7 6

BACK PANEL SEPTEMBER 1, 2000

STORAGE AND DISPOSAL STATEMENTS

Do not contaminate water, food or feed by storage or disposal

PESTICIDE STORAGE:	Store in original container in a cool, dry area.
PESTICIDE DISPOSAL:	Pesticides are acutely hazardous. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal law. If these wastes cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste Representative at the nearest EPA Regional Office for guidance.
CONTAINER DISPOSAL:	Completely empty bag into application equipment. Then dispose of empty bag in a sanitary landfill or by incineration, or, if allowed by State and local authorities, by burning. If burned stay out of smoke

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling

FOR ALL APPLICATIONS
Apply PLT® evenly on top of the litter, do not mix PLT® into the litter. PLT® is activated by moisture. The ambient relative humidity of the poultry house must be maintained at greater than 30%. Bacterial 3 - 4 log reduction occurs with a 1 hour contact time.

AMMONIA CONTROL AND LITTER pH REDUCTION
FOR ALL BIRDS
Apply PLT® at rate of 5 - 8lbs/100 ft^2 floor, a minimum of 1 hour prior to bird placement. For litter older than 2 years, apply PLT® at a rate up to 10 lbs/100 ft^2 . With new litter, PLT® may be applied at the same rate at any time during the flock for ammonia control. Off chambers should be applied at the same rate a minimum of 1 hour prior to bird migration. .

BACTERIAL MANAGEMENT
BROILERS
Apply PLT® at rate of 8 - 12 lbs/100 ft^2 in the entire house a minimum of 1 hour before bird placement. Retreat the entire house at 10 lbs/100 ft^2 7 - 10 days before bird movement.

ACCEPTED
with COMMENTS
In EPA Letter Dated:
OCT 22 2001

Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No. 33907-3

BACK PANEL

July 21, 2001

BROILER BREEDERS
Apply PLT® to scratch area at rate of 8 - 12 lbs/100 ft^2 a minimum of 1 hour prior to bird placement in the breeder house. Apply PLT® at the rate of 5 - 10 lbs/100 ft^2 when using antibiotic therapy. Apply PLT® at the rate of 5 - 10 lbs/100 ft^2 one week prior to peak production or at any other times of stress. Retreat the entire house at 10 lbs/100 ft^2 7 - 10 days before bird movement.
PULLETS
Apply PLT® to whole house at rate of 8 - 12 lbs/100 ft^2 a minimum of 1 hour prior to pullet placement Apply PLT® at the rate of 5 - 10 lbs/100 ft^2 immediately prior to periods of stress, especially prior to vaccination or antibiotic therapy, or routinely apply PLT® at this rate every 3 weeks.
TURKEYS
Apply PLT® at rate of 8 - 12 lbs/100 ft^2 prior to bird placement in brood or grow out barn and at the rate of 5 - 10 lbs/100 ft^2 especially under feed and watering areas.

WARRANTY

Jones-Hamilton Co., warrant that this product conforms to the chemical description on the label. Jones-Hamilton Co., neither makes nor authorizes any agent or representative to make any other warranty of fitness or of merchantability, guarantee or representation, express or implied, concerning this material. Jones-Hamilton Co.'s maximum liability for breach of this warranty shall not exceed the purchase price of this product. Buyer and user acknowlecge and assume all risks and liabilities resulting from the handling, storage and use of this material.

ACCEPTED
with COMMENTS
In EPA Letter Dated:
OCT 22 2001
Under the Federal Insecticide, Fungicide, and Rodenticide Act as amended, for the pesticide, registered under EPA Reg. No.
33907-3

About Us *Outreach* *Custom Search* *Data Quality* *Contacts*

Product Report

Product Name Keyword: **PLT**
Number of Active Products: **1**

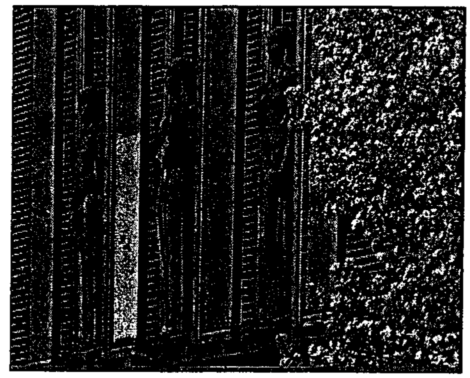
EPA View the label in the US EPA Pesticide Product Label System (PPLS).

PLT
EPA Registration Number: 33907-3

Company Number: 33907
JONES-HAMILTON CO
30354 TRACEY ROAD
WALLBRIDGE OH 43465
419/662-5277

Approval Date: 07-12-2001
Product Manager: Demson Fuller (703)308-8062

Percent	Active Ingredient
93.2000	Sodium bisulfate (73201)



Elliott Hall of Music

The NPIRS Public website contains information pertaining to pesticides either currently or previously licensed for distribution and sale in the United States and is provided for informational purposes only. Information derived from this website does not constitute a label replacement or a recommendation. Before applying any pesticide, applicators must determine if the product under consideration is correct for the intended use site. Always check the container/package label to determine if the intended use site is included on the label. **READ AND FOLLOW LABEL INSTRUCTIONS BEFORE USING ANY PESTICIDE PRODUCT.**

Pesticide Product Label System

Product Labeling
Pesticide Product Label System (PPLS)

You can use the field below to search specific products or product numbers from your results.

Current Status: ☑ **Active**
☐ **Inactive**

Go Rows 15 Search Again

1 - 1 of 1

Product Name	Approved Date	EPA Reg. No.	Current Status
PLT	October 22, 2001	33907-3	Active (JUL 12, 2001)

1 - 1 of 1

A5

JHAg A DIVISION OF THE JONES-HAMILTON CO. (http://www.joneshamiltonag.com/) English (http://www.linkedin.com/company/2718191?trk=tyah) Search Search 5

Products (http://www.joneshamiltonag.com/products/) Species Solutions (http://www.joneshamiltonag.com/species/) Sustainability (http://www.joneshamiltonag.com/sustainability/) Store (http://www.joneshamiltonag.com/store/) Contact (http://www.joneshamiltonag.com/contact-us/)

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Products

PLT®

PWT® (http://www.joneshamiltonag.com/product/pwt/)

LS-PWT2® (http://www.joneshamiltonag.com/product/ls-pwt2/)

SAS® (http://www.joneshamiltonag.com/product/sas/)

AFG (http://www.joneshamiltonag.com/product/afg/)

ParlorPal® (http://www.joneshamiltonag.com/product/parlor-pal/)

PLT®

Get product and application details! Download the PLT® Product Data Sheet for Broilers (http://www.joneshamiltonag.com/jh/wp-content/uploads/2011/10/PLT-for-Broilers-Info-Sheet.pdf), Broiler Breeders (http://www.joneshamiltonag.com/jh/wp-content/uploads/2011/10/PLT-for-Broiler-Breeders-Info-Sheet.pdf) and Turkeys (http://www.joneshamiltonag.com/jh/wp-content/uploads/2011/10/PLT-for-Turkeys-Info-Sheet.pdf).

PLT®-poultry litter treatment has proven to be the most effective and economical litter acidifier available. PLT® creates a beneficial environment in the poultry house by controlling ammonia released from the litter and reducing litter pH levels, allowing birds to optimize their genetic potential. The ammonia bound by PLT® reduces environmental emissions and increases the nutrient value of poultry manure.

Flexible. PLT® can be used in any litter-based commercial poultry operation including those that grow broilers, breeders, turkeys, commercial pullets and layers, quail, pheasants and ducks.

Easy & safe application. PLT® can be applied using any type of spreader and it's the only litter amendment that can be safely applied with birds in the house. Plus, PLT® is the only litter amendment that is classified as non-hazardous and non-corrosive.

Fuel Savings. By immediately binding ammonia, PLT® decreases ventilation needs, which reduces fuel costs.

Valuable poultry manure. By turning volatile ammonia into stable ammonium sulfate, the value of the poultry manure increases.

PLT® Product Chemistry

When PLT® is applied it breaks down into sodium, hydrogen and sulfate.

$NaHSO_4 \rightarrow Na^+ + H^+ + SO_4^-$

The hydrogen lowers pH and converts ammonia into ammonium. This ammonium then binds to the sulfate portion keeping ammonia bound in the litter for the life of the flock. PLT® is a safe mineral acid that breaks down into products naturally found in the environment.

Environmental Chemistry

PLT® meets the guidelines of a "Green" ingredient. It is:

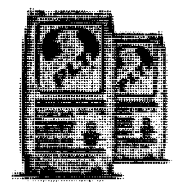
- **Biodegradable**
- **Non-toxic**
- **Ozone friendly**

PLT® follows the principles of "Green Chemistry" as described by the EPA and the California Department of Toxic Substances Control:

PLT®

Poultry Litter Treatment

Purchase Product



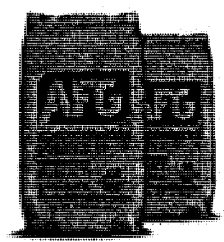
PLT® (http://www.joneshamiltonag.com/product

Contact to Purchase (/store/)

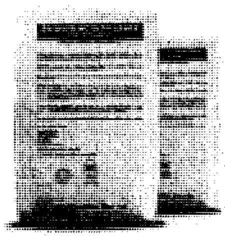
or call 1.888.858.4425

- The production process generates no waste and uses no solvents
- The process is analyzed in real time to prevent pollution and maximizes "atom economy" by containing all of the starting materials in the final products
- It is designed to be fully effective and has little toxicity
- It degrades after use breaking down into innocuous substances
- It is designed to minimize the potential for accidents including explosions, fires, and releases to the environment.

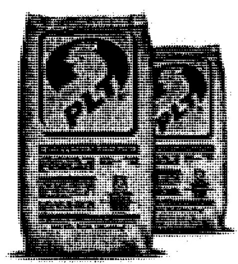
We provide safe, economical and environmentally friendly products that help manage some of the most significant issues the poultry industry faces. Contact your Jones-Hamilton rep (http://www.joneshamiltonag.com/contact-us/locate-a-representative/) today for assistance addressing your top issues.



AFG
(http://www.joneshamiltonag.com/product/afg/)



SAS®
(http://www.joneshamiltonag.com/product/sas/)



PLT®
(http://www.joneshamiltonag.com/product/plt/)

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Website Design by Red Clay Interactive (http://www.redclayinteractive.com)

A6

Jones-Hamilton - PLT - 82207

305 mm / 121 mm, 616 mm

40mm	153mm	121mm	305mm	121mm	152mm
Overlap		Gusset		Gusset	

7. APPLY PLT® ON TOP OF THE LITTER EVENLY 2-24 hours prior to bird placement. A broadcast or drop spreader can be used to apply PLT®. DO NOT INCORPORATE PLT® INTO THE LITTER.

8. Ventilate house to maintain a relative humidity between 50% and 70% while the birds are in the brood chamber. This will help minimize ammonia production, improve longevity of PLT® and provide the optimum environment for the birds. Humidity above 70% will cause litter caking and increased ammonia production.

9. After bird placement humidity will rise gradually. Check relative humidity levels frequently to control moisture and avoid unnecessary over-ventilation.

10. PLT® litter Treatment activation is not dependent on litter temperature. Relative humidity of 50%-70% is recommended for proper activity.

PLT® LITTER TREATMENT
PROPER HANDLING INSTRUCTIONS

Please wear the following protective items when applying PLT®: Safety Goggles, Long Pants with Pant Leg Outside of Boot or Shoe, Long Sleeve Shirt, Gloves and Dust Mask.

Any Questions or Comments?
Call the PLT® Hotline-800-379-2243
Jones-Hamilton Co. Agricultural Division
www.jones-hamilton.com

PLT® is a trademark of Jones-Hamilton Co. It is registered in the US and other countries.

THE SCIENCE OF LITTER MANAGEMENT®

Sodium hydrogen sulphate
Hydrogénosulfate de sodium

Poultry Litter Treatment

Poultry Litter Treatment

PLT®

Poultry Litter Treatment

JH Ag

www.JonesHamiltonAg.com

Manufactured in U.S.A. by
JONES-HAMILTON CO.

INGREDIENTS: Sodium hydrogen sulfate
CAS No. 7681-38-1

NOT APPROVED FOR USE IN ANIMAL FEED OR WATER

NET WT. 50 LB. (22.68kg)

Poultry Litter Treatment

Poultry Litter Treatment

PLT® LITTER TREATMENT
APPLICATION INSTRUCTIONS
BROILERS, TURKEYS &
PULLETS & BREEDERS

1. Close poultry house up tightly immediately after prior flock is moved. Ventilate only enough to prevent moisture condensation. This will help to release ammonia from the litter. Ventilate to remove ammonia when personnel are working in the house.

2. Remove caked and wet areas from the surface of the litter immediately after the last flock moves out. Do not disturb deep litter • DO NOT TILL.

3. Turn on brooders to preheat the litter to increase ammonia release from the litter prior to bird placement. The floor temperature should be a minimum of 85°F for at least 48 hours. Heating the litter helps release ammonia and moisture stored in the litter before birds are placed.

4. Prepare house as normal for chick, poult or pullet placement.

5. Fifteen (15) minutes before PLT® application, open inlets fully and turn fans on or drop sidewall curtains to exhaust ammonia as quickly as possible. Once ammonia gas is exhausted, turn fans off or close sidewall curtains. This prevents PLT® from being wasted on ammonia already released.

6. PLT® Litter Treatment ammonia control application rates:

- Broiler litter; 1 year old or less – 75-100 lbs./1,000 sq. ft. of floor space
- Broiler litter; Older than 1 year – 100-150 lbs./1,000 sq. ft. of floor space
- Turkey brood rings – 50 lbs./1,000 sq. ft. floor space
- Turkey growout barns – 75-100 lbs./1,000 sq. ft. of floor space
- Pullets or Breeders – 75-100 lbs./1,000 sq. ft. of floor space

Extreme conditions or special circumstances may require higher application rates for longer ammonia reduction.

JH-82207
FFB-1219-1111

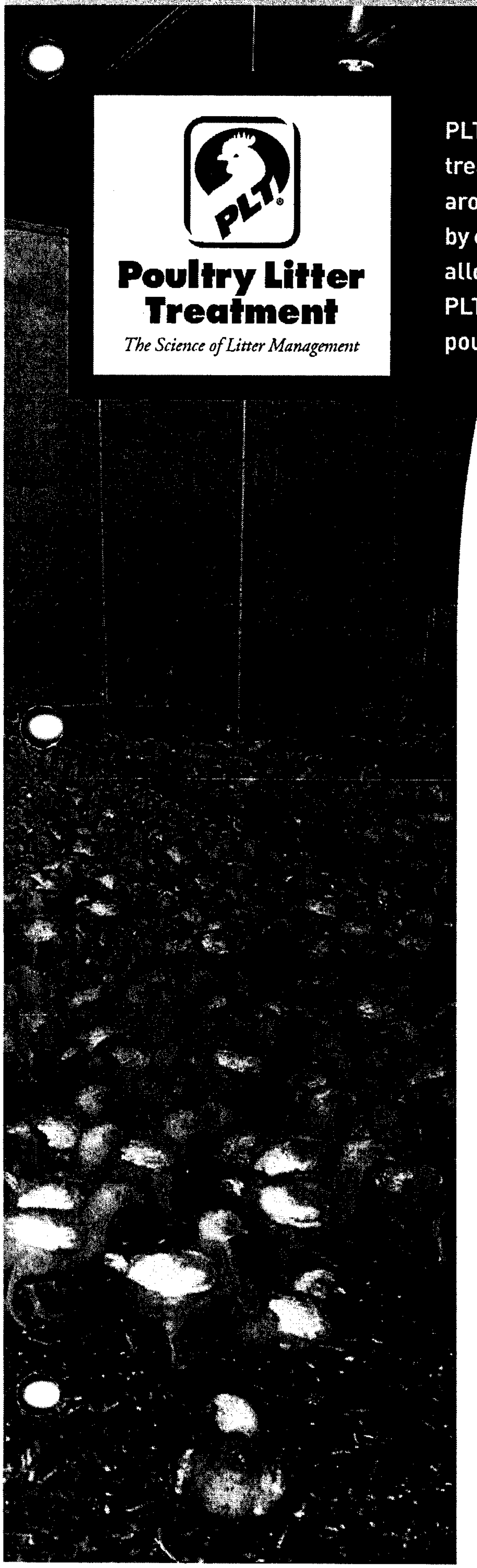
TUBING DIRECTION

892mm

98542	Poultry Litter Treatment	Jones-Hamilton - PLT - 82207

A7

PRODUCT DATA SHEET FOR BROILERS



Poultry Litter Treatment

The Science of Litter Management

PLT® litter acidifier has proven to be the most effective and economical litter treatment available, used in tens of thousands of commercial poultry houses around the world. PLT® creates a beneficial environment in the poultry house by controlling ammonia released from the litter and reducing litter pH levels, allowing birds to optimize their genetic potential. The ammonia bound by PLT® reduces environmental emissions and increases the nutrient value of poultry litter.

PHYSICAL DESCRIPTION

Appearance: Dry, white granular product. Odor: Slightly acidic, non-offensive.

USES

PLT® can be utilized with broilers, breeders, turkeys, commercial pullets and layers, quail, pheasants, ducks and any other litter-based operation.

PACKAGING

- 50 pound poly-vinyl bags
- 2,000 pound super sacks on pallet

APPLICATION

- PLT® is applied only once, as close to bird placement as possible.
- Due to its uniformity, PLT® application is quick and easy.
- Can be applied with any type of spreader.
- Commercial application is available in certain areas of the United States.
- Only litter amendment that can be safely applied with birds in the house.

BENEFITS

Ammonia Control/Fuel Savings

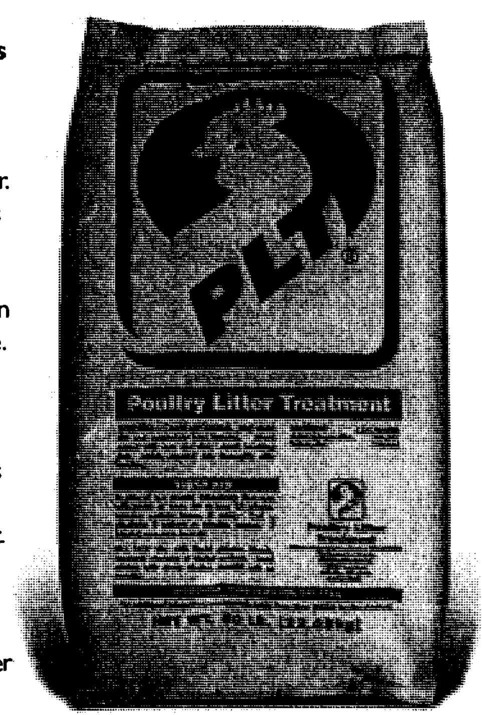
- Immediately binds ammonia in the treated area of the poultry house.
- Reduces urease production.
- Reduces ammonia released from the litter.
- Ammonia bound in the litter increases fertilizer value.

Litter Acidification

- Lowers the pH of poultry litter from an average 8.5 down to 1.5 on the pH scale.
- Acidifying litter dramatically improves litter ecology.

Safe Reuse of Litter

- Use of PLT® before each flock extends life of the litter.
- Saves the cost of new litter and cleanout.
- PLT®-treated litter is good for crops and the environment.
- Turns volatile ammonia into stable ammonium sulfate increasing the fertilizer value of the litter.



APPLICATION PROCEDURE FOR BROILERS

1. Close poultry house up tightly immediately after prior flock is moved. Ventilate only enough to prevent moisture condensation. This will help to release ammonia from the litter. Ventilate to remove ammonia when personnel are working in the house.
2. Remove caked and wet areas from the surface of the litter immediately after the last flock moves out. Do not disturb deep litter—DO NOT TILL.
3. Turn on brooders to preheat the litter to increase ammonia release from the litter prior to bird placement. The floor temperature should be a minimum of 85°F for at least 48 hours. Heating the litter helps release ammonia and moisture stored in the litter before birds are placed.
4. Prepare houses as normal for chick placement.
5. If applying on built-up litter, then fifteen (15) minutes before PLT® application, open inlets fully and turn fans on OR drop sidewall curtains to exhaust ammonia as quickly as possible. Once ammonia gas is exhausted, turn fans off or close sidewall curtains. This prevents PLT® from being wasted on ammonia already released.
6. **PLT® litter acifidier ammonia control application rates:**
   - **Broiler litter I year old or less: 75-100-lbs./1,000 sq. ft. of floor space**
   - **Broiler litter older than I year: 100-150-lbs./1,000 sq. ft. of floor space**

   Extreme conditions such as windrowing or special circumstances may require higher application rates.
7. Apply PLT® on TOP OF THE LITTER EVENLY 2-24 hours prior to bird placement. A broadcast or drop spreader can be used to apply PLT®. DO NOT INCORPORATE PLT® INTO THE LITTER.
8. Ventilate house to maintain a relative humidity between 50% and 70% while the birds are in the brood chamber. This will help minimize ammonia production, improve longevity of PLT® and provide the optimum environment for the birds. Humidity above 70% will cause litter caking and increased ammonia production.
9. After bird placement, humidity will rise gradually. Check relative humidity levels frequently to control moisture and avoid **unnecessary over-ventilation.**
10. PLT® litter amendment activation is not dependent on litter temperature. Relative humidity of 50%-70% is recommended for proper activity.
11. PLT® can be safely applied or re-applied with birds in the house at any time.

PAD ACIDIFICATION

1. **Completely** clean out old litter from house. The thick dark, wet decayed litter on the floor MUST be removed. Corners and footings should be swept or shoveled if necessary.
2. Wash and disinfect house as desired. Allow time for dirt pad to dry completely. Disinfectants with an acidic pH are preferred.
3. Apply PLT® directly to surface of DRY dirt pad at rate of 100-150 lbs./1000 sq. ft.
4. If desired, apply insecticides to dirt pad during or after PLT® application.
5. Install dry bedding material.
6. Prepare house as normal for bird placement.

PROPER USE AFTER IN-HOUSE COMPOSTING OR WINDROWING

In order to maintain air quality and ammonia levels below 25 PPM during brooding, much higher rates of PLT® will be necessary to neutralize the high ammonia challenge created from windrowing litter. In general, PLT® application rates need to be increased by 50-100% over the normal rate for the house type and litter age. Houses that would normally use 75 lbs./1000 sq. ft. of PLT® should now use 125 lbs. If your normal application rate is 100 lbs./1000 sq. ft. you should increase to 150-200 lbs./1000 sq. ft. in order to be able to counteract the high levels of ammonia being released when litter is leveled and pre-heated after windrowing.

PROPER STORAGE AND HANDLING INSTRUCTIONS

When applying PLT®, please wear the following protective items: Safety goggles, long pants with pant leg outside of boot or shoe, long sleeve shirt, gloves and dust mask. Store PLT® in a dry area and tightly re-seal open bags when storing. Be sure to prevent exposure from moisture prior to application. **DO NOT MIX** PLT® with liquid chlorine bleach, ammonia cleansers or similar products.

QUALITY AND SAFETY

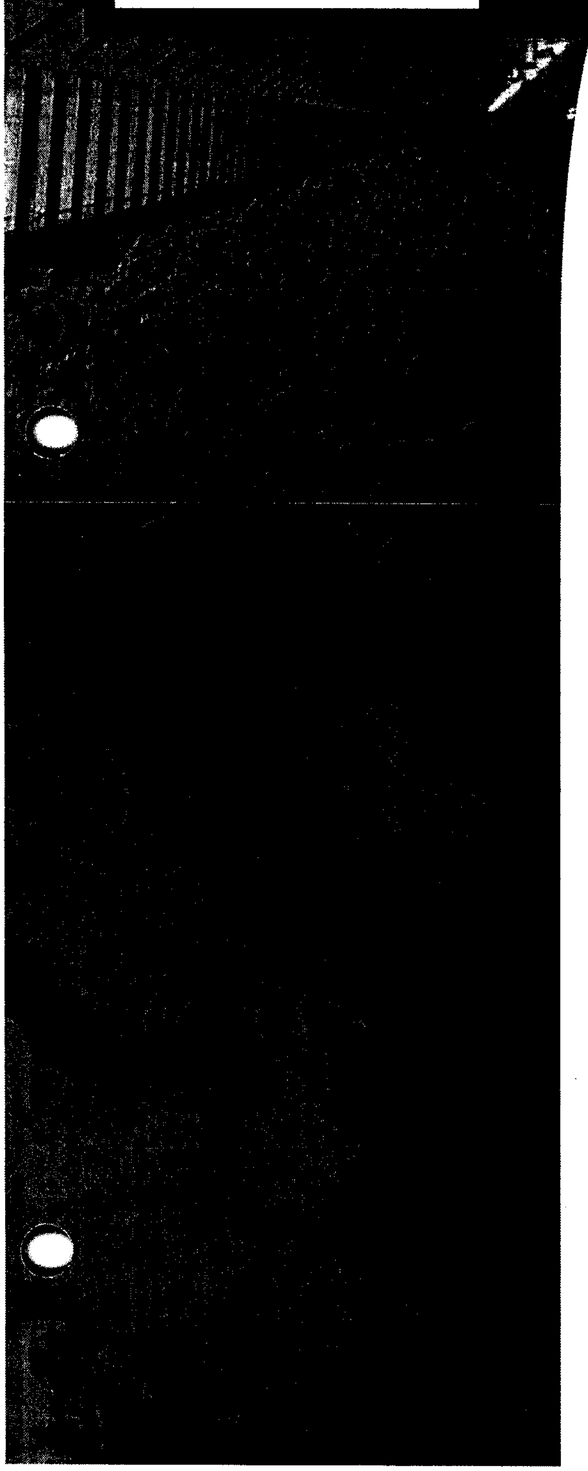
- Non-hazardous per current U.S. Department of Transportation definition
- Produced following a Quality Management System certified to the ISO 9001:2008 Standard
- GMO-Free
- BSE-risk free material

JHAg

PRODUCT DATA SHEET FOR BROILER BREEDERS

Poultry Litter Treatment
The Science of Litter Management

PLT® litter acidifier has proven to be the most effective and economical litter amendment available, used in tens of thousands of commercial poultry houses around the world. PLT® creates a beneficial environment in the poultry house by controlling ammonia released from the litter and reducing litter pH levels, allowing birds to optimize their genetic potential. The ammonia bound by PLT® reduces environmental emissions and increases the nutrient value of poultry litter.



PHYSICAL DESCRIPTION

Appearance: Dry, white granular product. Odor: Slightly acidic, non-offensive.

USES

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PACKAGING

- 50 pound poly-vinyl bags
- 2,000 pound super sacks on pallet

APPLICATION

- Due to its uniformity, PLT® application is quick and easy.
- Can be applied with any type of spreader.
- Commercial application is available in certain areas of the United States.
- Only litter amendment that can be safely applied with birds in the house.

BENEFITS

Ammonia Control/Fuel Savings

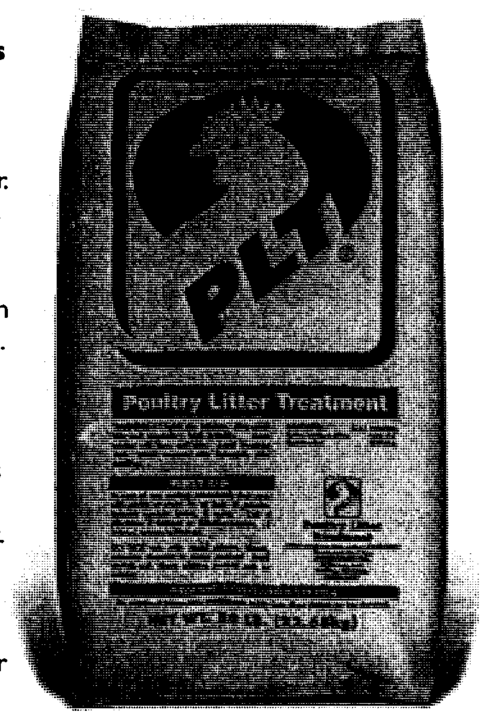
- Immediately binds ammonia in the treated area of the poultry house.
- Reduces urease production.
- Reduces ammonia released from the litter.
- Ammonia bound in the litter increases fertilizer value.

Litter Acidification

- Lowers the pH of poultry litter from an average 8.5 down to 1.5 on the pH scale.
- Acidifying litter dramatically improves litter ecology.

Safe Reuse of Litter

- Use of PLT® before each flock extends life of the litter.
- Saves the cost of new litter and cleanout.
- PLT®-treated litter is good for crops and the environment.
- Turns volatile ammonia into stable ammonium sulfate increasing the fertilizer value of the litter.



APPLICATION PROCEDURE FOR FLOOR-RAISED PULLETS

1. **Completely** clean out old litter from house. The thick dark, wet decayed litter on the floor MUST be removed. Corners and footings should be swept or shoveled if necessary.
2. Wash and disinfect house as desired. Allow time for dirt pad to dry completely. Disinfectants with an acidic pH are preferred.
3. Apply PLT® litter amendment directly to surface of DRY dirt pad at rate of 100-150 lbs/1000 sq. ft.
4. If desired, apply insecticides to dirt pad during or after PLT® application.
5. Install dry bedding material.
6. Prepare house as normal for bird placement.
7. If applying on built-up litter, then fifteen (15) minutes before PLT® application, open inlets fully and turn fans on OR drop sidewall curtains to exhaust ammonia as quickly as possible. Once ammonia gas is exhausted, turn fans off or close sidewall curtains. This prevents PLT® from being wasted on ammonia already released.
8. Apply PLT® on TOP OF THE LITTER EVENLY 2-24 hours prior to bird placement at a rate of 75-100 lbs/1000 sq. ft. A broadcast or drop spreader can be used to apply PLT®. DO NOT INCORPORATE PLT® INTO THE LITTER.
9. Ventilate house to maintain a relative humidity between 50% and 70% while the birds are in the brood chamber. This will help minimize ammonia production, improve longevity of PLT® and provide the optimum environment for the birds. Humidity above 70% will cause litter caking and increased ammonia production.
10. After bird placement, humidity will rise gradually. Check relative humidity levels frequently to control moisture and avoid **unnecessary over-ventilation**.
11. PLT® litter treatment activation is not dependent on litter temperature. Relative humidity of 50%-70% is recommended for proper activity.
12. Re-apply PLT® to the entire house at 75-100 lbs/1000 sq. ft. 24 hours prior to initiation of restricted feeding.
13. Re-apply PLT® to the entire house at 75-100 lbs/1000 sq. ft. 24 hours prior to cholera vaccination and final series of killed vaccinations.
14. PLT® litter amendment activation is not dependent on litter temperature. Relative humidity of 50-75% is recommended for proper activation (low or high humidity conditions may affect results).

APPLICATION PROCEDURE FOR BROILER BREEDERS & FLOOR-RAISED COMMERCIAL LAYERS

1. Completely remove all litter from the house. Sweep or shovel litter from corners, around footings, etc.
2. Wash down and disinfect house, if necessary and allow pad to dry completely.
3. Apply PLT® to the entire dirt pad at 75-100 lbs/1000 sq. ft.
4. Install dry bedding material.
5. Prepare houses as normal for pullet transfer.
6. Apply PLT® to the scratch area at 75-100 lbs/1000 sq. ft. 24 houses prior to pullet transfer. Do not incorporate PLT® into the litter.
7. Re-apply PLT® to the scratch area at 75-100 lbs/1000 sq. ft. on week 24, 28, 32, 38, 44, 50 and 56 (if carrying flock out to 65 weeks).

PLT® LITTER AMENDMENT PROPER STORAGE AND HANDLING INSTRUCTIONS

When applying PLT®, please wear the following protective items: Safety goggles, long pants with pant leg outside of boot or shoe, long sleeve shirt, gloves and dust mask. Store PLT® in a dry area and tightly re-seal open bags when storing. Be sure to prevent exposure from moisture prior to application. **DO NOT MIX** PLT® with liquid chlorine bleach, ammonia cleansers or similar products.

QUALITY AND SAFETY

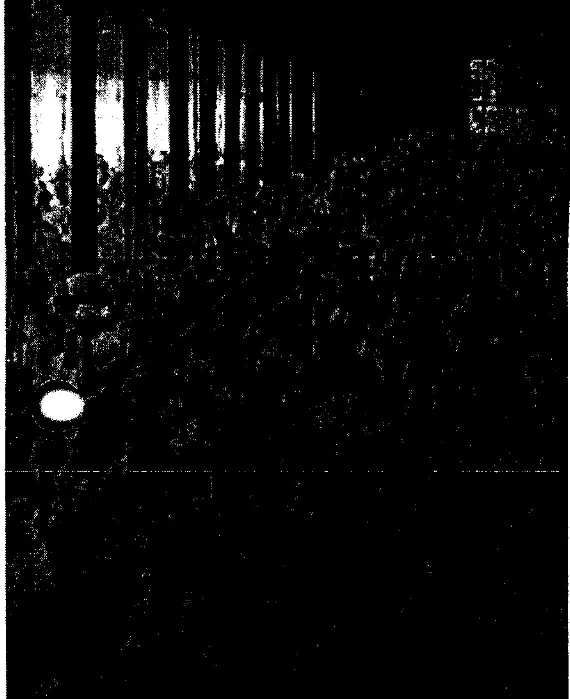
- Non-hazardous per current U.S. Department of Transportation definition
- Produced following a Quality Management System certified to the ISO 9001:2008 Standard
- GMO-Free
- BSE-risk free material

JHAg

PRODUCT DATA SHEET FOR TURKEYS

Poultry Litter Treatment
The Science of Litter Management

PLT® litter acidifier has proven to be the most effective and economical litter treatment available, used in tens of thousands of commercial poultry houses around the world. PLT® creates a beneficial environment in the poultry house by controlling ammonia released from the litter and reducing litter pH levels, allowing turkeys to optimize their genetic potential. The ammonia bound by PLT® reduces environmental emissions and increases the nutrient value of poultry litter.



PHYSICAL DESCRIPTION

Appearance: Dry, white granular product. Odor: Slightly acidic, non-offensive.

USES

PLT® can be utilized with broilers, breeders, turkeys, commercial pullets and layers, quail, pheasants, ducks and any other litter-based operation.

PACKAGING

- 50 pound poly-vinyl bags
- 2,000 pound super sacks on pallet

APPLICATION

- Due to its uniformity, PLT® application is quick and easy.
- Can be applied with any type of spreader.
- Commercial application is available in certain areas of the United States.
- Only litter treatment that can be safely applied with turkeys in the house.

BENEFITS

Ammonia Control/Fuel Savings

- Immediately binds ammonia in the treated area of the poultry house.
- Reduces urease production.
- Reduces ammonia released from the litter.
- Ammonia bound in the litter increases fertilizer value.

Litter Acidification

- Lowers the pH of poultry litter from an average 8.5 down to 1.5 on the pH scale.
- Acidifying litter dramatically improves litter ecology.

Safe Reuse of Litter

- Use of PLT® before each flock extends life of the litter.
- Saves the cost of new litter and cleanout.
- PLT®-treated litter is good for crops and the environment.
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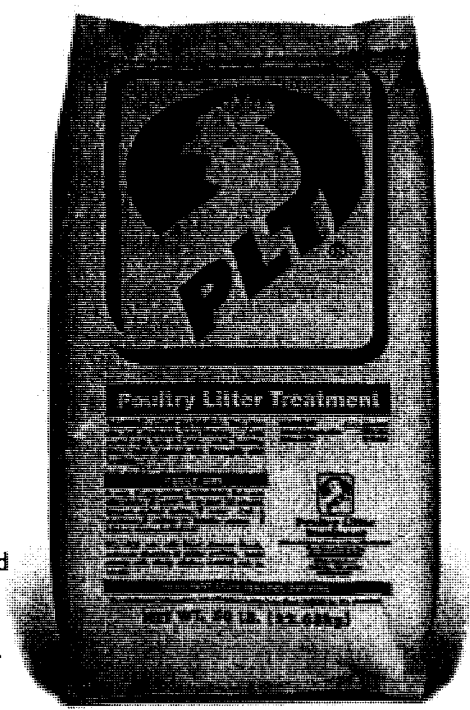

APPLICATION INSTRUCTIONS FOR COMMERCIAL TURKEYS—BROOD BARN

1. **Prepare houses as normal for poult placement.**
2. **Apply PLT® evenly on top of the litter** in the entire brood barn at 50 lbs./1000 sq. ft. 2 to 24 hours prior to poult placement. **Do not** incorporate PLT® into the litter.

APPLICATION INSTRUCTIONS FOR COMMERCIAL TURKEYS—GROW-OUT BARN

1. Completely close turkey barn immediately after prior flock is removed to maintain heat and purge ammonia. Ventilate enough to prevent moisture condensation or when personnel are working in the house.
2. **Remove caked and wet areas only** from the surface of the litter. **Do not till or disturb deep litter** (increasing surface area increases ammonia release). The litter serves as a barrier to ammonia stored in the deep layers of bedding.
3. Preheat the litter to purge ammonia prior to turkey transfer. Heating the litter causes a large purge of ammonia and moisture regardless of the litter's starting temperature. Preheating 48 hours in advance of turkey placement allows time for this purge to occur before the turkeys are in the house. The more ammonia that is purged at this stage, the longer low ammonia levels will be maintained after PLT® is applied.
4. If applying on built-up litter, then fifteen (15) minutes before PLT® application, open inlets fully and turn fans on OR drop sidewall curtains to exhaust ammonia as quickly as possible. Once ammonia gas is exhausted, turn fans off or close sidewall curtains. This prevents PLT® from being wasted on ammonia already released.
5. **Apply PLT® evenly on top of the litter** of the entire grow-out barn at 75-100 lbs./1000 sq. ft. 2 to 24 hours prior to turkey placement. Do not incorporate PLT® into the litter. The more ammonia and moisture present, the more PLT® required.
6. Begin minimum ventilation just prior to turkey placement.
7. PLT® can be **safely** applied or re-applied with turkeys in the house at any time.

PAD ACIDIFICATION

1. **Completely** clean out old litter from house. The thick dark, wet decayed litter on the floor MUST be removed. Corners and footings should be swept or shoveled if necessary.
2. Wash and disinfect house as desired. Allow time for dirt pad to dry completely. Disinfectants with an acidic pH are preferred.
3. Apply PLT® directly to surface of DRY dirt pad at rate of 100-150 lbs./1000 sq. ft.
4. If desired, apply insecticides to dirt pad during or after PLT® application.
5. Install dry bedding material.
6. Prepare house as normal for turkey placement.

RECOMMENDATIONS FOR TURKEY BREEDER APPLICATION

1. Apply PLT® at a rate of 100 lbs./1000 sq. ft. 24 hours prior to poult placement.
2. Apply PLT® at a rate of 75 lbs./1000 sq. ft. immediately prior to periods of highest stress in either the young hen or breeder house (i.e. 24 hours prior to killed vaccine administration).
3. Apply PLT® (whole house) at the rate of 100-150 lbs./1000 sq. ft. at least 24 hours prior to breeder placement. Make sure to include the cull pens and broody pens.
4. Re-apply PLT® at a rate of 75-100 lbs./1000 sq. ft. at times of therapeutic antibiotic usage in the breeder house (i.e. Amprol, penicillin).
5. Re-apply PLT® at a rate of 75-100 lbs./1000 sq. ft. approximately one week prior to anticipated peak production.

PROPER STORAGE AND HANDLING INSTRUCTIONS

When applying PLT®, please wear the following protective items: Safety goggles, long pants with pant leg outside of boot or shoe, long sleeve shirt, gloves and dust mask. Store PLT® in a dry area and tightly re-seal open bags when storing. Be sure to prevent exposure from moisture prior to application. **DO NOT MIX** PLT® with liquid chlorine bleach, ammonia cleansers or similar products.

QUALITY AND SAFETY

- Non-hazardous per current U.S. Department of Transportation definition
- Produced following a Quality Management System certified to the ISO 9001:2008 Standard
- GMO-Free
- BSE-risk free material

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Science and Cultivation of Edible and Medicinal Fungi/Romaine, Keil, Rinker & Royse (eds)/© 2004 Penn State/ISBN 1-883956-01-13

Effect of Ammonia Suppressants Used in Poultry Litter on Composting and Mushroom Production

R. Gonzalez-Matute and D. L. Rinker

Department of Plant Agriculture, University of Guelph, Vineland Station, ON L0R 2C0 Canada (DRinker@UoGuelph.Ca)

ABSTRACT

In the poultry industry, chemical suppressants are applied to chicken litter to decrease the level of ammonia. At the same time, mushroom (*Agaricus bisporus*) producers use poultry litter to increase the nitrogen level in the compost. To determine the influence of ammonia suppressants on composting and mushroom production, mushrooms were cultivated from compost prepared using litter treated during the poultry production process with PLT, Barn Fresh and Impact-P at 25.22 kg/100 m^2, 40 kg/100 m^2 and 0.49 kg/100 m^2, respectively. During all stages of composting, no significant differences (P>0.05) were noted between the treatments for total nitrogen, ammonia, pH, EC, ash and moisture in the compost and headspace air. Moreover, mushroom yield, and amino acid contents of the substrates and the mushrooms were not significantly affected ($P>0.05$) by the ammonia suppressants in the poultry litter. Thus, the mushroom industry can confidently use poultry litter amended with PLT, Impact-P and Barn Fresh at the recommended rates.

INTRODUCTION

The mushroom and poultry industries are significant contributors to the Canadian economy. In 2001, Canada produced poultry products worth $1.8 billion, 5% of cash receipts from farming operations. During the same year, Canadian mushroom producers cultivated 86,228 tonnes of mushrooms (*Agaricus bisporus*) valued at $274 million in farm gate value.

Vast quantities of poultry litter, a mixture of bedding and manure, are produced. The mushroom industry is a desirable outlet for re-cycling poultry manure wastes in its compost. Approximately 22,500 tonnes of dry-bedded poultry litter is used by the Ontario mushroom industry annually (William Stevens, Canadian Mushroom Growers' Association, pers. comm.).

Ammonia, produced from the nitrogenous fraction of animal wastes by microbial activity, is detrimental to the health of the birds and farm workers. One method of lowering the ammonia emissions is to add materials to the litter. The most common additives can be categorized, according to their modes of action, into the following five groups: digestive additives, acidifying additives, adsorbents, urease inhibitors and saponins from Mohave yucca (*Yucca schidigera*) (McCrory & Hobbs 2001). Ammonia gas is a necessity during mushroom (*Agaricus bisporus*) compost preparation but detrimental to the growth of the mushroom mycelium or production. Companies producing ammonia suppressant materials claim that their products may lower litter pH, bind ammonia or nitrogen compounds or manage the microorganism in the litter; however, the active life of the products is not completely clear.

The compatibility of the two industries is in question. This paper focuses on the effects that ammonia suppressants used in poultry litter may have on mushroom compost preparation and production so that mushroom industry can confidently and economically recycle poultry litter.

MATERIALS AND METHODS

In order to evaluate the effects of the ammonia suppressants on mushroom production, the ammonia suppressants were first applied to poultry litter during the rearing of a flock of birds and later the litter was harvested for use in mushroom compost preparation and production.

Ammonia suppressant treatments

The products tested in this research were selected among those most commonly used in Ontario with the intent that each tested product has a different mode of action. Three ammonia suppressant products: Poultry Litter Treatment ™ (PLT) (Jones-Hamilton Co., Salisbury, MD), Barn Fresh (Absorbent Marketing Co. Ltd., Kamloops, BC) and Impact-P (Papillon Agricultural Products Canada, Innerkip, ON) were applied to the bedding material in a broiler chicken barn (Clark Co. Ltd., Wainfleet, ON). Bedding material consisted of a 5-cm layer of chopped wheat straw. Each product was randomly applied to the litter in three 2.5-m wide strips after the third wk of the bird's growth. Rates used on each trial for PLT, Impact-P and Barn Fresh were 25.22 kg/100 m^2, 0.49 kg/100 m^2, and 40 kg/100 m^2, respectively. Four wks after application the litter was collected, blended and used for the preparation of the mushroom compost. Four batches of compost were prepared, one per product and a control with the experiment repeated four times.

Phase I compost preparation

Mushroom compost formulation was calculated based on chicken litter moisture and total nitrogen obtained the wk previous to compost preparation and later adjusted.

The chicken litter for each treatment was added separately to chopped wheat straw (~120 kg) together with the gypsum and 500 L of water the day following collection of litter in the first three trials. In trial 4, the pre-wet started 4 days after litter collection. Control was prepared first followed by the treatments. The well-mixed material from each treatment was placed into a single insulated composting box, 2-m x 1-m^2, with a perforated floor and a lid with a hole. Compost from each treatment was removed from its box every 2-5 days with the help of a bobcat, mixed, watered as necessary and re-filled into the same box four times during the composting process.

Compost temperatures were recorded by a computer (Chameleon TC^2, Groft Electronics Inc., Landenberg, PA) hourly during the composting process. Six probes were used per box, two near the bottom, two in middle and two near the top part of the material at different depths. The two probes on each level were placed on opposite corners.

Initial mix (pre-wet) samples from each treatment were randomly collected after all the ingredients were well mixed. At each turn and prior to Phase II, samples of compost from each treatment were collected from different parts of the pile (top, middle and bottom). In both cases, two sub-samples were analysed for moisture, pH, electrical conductivity (EC), nitrogen, ammonia and ash.

The gaseous ammonia concentration from each treatment was measured daily during the Phase I composting process. A hole was dug on top of the compost and a plastic container (6-cm x 5-cm x 7-cm) was placed in it and covered with compost completely. Container content was aspirated with an air-sampling pump (Gilian HFS-513, Sensidyne Inc., Clearwater, FL) at 2.5 L/min through a NH_3 and oxygen analyzer (Reader Industrial Scientific TX-418, USA). Additionally, the NH_3 concentration within the container was measured using sampling tubes (Gastec-3M Detector tubes).

Phase II

The compost after 14 days was filled into plastic trays (46-cm x 46-m x 26-cm with 12 holes of 3-cm on the bottom) with approximately 21 kg of compost. Nine trays of each treatment were placed on carts inside two climate-controlled rooms whose environment was managed by a process control computer (Fancom 665, Techmark Inc., USA). Each cart had three levels, and three trays of each treatment were placed on each level in each room on the last three trials. Compost and air temperatures were recorded by the Fancom computer system.

Phase II included a pre-pasteurization period to stabilize the compost temperatures, a pasteurization for 5 h at 60 C within the first 24 h, and a conditioning at 50 C. This was accomplished in 9 days on the first trial and 6 days on the rest of the trials. When ammonia was under 10 ppm, according to the gas detector tubes the compost temperature was cooled down to 25 C for spawning.

From the first day of conditioning, samples of ammonia gas were taken from each compost treatment. A plastic beaker (500 mL) was inserted 3-4 cm deep into the top of the compost with its borders covered with compost. Air and gas were aspirated and measured from a hole in the beaker using the same equipment as in the Phase I compost preparation.

Spawning and spawn-run

Phase II compost was inoculated with 225 g *A. bisporus* spawn (Sylvan A-15) per 27 kg compost, placed into plastic trays (24-cm high x 44-cm wide x 56-cm long), pressed and covered with a plastic. The trays of spawned compost were placed on carts and moved into the climate-controlled room. Each treatment had nine replicates placed at three different levels. In trial 1, trays were arranged in a complete randomized design (CRD), and on the rest, the compost trays were placed in a randomized complete block design (RCBD) with three trays of each treatment per level.

Air temperature and circulation of the room were controlled to keep the compost temperature around 24-28°C. Relative humidity of the room was maintained between 90-95%.

Samples of compost were collected randomly from each treatment from the mixed compost at spawning for moisture, pH, electrical conductivity (EC), ash, nitrogen and ammonia.

Casing

After 2 wks the colonized compost was cased (top dressed) with moistened peat moss (56 kg), lime (52 kg), casing inoculum (CI) (Sylvan A-15). Compost temperature was maintained at 24-26°C during the wk after casing. The CO_2 levels were maintained less than 0.1% and relative humidity between 90-95%. The casing material was watered sufficiently to keep desired moisture content.

Pinning

Between 9 and 14 days after casing, pinning was initiated. Air temperature and the CO_2 concentration were changed to 17-19°C and to under 0.1%, respectively, to trigger the development of the mushrooms. Relative humidity was maintained at 90% and compost temperature around 20°C.

Mushroom harvest

Three flushes of mushrooms were harvested. All mushrooms were picked by hand at market maturity with the veil closed and trimmed leaving approximately 2 cm of stem. Mushrooms from each tray were weighed and counted. Compost temperatures were measured and recorded with the Fancom computer control system.

Statistical analysis

Phase I data for compost analysis and NH_3 gas were analyzed by using Proc MIXED (SAS® 8.02; SAS Institute Inc., USA) as a randomized complete block design (RCBD) with each trial as a block. Means were separated using Tukey's Honestly Significant Difference test (Tukey's $_{HSD}$) at P=0.05.

Phase II data were analyzed by using Proc MIXED. The first trial was analyzed separately as a completely randomized design (CRD) with treatment as a fixed factor and each room as a random factor. A RCBD was used for the last three trials, with each trial as a block. Blocks, rooms, levels and its correspondent interaction were considered random factors. Means were separated using Tukey's HSD at a significance level of P=0.05.

Spawning and spent mushroom substrate data were analyzed by using Proc MIXED. A RCBD with random block effects was used, with each trial as a block. Significant differences between the means were assessed by Tukey's HSD at a significance at P=0.05.

Mushroom yields and counts were compared within treatments on each flush, trial and in total. For total yields and counts of mushrooms, trials 2, 3, and 4 were arranged as a RCBD with the levels of the shelves used as blocks. Once the levels were confirmed to be not significant, the data were re-analysed, including the trial 1, as a new RCBD with each trial used as a block as a random effect. Data were analyzed by using Proc MIXED. Means were separated using Tukey's HSD at a significance at P=0.05.

RESULTS

Phase I

Nitrogen contents were significantly higher than the control at the pre-wet stage. IMPACT-P was significantly higher in total nitrogen at filling than PLT (Table 1).

Total nitrogen values increased about 32% for IMPACT-P from the start of composting. Whereas, the other products and control increased 20 to 24% during the same period.

Moisture, pH, EC, ash, ammonia content, ammonia gas and temperature were not significantly affected by the addition of poultry litter amended with ammonia suppressants at any time measured during the composting cycle (Tables 1 & 2).

Phase II

Ammonia gas for trial 1 was analyzed separately from the others, because the initial nitrogen content was higher. Phase II period for trial 1 lasted 9 days (3 days more than the other trials). However, no significant differences due to the treatment effect were observed. PLT and Impact-P showed values of ammonia gas (ppm) up to 4.2 times higher than the other treatments. On day 9, previous to spawning, Impact-P showed a mean value of 11.25 ppm (Table 3).

Mushroom harvest

Three flushes of mushrooms were harvested. All mushrooms were picked by hand at market maturity with the veil closed and trimmed leaving approximately 2 cm of stem. Mushrooms from each tray were weighed and counted. Compost temperatures were measured and recorded with the Fancom computer control system.

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In trials 2-4, significant differences were observed in the ammonia content (ppm) with some differences between instruments (Table 3). In general, Impact-P either ranked higher or was significantly higher than the control for the majority of the 6-day period. PLT almost always second. Despite the higher levels in the suppressant treatments, the ammonia concentrations were at acceptable levels for spawning.

Table 1. Means of different compost treatments prepared with broiler litter amended with ammonia suppressants at different stages of the Phase I mushroom composting process

Treatments	Turn	Moisture	pH	EC	Ash	Nitrogen	Ammonia
Control	Pre-wet	71.19 a	7.17 a	1.67 a	12.75 a	0.93 b	-
PLT	Pre-wet	72.92 a	7.17 a	1.91 a	13.12 a	1.12 a	-
IMP-P	Pre-wet	73.19 a	7.26 a	1.89 a	14.25 a	1.22 a	-
Barn Fresh	Pre-wet	71.78 a	7.41 a	1.99 a	12.62 a	1.12 a	-
SE[3]	Pre-wet	1.068	0.223	0.299	0.882	0.056	-
Control	1	70.17 a	8.14 a	2.04 a	14.00 a	1.28 a	0.175 a
PLT	1	71.16 a	8.14 a	2.09 a	14.50 a	1.28 a	0.155 a
IMP-P	1	71.35 a	8.23 a	2.05 a	13.75 a	1.35 a	0.179 a
Barn Fresh	1	71.55 a	8.04 a	2.14 a	14.37 a	1.28 a	0.178 a
SE	1	1.072	0.091	0.279	1.216	0.109	0.1439
Control	2	70.55 a	7.99 a	2.69 a	15.25 a	1.53 a	0.221 a
PLT	2	72.56 a	7.96 a	2.86 a	15.75 a	1.56 a	0.274 a
IMP-P	2	72.07 a	8.04 a	2.74 a	15.87 a	1.58 a	0.282 a
Barn Fresh	2	72.57 a	8.00 a	2.71 a	17.12 a	1.57 a	0.299 a (n=3)
SE	2	1.505	0.069	0.392	0.566	0.119	0.1556
Control	3	72.32 a	7.88 a	2.82 a	16.87 a	1.58 a	0.037 a (n=3)
PLT	3	73.04 a	7.94 a	2.65 a	17.62 a	1.66 a	0.018 a (n=3)
IMP-P	3	72.46 a	7.99 a	2.80 a	17.87 a	1.71 a	0.055 a (n=3)
Barn Fresh	3	72.48 a	7.96 a	2.97 a	17.50 a	1.75 a	0.028 a (n=3)
SE	3	1.288	0.089	0.292	0.744	0.090	0.0257
Control	4	73.30 a	7.77 a	3.00 a	18.37 a	1.82 a	0.024 a (n=3)
PLT	4	74.40 a	7.88 a	3.39 a	18.87 a	1.83 a	0.006 a (n=3)
IMP-P	4	74.19 a	7.87 a	3.31 a	18.62 a	1.84 a	0.012 a (n=3)
Barn Fresh	4	74.18 a	7.97 a	2.76 a	18.87 a	1.79 a	0.007 a (n=3)
SE	4	0.980	0.103	0.450	0.881	0.113	0.0118
Control	Filling	73.43 a	7.92 a	3.09 a	18.50 a	1.84 ab	0.005 a (n=3)
PLT	Filling	74.70 a	7.90 a	3.37 a	19.50 a	1.83 b	0.004 a (n=3)
IMP-P	Filling	73.96 a	7.91 a	2.45 a	19.00 a	2.02 a	0.002 a (n=3)
Barn Fresh	Filling	73.66 a	7.98 a	2.88 a	20.37 a	1.94 ab	0.003 a (n=3)
SE	Filling	1.134	0.093	0.427	0.981	0.114	0.0020

[1] Poultry Litter Treatment™ (Jones-Hamilton Co., USA) at 25.22, Impact-P (Papillon Agricultural Products Canada, Innerkip, ON) at 0.49 and Barn Fresh (Absorbent Marketing Co. Ltd., Kamloops, BC) at 40 kg/100 m^2

[2] Means in the same column and turn followed by a different letter are significantly different at P=0.05 according to Tukey's $_{HSD}$. Means are the average of four trials (n=4) and their respective duplicates unless otherwise noted

[3] Standard error (SE) of the mean

[4] Moisture, ash, total nitrogen, and ammonia are expressed as % and electrical conductivity (EC) in mho/cm

Table 2. Ammonia gas (ppm) released by the different compost treatments during the different stages of the Phase I mushroom composting

Treatment[1]	Sampling Day[2]	NH₃ Analyzer Mean	NH₃ Analyzer SE	NH₃ Tubes Mean	NH₃ Tubes SE	Temperature Mean	Temperature SE
Control	Day 2[3]	628	160.6	670 (n=2)	240.9	64.0	4.17
PLT	Day 2	641		730 (n=2)		65.3	
Impact-P	Day 2	760		800 (n=2)		68.4	
Barn Fresh	Day 2	498		680 (n=2)		69.0	
Control	1st turn	442	90.4	560 (n=2)	92.1	67.4	3.38
PLT	1st turn	373		530 (n=2)		64.2	
Impact-P	1st turn	525		695 (n=2)		68.4	
Barn Fresh	1st turn	433		500 (n=2)		68.5	
Control	2nd turn	267	115.0	363	149.8	68.7	2.24
PLT	2nd turn	226		267		67.2	
Impact-P	2nd turn	191		260		70.1	
Barn Fresh	2nd turn	141		193		69.1	
Control	3rd turn	186	43.0	237	47.8	68.5	1.50
PLT	3rd turn	134		187		66.3	
Impact-P	3rd turn	128		140		67.7	
Barn Fresh	3rd turn	148		187		67.3	
Control	4th turn	63	54.0	75	65.0	62.0	4.16
PLT	4th turn	56		67		62.0	
Impact-P	4th turn	81		93		61.6	
Barn Fresh	4th turn	68		77		62.0	
Control	1 day bf[4]	66	52.7	62	56.8	63.9	2.45
PLT	1 day bf	35		48		59.2	
Impact-P	1 day bf	95		134		58.8	
Barn Fresh	1 day bf	64		86		61.2	
Control	Filling	75	53.0	117	48.5	64.2	3.37
PLT	Filling	67		76		59.1	
Impact-P	Filling	109		95		60.7	
Barn Fresh	Filling	77		79		59.7	

[1]Poultry Litter Treatment ™ (Jones-Hamilton Co., USA) at 25.22 kg/100 m^2, Impact-P (Papillon Agricultural Products Canada, Innerkip, ON) at 0.49 kg/100 m^2 and Barn Fresh (Absorbent Marketing Co. Ltd., Kamloops, BC) at 40 kg/100 m^2

[2]Means in the same column and sampling day are not significantly different at P=0.05% according to Tukey's $_{HSD}$. Means are the average of three trials (n=3) unless noted. Means and standard errors (SE) were obtained with Proc MIXED (SAS 8.02, SAS Institute Inc., USA). Each temperature value is the average of 6 values obtained at different points of the compost when NH_3 was measured

[3]Second day of composting

[4]1 day before filling

Table 3. Ammonia gas (ppm) measured from different composts previously amended with poultry litter containing different ammonia suppressants during the conditioning stage of Phase II composting on trial 1 and trials 2, 3 and 4

Trial	Treatment[1]	Phase II Day	NH_3 Analyzer Mean[2]	NH_3 Analyzer SE	NH_3 Tubes Mean[2]	NH_3 Tubes SE
1	Control	6	26.91 a (n=3)	21.511	-	-
	PLT	6	108.55 a (n=5)	16.753	-	-
	IMP-P	6	114.24 a (n=3)	21.511	-	-
	Barn Fresh	6	31.00 a (n=2)	26.246	-	-
	Control	8	25.25 a (n=4)	27.705	-	-
	PLT	8	75.75 a (n=4)	27.705	-	-
	IMP-P	8	33.50 a (n=4)	27.705	-	-
	Barn Fresh	8	19.75 a (n=4)	27.705	-	-
	Control	9	6.00 a (n=4)	1.944	-	-
	PLT	9	7.00 a (n=4)	1.944	-	-
	IMP-P	9	11.25 a (n=4)	1.944	-	-
	Barn Fresh	9	7.25 a (n=4)	1.944	-	-
2, 3 & 4	Control	1	57.87 b (n=14)	20.856	114.68 a (n=8)	49.276
	PLT	1	62.21 b (n=15)	20.825	122.85 a (n=8)	49.302
	IMP-P	1	80.68 a (n=15)	20.825	126.19 a (n=8)	49.276
	Barn Fresh	1	59.46 b (n=15)	20.831	106.73 a (n=8)	49.302
	Control	2	19.34 b (n=18)	7.729	49.23 b (n=12)	19.215
	PLT	2	21.54 b (n=17)	7.761	54.70 b (n=13)	18.995
	IMP-P	2	42.24 a (n=18)	7.730	97.70 a (n=13)	18.971
	Barn Fresh	2	20.68 b (n=18)	7.730	50.82 b (n=14)	18.735
	Control	3	5.20 a (n=11)	5.762	11.02 b (n=15)	4.132
	PLT	3	6.29 a (n=12)	5.731	13.43 ab (n=14)	4.173
	IMP-P	3	8.76 a (n=15)	5.664	16.77 a (n=15)	4.146
	Barn Fresh	3	4.55 a (n=13)	5.713	12.98 ab (n=14)	4.173
	Control	4	5.57 a (n=6)	2.471	9.35 b (n=9)	8.965
	PLT	4	7.42 a (n=5)	2.615	12.12 ab (n=9)	8.965
	IMP-P	4	13.30 a (n=8)	2.265	20.29 a (n=10)	8.846
	Barn Fresh	4	4.61 a (n=5)	2.615	8.49 b (n=10)	8.880
	Control	5	3.56 b (n=5)	2.915	4.93 a (n=18)	2.321
	PLT	5	4.96 ab (n=5)	2.915	8.38 a (n=15)	2.404
	IMP-P	5	11.26 a (n=6)	2.938	5.39 a (n=16)	2.369
	Barn Fresh	5	4.44 b (n=5)	3.014	5.11 a (n=16)	2.373
	Control	6	-	-	3.19 a (n=36)	0.635
	PLT	6	-	-	2.46 ab (n=36)	0.635
	IMP-P	6	-	-	2.17 b (n=36)	0.636
	Barn Fresh	6	-	-	2.74 ab (n=36)	0.635

[1]Poultry Litter Treatment™ (Jones-Hamilton Co., USA) at 25.22 kg/100 m^2, Impact-P (Papillon Agricultural Products Canada, Innerkip, ON) at 0.49 kg/100 m^2 and Barn Fresh (Absorbent Marketing Co. Ltd., Kamloops, BC) at 40 kg/100 m^2

[2]Means in the same column followed by a different letter are significantly different at P=0.05% according to Tukey's $_{HSD}$.

Means and standard errors (SE) were obtained with Proc MIXED (SAS 8.02, SAS Institute Inc., USA)

Table 4. Combined mushroom count and yield per tray (0.254 m^2) for all trials

Treatment[1]	Flush 1		Flush 1+2		Total	
	Count	Yield[2]	Count	Yield	Count	Yield
Control	176[3]	11.93	477	24.68	535	28.90
PLT	171	11.93	459	24.37	531	29.13
Impact-P	178	12.99	471	25.75	541	30.59
Barn Fresh	176	12.20	462	24.21	524	28.35
SE	26.4	1.457	38.5	1.341	46.6	1.631

[1]Poultry Litter Treatment™ (Jones-Hamilton Co., USA) at 25.22 kg/100 m^2, Impact-P (Papillon Agricultural Products Canada, Innerkip, ON) at 0.49 kg/100 m^2 and Barn Fresh (Absorbent Marketing Co. Ltd., Kamloops, BC) at 40 kg/100 m^2

[2]Yield means and SE were transformed to be expressed as kg/m^2

[3]All values in the same column are not significantly different from one another at P=0.05% according to Tukey's HSD. Each value is the mean of 36 observations (n=36). Means and standard errors (SE) were obtained with Proc MIXED (SAS 8.02, SAS Institute Inc., USA)

Spawning

Moisture, pH, EC, ash and nitrogen were significantly the same for each variable within treatment (data not shown).

Mushroom production

Yield and count of mushrooms harvested on the 1st flush, 1st + 2nd flush, and the sum of the three flushes for four trials were not significant affected by treatments. Impact-P was the highest yield of mushrooms on the first, second and total of all flushes, but was not significantly different from the control and other ammonia suppressants. Total counts for ammonia suppressants were lower, but not significant when compared to the control treatment (Table 4).

DISCUSSION

Ammonia suppressants-treated poultry litter did not alter the composting process or affect the mushroom production process or yield. Beyer et al. (2000) had similar results. They used one-sixth of the treated poultry litter that we used, and the initial nitrogen content for the "standard treated and untreated poultry manure" and the "treated poultry manure" were 1.52% and 1.43%, respectively, which were similar to the rates used the present study.

In this study, no significantly negative effect was found on the mushroom composts prepared with litter treated with PLT, Barn Fresh and Impact-P ammonia suppressants at the manufacturers recommended rates. At pre-wet stage, the total nitrogen content of the mixed material was significantly higher in treatments than in the control. However, no differences in moisture, pH, EC and ash content were observed.

During Phase I composting, Beyer et al. (2000) did not find differences in temperature among treatments. After Phase I, all treated and untreated composts were similar in the degree of decomposition. The pH, moisture, ash content and total nitrogen for all composts were not significantly different. In our case, the only significant difference was observed was for total nitrogen content at filling. Impact-P showed the highest nitrogen content and was significantly higher than PLT; Impact-P was significantly higher than control, but only at P<0.06.

In this study, ammonia gas released from the different compost batches during Phase I showed no significant differences. Beyer et al. (2000), observed significant differences on ammonia gas at the end of Phase I, however, only in the case where the compost was treated with Ammonia Hold (AH).

In this study, during Phase II, Impact-P compost showed significantly higher levels of ammonia gas during all the days of the conditioning on at least one of the measuring methods in the last three trials, where the initial nitrogen content was lower than 1.68%. However, on the last day of conditioning, ammonia content on Impact-P was significantly lower than the control. Ammonia volatilization took longer (3 days) in the trial with higher than 1.83% initial nitrogen content. Nitrogen content of all treatments at end of Phase I in this trial was above 2%. High nitrogen (>2%) at end of Phase I is more difficult to condition during Phase II (Beyer et al. 2000).

Our results from an analysis of compost at spawning were similar to those of Beyer et al. (2000). At spawning, they reported that all composts showed very high nitrogen contents (2.26-2.48%). In this study, mean nitrogen contents ranged between 2.18 to 2.26% at spawning. Moisture, pH, percent nitrogen and ash were similar for all composts in both studies. Beyer et al. (2000) found significant differences for percent NH_3-N, but only where the poultry manure was repeatedly treated with PLT. Control treatments were a little higher than the PLT-treated material. No temperature differences were recorded between treatments during the spawn-growing period in both studies.

In this study, the poultry litter treated with ammonia suppressants did not adversely affect mushroom productivity and quality. Only in the fourth trial, Barn Fresh was significantly lower in total yield and count of mushrooms than the control. However, that could be a consequence of the high moisture content (77%) that Barn Fresh showed at spawning. According to Flegg and Wood (1985), good yields can be obtained in synthetic compost with water contents as high as 72% at spawning. Analysis of the yield from all trials on first flush, accumulation of first and second flush and all three flushes, showed no significant differences. However, on an individual trial basis, Barn Fresh produced a significantly higher total yield than the control or PLT. The PLT treatment yielded significantly lower than the control, and, in another trial, Impact-P was significantly higher in total yield than the other the treatments. This suggested that sometimes yields might be lower or higher for individual composts when an ammonia suppressant amended poultry litter is used.

In the study of Beyer et al. (2000), mushroom harvest began at 16-18 days post casing. The influence of the two suppressants used on mushroom yield produced mixed results. Mushroom yield and size in the AH-treated composts were not significantly different from the manure control. Mushroom yield from the PLT-treated composts was not significantly different than one of the control substrates. However, for the PLT-treated (1X rate) compos,t yield was significantly higher than the other control compost, but not significantly higher than the PLT-treated (2X rate). The poultry litter compost with multiple applications of PLT results showed no differences for both control treatments.

Further research is needed to evaluate the effect of the ammonia suppressants under different conditions, such as multiple applications of the products to the litter, different rates and higher initial compost nitrogen, on mushroom compost preparation and mushroom production.

In conclusion, ammonia suppressants as a component of the poultry litter used to make mushroom compost did not alter the composting process, the chemical components of the growth substrate or mushroom yield. Thus, the widespread practice of applying PLT, Barn Fresh or Impact-P according to label recommendations for managing ammonia in poultry barns does not compromise the use of poultry litter as a compost ingredient in the mushroom industry.

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PLT treated poultry manure used as a Phase I substrate supplement and its influence on mushroom composting and yield

Progress Report
by
David M. Beyer and Tom Rhodes
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Introduction

All commercial growing of the white button mushroom, *Agaricus bisporus*, depends on a composted material. Composting or mushroom substrate preparation is a process involving two interdependent procedures: Phase I, the outdoor composting process and Phase II, the indoor pasteurization process. Phase I is characterized by building the raw ingredient piles or ricks. These ricks are then periodically turned, watered and re-formed. At higher pile temperatures, many chemical reactions occur to form complex carbohydrates and lignin-humic complexes that serve as food for the mushroom. Raw substrate ingredients also accommodate many microorganisms. With the addition of water to the dry ingredients and the building of the pile, these microbes grow and reproduce. The growth requires (1) suitable temperatures; (2) adequate moisture; and (3) sufficient oxygen; and (4) available food. The addition of nutrients at this time is directed therefore toward the nourishing of a microbial population in the substrate rather than direct nutrient addition for the bulk substrate ingredients. Microorganisms also need nitrogen and carbohydrates if they are to grow and reproduce. The nitrogen content of the substrate pile should be approximately 1.4 to 1.5 percent before the composting process begins to assure that the microbes have a sufficient supply of nitrogen to complete an active fermentation efficiently. In horse manure substrate, the straw contains both droppings and liquid waste from horses giving it an average nitrogen content of 1.2 to 1.3 percent. To raise the nitrogen content of the substrate to the desired level, supplements containing organic nitrogen such as poultry manure, brewers grains, cottonseed meal, or soybean meal are added. In horse manure substrate, the carbohydrates are primarily supplied by the straw. Whereas in hay based substrates, cottonseed hulls or corn cobs supply the carbohydrates. Gypsum (at the rate of 60-95 lb/dry ton of substrate ingredients) is also added to improve their physical characteristics by preventing greasiness.

It has been suggested that adding PLT, a dry acid compound ($Na\text{-}H_2SO_4$), to poultry manure will suppress the release of ammonia in poultry manure while raising chickens. Poultry manure is the most widely used nitrogen supplement for mushroom composting. It had been reported that formaldehyde type ammonia-odor suppressive compounds used on poultry litter to suppress ammonia inside the poultry houses. However, they delayed the release of ammonia during Phase II, not Phase I as normal, and the substrate were difficult to condition and resulted in widespread crop losses. PLT treated poultry manure (PLTPM) has never been tested for use in substrate preparation for the commercial mushroom crop.

The intent of this research is to determine if mushroom growers can add treated poultry manure to a standard substrate formula without affecting the composting process, mushroom growth and yield. Statistical analysis of the yield and size of mushrooms grown with this poultry manure treated with PLT has never been conducted. Further testing may be proposed to evaluate application rates and timing of poultry manure applications.

The objectives of this project were to: 1) evaluate the effect on mushroom composting when using poultry litter containing PLT, as a nitrogen supplement for mushroom substrate preparation; 2) determine any differences in yield and size of freshly harvested mushrooms.

Material and Methods

Poultry manure was received from a farm reported to have applied PLT on the litter. The PLT poultry manure (PLTPM) was collected by the farm management at random from houses, where it was reported that a normal rate and application of PLT was used. Three separate crops were conducted testing two different batches of PLTPM in mushroom substrate. The first test used PLTPM and Tyson-control poultry manure received from the same source. The second and third tests used a different commercially supplied PLT treated and non treated (Ty-control) poultry manure and Mushroom Research Center (MRC) poultry manure was used as an addition control treatment. The composition of the poultry manures used in all tests are reported in Table 1. The treated poultry manure for the third test was obtained from a poultry house that had repeated treatments of PLT, in an attempt to use material with the highest possible concentration of PLT. This material was used to represent the highest possible concentration of PLT in poultry manure mushroom farmers may receive.

In the first test three piles of straw-bedded horse manure were supplemented with treated and untreated poultry manure, brewer's grain and gypsum according to accepted procedures at the MRC. The second and third tests a fourth pile with MRC poultry manure. The basic substrate formulas used for all tests are reported in Table 2. For each test, the quantity of poultry manure in the formula was adjusted according to its nitrogen content. The PLTPM was mixed on a dry weight basis with straw-bedded horse manure as a direct substitute for control poultry manure normally used and at almost twice the quantity of poultry manure used. In the 2x substrate, the quantity of brewer"s grain was reduced achieve the same total percent, substrate dry weight nitrogen content. The initial total nitrogen content for all piles was similar, Table 2. The outdoor composting (Phase I) had a duration of 7 and 8 days for Tests 1 and 2 respectively. At build (day 0), all piles were supplemented with poultry manure and one-half the brewers grains and gypsum. PLTPM was added to the substrate at the start of composting. At the first turning, the piles received the remainder of the brewers grains and gypsum. The temperatures of each treatment pile during the Phase I were recorded by remote sensors and the data accumulated in a computer.

Phase I was followed by an indoor decomposition, pasteurization and conditioning process (Phase II). Substrate was filled into wooden trays that were placed in computer-controlled environmental Phase II rooms at the Mushroom Test Demonstration Facility (MTDF) along with substrate prepared for a standard crop at the MTDF. Substrate temperatures were maintained between 118o F and 140o F. For pasteurization, the air and substrate temperatures of 140o F were maintained for two hours on the second day of Phase II. The substrate is then conditioned to convert ammonia into microbial protein used in part by the mushroom for its nutrients and is selective for mushroom growth and development. The Phase II was terminated once ammonia. Substrate selectivity is based on reducing certain very available substrates and encourаging the proliferation of a large and stable microbial community. This stable microbial population promotes growth of mushrooms, while preventing weed molds, competitor organisms, and diseases through ecological competition and antagonism.

Following Phase II the substrate was cooled and spawned with a hybrid off-white strain used in the commercial industry. One hundred and fifty grams of spawn per tray of spawn was mixed into the substrate. In the first two tests, 50 lbs of wet weight substrate were placed in each 4 ft^2 tray, in the third test 60 lbs wet weight substrate was added. Substrate was subjectively assessed at this time for the degree of conditioning and decomposition.

After 18 days of spawn growth at 76-78° F, the trays were covered with a 1¼ inch layer of pasteurized peat moss and limestone mix. This process, called casing, induces sporophore initiation. At casing time the spawn growth was subjectively assessed at this time for its vigor, amount of colonization through the substrate and any competitor or weed molds were noted. During the next week, the substrate temperature was maintained at 76-78° F after which time it was lowered to 65° F. As the pins formed and began to enlarge, the air temperature was maintained between 63-65° F and held at that temperature throughout the remainder of the crop. Mushrooms matured 15-16 days after the casing was applied. Mushrooms appear in a cyclic pattern known as flushes or breaks. Three to four such breaks were harvested during the 25-32 day picking period.

Experimental design, for each test, consisted of three or four treatments each including of 15 replicates for first test and 8 replicates for second and third tests. The weight and number of mushrooms harvested were recorded daily for each tray. Mushroom yield and size data were analyzed as a completely randomized design. The Waller-Duncan k-ratio t-test was used to separate the means.

Results and Discussion

The analysis of the poultry manure, Table 1, indicated that the total percent nitrogen was similar for all poultry manure used. It is interesting to note that the Tyson and PLTPM poultry manure was much lower in volatile ammonia nitrogen (NH_4N) content compared to the MRC poultry manure. However, the range of NH_4N from the PLTPM and Tyson-control poultry manure supplied by the commercial farms was similar to that of the MRC or mushroom industry. The pH was higher when compared to that of the MRC control poultry manure and the PLTPM used in the third test. These differences cannot be explained at this time. PLT is a dry acid applied to the bedding material in the poultry houses that lowers the pH of the litter. The lab analysis data suggests that the lowering of the pH is short-lived and had no long term influence on the pH of the poultry manure. The composition of the supplied material showed no difference in type or total nitrogen content, which may suggest that the PLT has no affect on the composition of the poultry manure used for mushroom substrate preparation. The higher nitrogen content in the third test PLTPM was most likely a result of the successive poultry flocks bedded on the same litter.

Composting temperatures during Phase I are shown in Figures 1, 2 and 3. The composting temperatures were similar for most treatments. In test #1 during the middle to later part of the process the PLTPM1 substrate had slightly higher temperatures when compared to the control and PLTPM2x substrates. The temperatures during the mid portion of the Phase I in test #2 were lower than normally experienced at this facility. However, the small temperature difference does not appear to be significant, nor did the lower temperatures adversely affect the composting process. Little to no temperature differences were noted in the third test, Figure 3. Observations for all tests showed that substrate at second and third turnings looked normal with regard to color, microbial activity and odor. All piles had strong some ammonia odor at second turn through to filling time. These observations during the turnings of the piles support these temperature data. At the end of Phase I all substrates were similar in degree of decomposition and length. The substrates in all treatments of the first test were a little less mature and drier than normally encountered. This was most likely a result of the shorter Phase I composting time.

Analysis of the various substrates for nitrogen, ammonia, ash, pH and percent moisture after Phase I and Phase II are shown in Table 3 and 4. In the first test, the pH, percent nitrogen and ash for all substrates were similar, and the values are considered normal for the MRC. The percent ammonia and moisture content was lower than normally encountered but within an acceptable range. Substrate analysis for the second test showed little difference between substrates for pH, nitrogen, ash, moisture and ammonia. However, the ammonia content for all substrates in this test was very low and not within a normal range.

In the first test during Phase II all substrate took longer to complete conditioning. The PLTPM was stronger than that of the Tyson Tyson-control substrate, however both treated and untreated substrate took 4 days longer to complete the conditioning in Phase II. Often difficulties in conditioning are caused by high nitrogen or low carbohydrate levels in Phase I. The substrate analysis does not support this possibility. It had been noted that when formaldehyde type ammonia suppressive compounds were used on poultry litter several years ago, that ammonia was released during Phase II, not Phase I as normal, and the substrate were difficult to condition. Had only the PLTPM been difficult to condition it might suggest that it had the same problem.

However, since the Tyson-control substrate reacted the same way it is possible that either the was an experimental design flaw; error in the substrate formulation or mixing; or an error in the rate, application or collecting of the PLTPM. These inconclusive results instigated the second and third tests to be conducted. In the second and third tests all substrate, including the MRC and MTDF substrates, conditioned normally and did not have the delayed ammonia release as the substrates during the first test.

The first test, PLTPM 1x and control substrates at spawning had a higher nitrogen content when compared to the PLTPM 1x substrate, Table 4. A slight residual ammonia smell was detected in all substrate, indicating an incomplete Phase II conditioning. PLTPM 2x substrate appeared to have slightly stronger ammonia when compared to the PLTPM 1x and control substrates. Residual ammonia at spawning may be a result of the higher nitrogen level at filling or lack of time to complete the conversion of the higher nitrogen substrate in Phase II. Control and PLTPM 1x substrate moisture at spawning was slightly lower than the PLTPM 2x substrate, but all were within an acceptable range. However, the results of the lab analysis did not support this subjective observation. The lab analysis did not indicate any other differences in the composition of the substrate from each treatment and all parameters were within a reasonable range.

In the second test the Tyson-control substrate had higher moisture and nitrogen content when compared to the MRC-control, PLTPM 1x and PLTPM 2x substrates at spawning, Table 4. The pH, percent ammonia and ash after Phase II, were similar for all substrates and within the range normally measured at the MRC. The quantity of microbial activity, fire-fang, observed in all substrate was about the same, but slightly less than normally observed.

The third test substrate analysis results show no difference between treated and untreated poultry manure substrates at filling or spawning, Tables 3 and 4. Filling nitrogen for all treatments were higher than normal, which can not be explained especially when the all the substrates' spawning nitrogen were normal. The ammonia content for all substrates at filling in this test was very low and not within a normal range. The ammonia level at spawning for the two control treatments were a little higher than the PLT treated material, which corresponds to the observations made at spawning time. More free ammonia was detected by the researchers at this time. The control substrate was also a little wetter than the PLTPM substrates, which may partially explain the residual ammonia. Wet substrate is often more difficult to condition and convert ammonia to microbial protein.

For all tests, temperatures during the spawn-growing period were considered normal and no differences were recorded between treatments. In the first experiment observations after spawn growing period, at casing, revealed poor to very poor spawn growth in all substrates. No noticeable differences between the three treatments were detected in the type of growth, rhizomorph formation and substrate moisture, except that control and PLTPM 1x substrates had slightly weaker growth than the PLTPM 2x substrate. Several trays of all substrates had black areas within the substrate with the primordia of the inkcap fungus, *Coprinus spp.* growing. Inkcaps are considered an indicator of residual ammonia left in substrate after Phase II. Other molds were found on substrate from all treatments. These other molds are indicators that Phase II conversion was incomplete and residual nitrogen compounds remained in the substrate as food for these molds, and had not been converted into microbial protein. The colonization of the mushroom spawn was rated very poor in all substrates. After casing, spawn growth into the casing was slow and very inconsistent. The pin development was spotty and uneven. Several trays did not have any growth and pins, therefore no mushrooms were harvested from those trays during the 25 d production period. Yields and biological efficiency (lbs fresh mushrooms per lb of dry substrate) were very poor, Table 5, and are not conclusive. Although mushroom yield from the PLTPM 2x substrate was significantly higher than the control and PLTPM 1x substrates, because the yields are so low it would be unreasonable to suggest that PLTPM at the higher rate increased yields. Mushroom size was not significantly different between the PLTPM and control substrates.

In the second and third experiments, observations at casing indicated very good mushroom spawn colonization and no molds or inkcaps. Growth was good in all substrates and only slight differences were noted between substrates. The vigor of the growth was less in the Tyson-control substrate when compared to the MRC-control substrate in the second test, and for the third test the MRC-control spawn growth was the slowest and less vigorous. The MRC-control and Tyson control substrates also had more rhizomorph formation, an indication of less nutrients and/or higher substrate moistures. In the second test, spawn growth into the casing was mediocre in all treatments and pin development was uniform. The third test spawn growth into the casing was normal and strong in all PLTPM substrates, not as strong in both control substrates.

Mushrooms were first harvested in 18 days, which is normal, and breaks were well defined and seemed productive. Yields and biological efficiency as shown in Table 6 and 7 were considered average for unsupplemented at spawning substrates. For the second test, mushroom yield from the PLTPM treated substrates were not significantly different on both pounds per square foot and pounds of mushrooms per pound dry weight of substrate basis when compared to the MRC-control substrate, Table 6. The PLTPM 1x substrate yield and biological efficiency were significantly higher than the Tyson-control substrate, but not significantly more than the PLTPM2x and MRC-control substrates. This difference cannot be explained by observations made during substrate preparation through cropping, or by lab analysis of the substrate. The Tyson-control substrate yielded lower than other treatments and its biological efficiency suggest it had a below average productivity. The size of the mushrooms was not significantly different between the PLTPM and both control substrates.

The third test yield results suggests that there was no significant difference in yield between the MRC-control, Tyson-control and PLTPM2x treatments. Yield data indicates that PLTPM1x yield was significantly higher than both control treatments. This result can be explained by the higher compost dry weight used for this treatment. Because the substrate moisture content was lower when the trays were filled on a wet weight basis at spawning, it results in more substrate, i.e., organic matter filled in the PLTPM1x treatment trays. This is shown by comparing the biological efficiency of the substrates. No significant difference in the biological efficiency verifies that PLTPM has no influence on mushroom yield, Table 7. The size of the mushrooms was not significantly different between the PLTPM and both control substrates.

Conclusions

The reaction of the substrate in the first test can not be explained, however, something in the formula or ingredients used caused the substrate not to be completely conditioned. However, using the mushroom cultural procedures and material employed in the second and third experiments, PLT treated poultry manure was used successfully with straw bedded horse manure substrate without adversely affecting fresh mushrooms yield. The differences in yield observed can be partially explained by the amount of substrate dry matter used in test #3. Based on these results it is difficult to make any definite conclusion on the influence of PLT treated poultry manure on increasing mushroom yields.

It has been reported that PLT added to poultry litter acts to lower the pH, remove volatile ammonia and form ammonia salts, such as ammonia sulfate. It is known that ammonia sulfate is not good source of nitrogen for mushroom substrate preparation (Sinden 1946 and MacCanna 1968). Unlike ammonia nitrate (a common ingredient for mushroom substrate preparation), quantities of ammonia sulfate (6 lb N/ton) will reduce yields when compared to other sources of nitrogen (MacCanna, 1968). The results do conclusively show that PLT applied to poultry manure at the recommended rates does not have any adverse influence on mushroom composting, spawn growth or yields. The results of these tests suggest that the quantity of ammonia sulfate that may be residual in the poultry manure is not detrimental to composting or mushrooms growth and production.

Any variation from the recommended PLT application procedures or rates could have different influence on mushroom composting and yield. Therefore, it is recommended that the rate and application of the product be used according to the manufacture's label. Furthermore, it is suggested that the product's rate and application be investigated under controlled conditions at the poultry farm or at a poultry research station.

Finally, it should be noted that the mechanism(s) by which PLT controls the ammonia level in poultry houses may differ from other available products. Other similar ammonia or odor suppressing products may not have the same reaction or results when that treated poultry manure is used for mushroom composting. At this time, other untested ammonia and odor controlling product-treated poultry manures are not recommended for use in mushroom substrate preparation.

References

MacCanna, C. 1968. Nitrogen supplementation of composts. Mushroom Science 7, 295-307.

Sinden, J. W. 1946. Synthetic compost for mushroom growing (further studies). The Pennsylvania State University Agricultural Experimental Station Special Bulletin 482.

Table 1. Composition of poultry manure used in the cropping experiments.

Poultry Sample	Volatile NH_4N	Organic N	Total N	% Moisture	% Ash	pH
MRC-control	0.48	3.57	4.05	25.7	18.5	6.7
Tyson-control Test #1	0.21	4.29	4.50	17.4	18.1	8.3
PLTPM Test #1	0.19	4.15	4.34	20.2	18.0	8.5
Tyson-control Test #2	0.22	4.35	4.57	14.6	16.8	8.1
PLTPM Test #2	0.20	3.52	3.72	14.8	18.1	8.1
Tyson-control Test #3	0.75	2.40	3.15	27.5	25.1	8.5
PLTPM Test #3	1.11	4.21	5.32	26.9	24.2	7.6

Table 2. Composition of experimental substrate piles for second test, Crop 9809. The first (Crop 9806) and third tests (9906), were formulated in the same manner with the quantity of poultry adjusted according to the percent nitrogen.

Pile 1 (MRC-control)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	15	8.0%	13.8	4.0%	0.6
Poultry manure	35	25.7%	26.0	4.1%	1.1
Gypsum	20	0.0%	20.0	0.0%	0.0
	570		434.8		6.3

Estimated make-up Nitrogen = 1.43

Pile 2 (Tyson-Control)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	15	8.0%	13.8	4.0%	0.6
PLT poultry manure	26	14.6%	22.2	4.6%	1.0
Gypsum	20	0.0%	20.0	0.0%	0.0
	561		431.0		6.3

Estimated make-up Nitrogen = 1.44

Pile 3 (PLTPM 1x)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	15	8.0%	13.8	4.0%	0.6
PLT Poultry manure	35	14.8%	29.8	3.7%	1.1
Gypsum	20	0.0%	20.0	0.0%	0.0
	570		438.6		6.3

Estimated make-up Nitrogen = 1.43

Pile 4 (PLTPM 2x)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	5	8.0%	4.6	4.0%	0.2
PLT poultry manure	48	14.8%	40.9	3.7%	1.5
Gypsum	20	0.0%	20.0	0.0%	0.0
	573		440.5		6.4

Estimated make-up Nitrogen = 1.44

Table 3. Analysis of various substrates after Phase I and Phase II of composting – Crops 9806, 9809 and 9906.

Substrate after Phase I	Moisture (%)	Nitrogen (%)	Ash (%)	Volatile NH_4N (%)	pH
9806 Pile 1 – Ty-control	70.5	1.70	25.6	0.20	7.8
9806 Pile 2 – PLTPM 1x	72.8	1.69	27.2	0.22	8.1
9806 Pile 3 – PLTPM 2x	73.9	1.87	24.3	0.15	7.9
9809 Pile 1 – Control	75.8	1.96	32.4	0.08	8.0
9809 Pile 2 – Ty-control	74.9	1.72	30.4	0.07	8.0
9809 Pile 3 – PLTPM 1x	74.4	1.83	32.2	0.10	8.0
9809 Pile 4 – PLTPM 2x	73.1	1.81	33.3	0.04	7.8
9906 Pile 1 – Control	72.1	2.34	30.1	0.04	7.6
9906 Pile 2 – Ty-control	73.2	2.05	28.3	0.10	7.7
9906 Pile 3 – PLTPM 1x	73.2	2.05	28.9	0.10	8.0
9906 Pile 4 – PLTPM 2x	74.1	2.11	32.9	0.08	7.9

Table 2. Composition of experimental substrate piles for second test, Crop 9809. The first (Crop 9806) and third tests (9906), were formulated in the same manner with the quantity of poultry adjusted according to the percent nitrogen.

Pile 1 (MRC-control)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	15	8.0%	13.8	4.0%	0.6
Poultry manure	35	25.7%	26.0	4.1%	1.1
Gypsum	20	0.0%	20.0	0.0%	0.0
	570		434.8		6.3

Estimated make-up Nitrogen = 1.43

Pile 2 (Tyson-Control)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	15	8.0%	13.8	4.0%	0.6
PLT poultry manure	26	14.6%	22.2	4.6%	1.0
Gypsum	20	0.0%	20.0	0.0%	0.0
	561		431.0		6.3

Estimated make-up Nitrogen = 1.44

Pile 3 (PLTPM 1x)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	15	8.0%	13.8	4.0%	0.6
PLT Poultry manure	35	14.8%	29.8	3.7%	1.1
Gypsum	20	0.0%	20.0	0.0%	0.0
	570		438.6		6.3

Estimated make-up Nitrogen = 1.43

Pile 4 (PLTPM 2x)	Wet Wt.	% Moisture	Dry Wt.	% N	lbs. N
Straw-bedded horse manure	500	25.0%	375.0	1.3%	4.7
Brewers grains	5	8.0%	4.6	4.0%	0.2
PLT poultry manure	48	14.8%	40.9	3.7%	1.5
Gypsum	20	0.0%	20.0	0.0%	0.0
	573		440.5		6.4

Estimated make-up Nitrogen = 1.44

Table 4. Analysis of various substrates after Phase II, at spawning – Crops 9806, 9809 and 9906.

Substrate after Phase II	Moisture (%)	Nitrogen (%)	Ash (%)	Volatile NH_4N (%)	pH
9806 Pile 1 – Ty-control	66.4	2.51	32.9	0.03	7.9
9806 Pile 2 – PLTPM 1x	66.4	2.65	32.2	0.03	8.1
9806 Pile 3 – PLTPM 2x	67.9	2.30	34.6	0.02	7.8
9809 Pile 1 – Control	73.0	2.26	37.0	0.01	8.3
9809 Pile 2 – Ty-control	74.7	2.48	36.2	0.01	8.2
9809 Pile 3 – PLTPM 1x	72.1	2.39	35.1	0.01	8.0
9809 Pile 4 – PLTPM 2x	71.1	2.35	38.2	0.01	8.2
9906 Pile 1 – Control	73.1	2.30	33.5	0.11	8.2
9906 Pile 2 – Ty-control	72.0	2.47	32.3	0.11	8.2
9906 Pile 3 – PLTPM 1x	68.0	2.34	35.0	0.03	8.1
9906 Pile 4 – PLTPM 2x	70.3	2.34	34.0	0.04	8.0

Table 5. Yield and size of mushrooms produced from PLTPM treated and untreated substrates in the first test, Crop 9806. Yield is expressed as pounds per square foot and pounds of mushrooms per pound dry weight of substrate (biological efficiency).

Crop 9806 Substrate Treatment	Yield		Size
	Lbs./ft^2	lbs. Fresh mushrooms / Substrate Dry Wt.	g/mushroom *
9806 Pile 1 – Tyson control	0.66 b	0.19 b	24.1 a
9806 Pile 2 – PLTPM 1x	0.68 b	0.19 b	24.4 a
9806 Pile 3 – PLTPM 2x	1.11 a	0.32 a	20.6 a

* Yield and size in the same column followed by the same letter are not significantly different and the 0.5 significant level.

Table 6. Yield and size of mushrooms produced from PLTPM treated and untreated substrates in the second test, Crop 9809. Yield is expressed as pounds per square foot and pounds of mushrooms per pound dry weight of substrate (biological efficiency).

Crop 9809 Substrate Treatment	Yield		Size
	lbs./ft^2	lbs. Fresh mushrooms / Substrate Dry Wt.	g/mushroom *
9809 Pile 1 – Control	2.51 ab	0.72 ab	11.7 ab
9809 Pile 2 – Tyson control	2.16 b	0.62 b	12.8 a
9809 Pile 3 – PLTPM 1x	2.88 a	0.82 ab	12.1 ab
9809 Pile 4 – PLTPM 2x	2.44 ab	0.70 a	13.2 a

* Yield and size in the same column followed by the same letter are not significantly different and the 0.5 significant level.

Table 7. Yield and size of mushrooms produced from PLTPM treated and untreated substrates in the third test, Crop 9906. Yield is expressed as pounds per square foot and pounds of mushrooms per pound dry weight of substrate (biological efficiency).

Crop 9906	Yield		Size
Substrate Treatment	Lbs./ft^2	lbs. Fresh mushrooms / Substrate Dry Wt.	g/mushroom *
9906 Pile 1 – Control	3.08 b	0.76 a	11.5 a
9906 Pile 2 – Tyson control	3.14 b	0. 75 a	11.9 a
9906 Pile 3 – PLTPM 1x	3.47 a	0. 72 a	11.2 a
9906 Pile 4 – PLTPM 2x	3.29 ab	0. 74 a	11.3 a

* Yield and size in the same column followed by the same letter are not significantly different and the 0.5 significant level.

Figure 1. Phase I composting temperatures of PLTPM treated and untreated substrates, crop 9806.

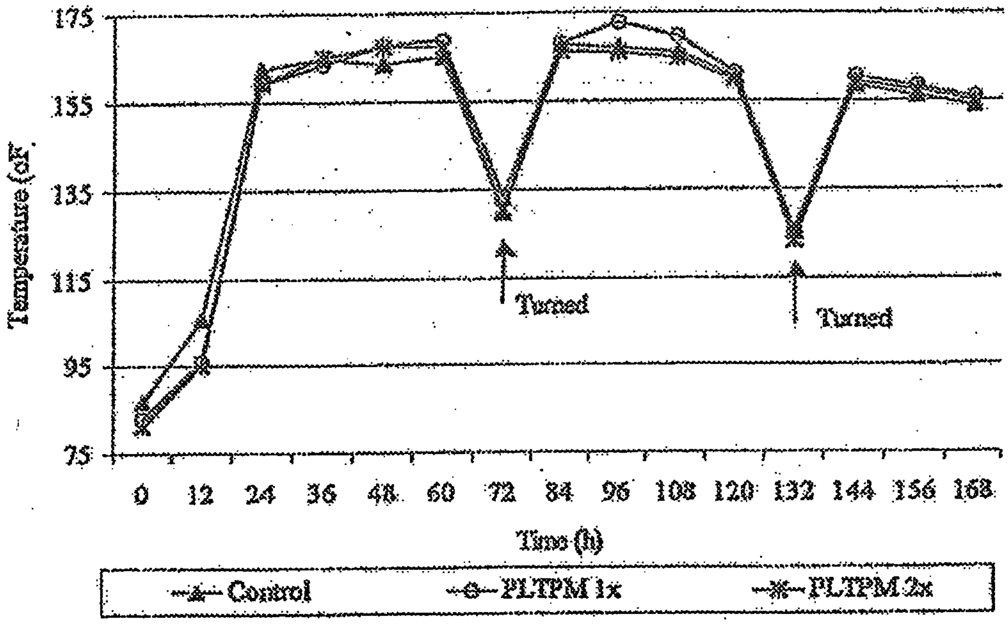


Figure 2. Phase I composting temperatures of PLTPM treated and untreated substrates, crop 9809.

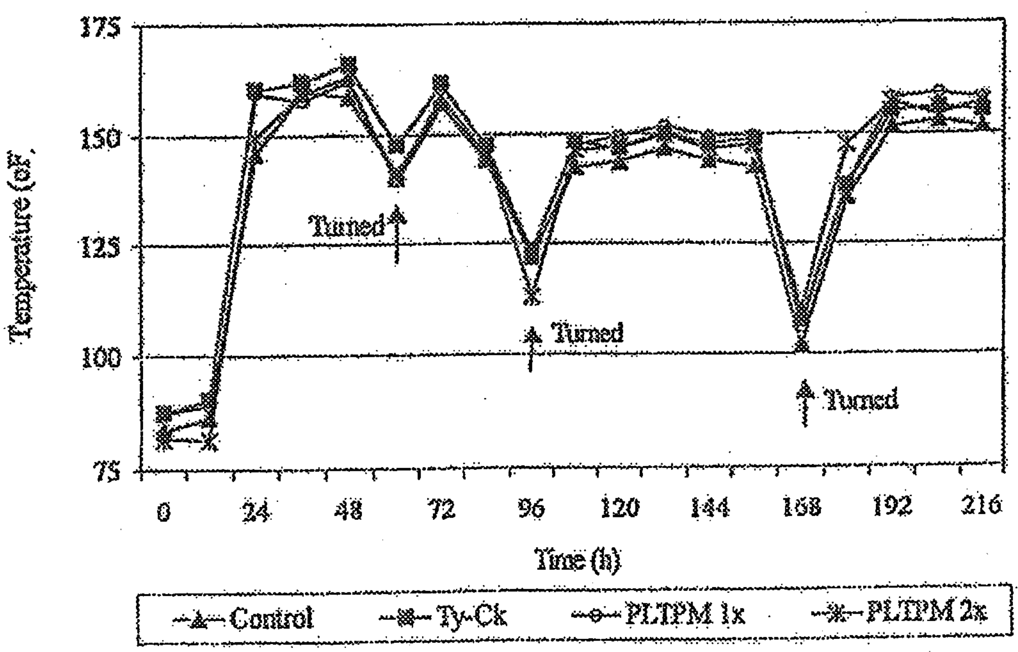
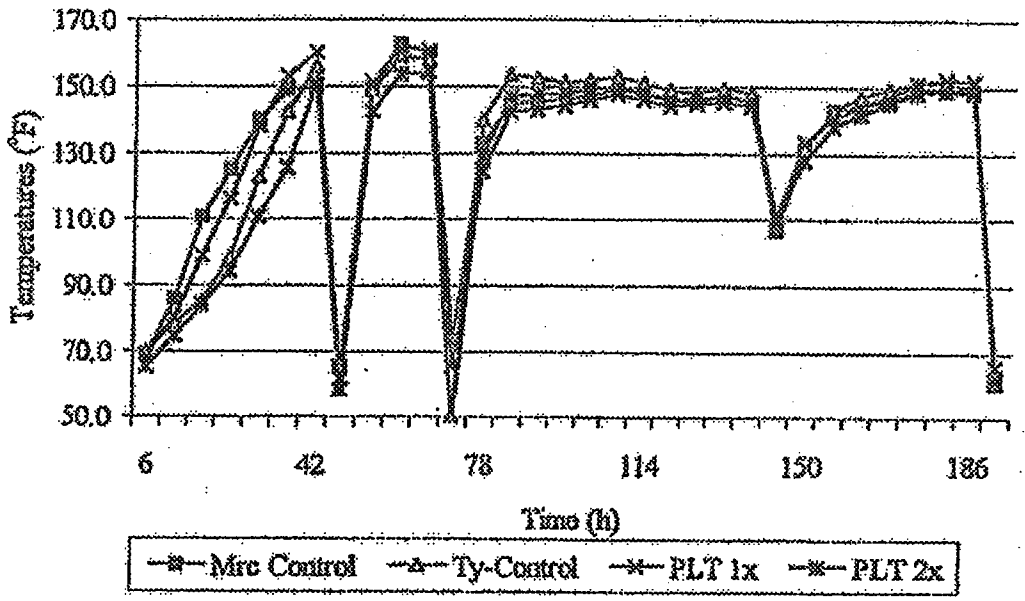


Figure 3. Phase I composting temperatures of PLTPM treated and untreated substrates, crop 9906.



A 11

The University of Georgia
Cooperative Extension Service
College of Agricultural and Environmental Sciences / Tifton, Georgia 31793

1785

May 12, 1994

David R. Morgan
Jones-Hamilton Co.
30354 Tracy Rd.
Walbridge, OH 43465
FAX 419/666-1817

Dear David:

I have reviewed the results of analyses of broiler litter you supplied to me from a farm in the Gainesville, GA area. Your question to me concerned the possible effects on tobacco seedbeds of nutrients contained in liter treated with PLT ($NaHSO_4$).

The material I received was labeled as treated and untreated. The liter was reported to have come from houses in which four flocks of birds had been grown without cleaning out the liter. The treated liter received a single application of PLT for each flock at 5 pounds per 100 square feet.

Subsamples were taken from each of the samples I received and were submitted for analysis to the University of Georgia Agricultural Services Laboratories. Analyses were perfomed for nitrate, phosphorus, potassium, calcium, magnesium, manganese, iron, aluminum, boron, copper, zinc, sodium, lead, cadmium, chromium, nickel, molybdenum, total kjeldahl nitrogen and sulfur.

The nitrogen content of the treated and the untreated samples was approximately the same with 3.43 and 3.49 percent respectively. P_2O_5 content of the treated liter was greater than that of the untreated with 3.91 and 2.75 percent respectively. K_2O content was greater in the treated than the untreated with levels of 3.02 and 2.58 percent respectively. Sulfur and sodium content of the treated samples were greater than those of the untreated with sulfur contents of 0.71 and 0.42 percent respectively and sodium content of 0.89 and 0.57 percent respectively. In general, the fertilizer value of the treated liter was slightly greater than that of the untreated except in the cases of magnesium, iron, aluminum, manganese, lead and cadmium.

Of particular interest based on the chemical nature of PLT was the sulfur and the sodium content of the treated liter. Treatment resulted in a 69 percent higher sulfur content and an additional 56 percent higher sodium content. An application of two tons of treated liter to soil intended for the production of tobacco seedbeds would supply 11.6 pounds more sulfur and 12.8 pounds more sodium than would untreated liter.

CERTIMEX. CERTIFICADORA MEXICANA DE PRODUCTOS Y PROCESOS ECOLÓGICOS S.C.
CERTIFICADO DE CONTROL DE PRODUCTOS ORGÁNICOS

1. Nombre y dirección del organismo certificador

CERTIMEX S. C.
Calle 16 de Septiembre No.204,
Ejido Guadalupe Victoria, Oaxaca, Oax., México.
Tel/fax: ++951 52 02687 / 951 52 00617
E-mail: certimex@certimexsc.com

2. Standares NOP apartados 205.403(a), 205.403 (2) (I), 205.403 (I I) y 205.403 (c) (2).

Número de referencia del certificado de transacción

CMX-NOP-288-2008-62-13

3. Nombre y dirección del productor

NUBES DE ORO S.S.S
Camino al panteón Dominguez 1, Col. El Llanito
Mapastepec, Chiapas
Tel: 01 918 6431565
E-mail: nubesdeoro@yahoo.com.mx

4. Nombre y dirección del procesador y exportador del producto

CAFÉ Y DESARROLLO S. A. DE C.V.

Av. Guerrero No.10
Col. Centro, Chocaman, Veracruz, México Cp.29160
Tel/Fax: 0052 273 732 2033
E-mail: redcafes_ac@yahoo.com.mx

5. Número de referencia del certificado orgánico

CMX/NOP-288-2008-62

6. Destinatario del producto en los Estados Unidos de Norte América.

INTERAMERICAN COFFEE, INC
19500 State Hwy.249, Suite 225
Houston Texas, 77070 USA
Tel:++8329127000, E_Mail: erika@atsorganic.com
At'n: Erika Hernandez

7. Marcas y números, número de contenedores, características.
Tipo de producto: Green Coffee 100% Organic
cosecha: 2008/2009
Origen: Veracruz
Núm. De contrato: N/A
Núm. De factura 114
Núm. de lote: 018-2641-01
Núm. de B/L: MSCUMM844124
Núm. de contenedor: MSCU3365138
Cantidad de contenedores: 1

8. Peso bruto (kg)
19,250.00

9. Peso neto (kg)
18, 975.00

10 Otras unidades*

275 Sacos de 69 Kg. Cada Uno.

11. Declaración del organismo expedidor del certificado.
Con el presente documento se certifica que los productos mencionados arriba han sido obtenidos con apego a los estándares de National Organic Program (NOP), lo cual está vigilado de manera continua por esta certificadora.

12. Declaraciones adicionales.

De acuerdo a la factura núm. 110 **de fecha:** 10-02-2009

13. Lugar y fecha de expedición del certificado

Oaxaca de Juárez, Oax. a 02 de Marzo de 2009

Taurino Reyes Santiago
Director Ejecutivo

Sello del organismo expedidor

CERTIFICADORA MEXICANA DE PRODUCTOS Y PROCESOS ECOLÓGICOS S.C.
R.F.C. CCM-970829-873
CertimeX
ACREDITADA
DAP-ZE3660

Sulfur is important to the production of tobacco with the application of at least 18 pounds of sulfur recommended to be included in mixed fertilizer on a yearly basis. Because of the sandy soils used for tobacco production and the leachable nature of sulfur problems relating to sulfur are most often related to deficiencies. This level of application of the treated liter would supply 28.4 pounds of sulfur per acre. Although this is in excess of the minimum suggested sulfur to be applied yearly, problems with excess supply of sulfur are common or expected from this level of application.

Sodium is also important to the production of tobacco and has been shown to stimulate the growth characteristics of tobacco. Sodinm is normally applied to tobacco as $NaNO_3$ and $NaSO_4$. Absence of Na may result in a depression of growth of seedlings when potassinm is insufficient. The Na content of flue-cured tobacco ranges from 240 to 330 pppm. Application of two tons of liter with PLT would result in only 35.6 pounds of Na per acre. I believe this to be within the range of application for production of flue-cured tobacco.

It is my opinion that moderate applications of liter treated with PLT should not cause injury to tobacco seedbeds if applied uniformly and at least six months prior to the seeding of the seedbed.

However, I suggest that liter should not be applied to soil intended for the production of tobacco seedlings due to the unknown availability of nitrogen from liter, the prevalence of weed seeds which are scarified as they pass through the bird and germinate in large numbers once applied to the soil and the presence of medications provided to the birds which may have unknown effects on normal plant growth. If liter is to be used as a soil amendment, I suggest that the liter should be applied in moderation and at least six months prior to the seeding of tobacco. During this time the incorporation into the soil and the percolation of rainfall into the soil will help to reduce any excess of soluble elements.

I hope that the enclosed results of the analyses and the above explanation sufficiently answers your concens regarding the use of PLT treated liter as a soil amendment for tobacco seedbeds.

Sincerely,

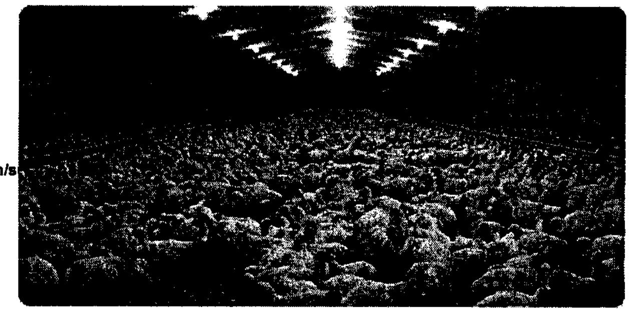
J. Michael Moore
Extension Agronomist - Tobacco

The above information is provided as a description of the organic system under certification. This document does not replace the organic certificate. It is provided as customer service to assist in the representation of the certified organic products.

Signed on behalf of QAI Inc

Alexis Randolph

Alexis Randolph September 9, 2010



Sustainability

Environmental Chemistry

Related Info

See More Resources (/resources/)

Environmental Chemistry of Jones-Hamilton Co. Products

Sodium bisulfate, the main ingredient of PLT®, PWT®, LS-PWT®, Parlor Pal®, SAS®, and AFG, is a medium strength acid that meets FTC Green ingredient guidelines[1] and can be classified as:

- Biodegradable
- Non-toxic and non-hazardous*
- Ozone friendly
- Environmentally friendly

Sodium bisulfate is not regulated by the DOT and does not have a hazardous or corrosive DOT rating. It is classified as a mild irritant by OSHA and has earned a very safe 1-0-1 hazard rating from the National Fire Protection Agency. Additionally, sodium bisulfate is a mineral based phosphate-free compound produced in the USA without the use of crude oil and it contains no chlorine, fluorine or organic compounds. If spilled, it can be safely swept up – not the case for liquid acids.

Benefits of Green Environmental Chemistry

The production process of Jones-Hamilton's leading product, PLT®, follows the principles of Green Chemistry[2,3] which strives to:

- **Boost safety.** PLT® is designed to be fully effective while minimizing the potential for accidents such as explosions, fires and releases to the environment. It also degrades after use and breaks down into substances naturally found in the environment.
- **Eliminate the waste stream.** Real-time analysis during the production process prevents pollution —ensuring that all starting materials are contained in the final product so no waste is generated.

Plus, toxicity research has proven that PLT® has no adverse affects on poultry—including bird weight, feed efficiency, abnormal behavior, skin pigmentation or feathering and mortality rates—even when used at application rates of up to ten times the recommended rate.

*based on FDA guidelines.

[1] http://www.ftc.gov/bcp/grnrule/guides980427.htm

[2] EPA; http://www.epa.gov/greenchemistry/pubs/principles.html

[3] California Department of Toxic Substances Control;

http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/index.cfm (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/index.cfm)

We provide safe, economical and environmentally friendly products that help manage some of the most significant issues the industry faces. Contact your Jones-Hamilton rep (http://www.joneshamiltonag.com/contact-us/locate-a-representative/) today for assistance addressing your top issues.

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Contact (http://www.joneshamiltonag.com/contact-us/) (/feed/) (/sustainability/) (http://www.linkedin. trk=tyah)

A13

Conforms to ANSI Z400.5-2004 Standard (United States, Canada, Mexico).

Material Safety Data Sheet

PLT® / Poultry Litter Treatment

1. Product and company identification

Product name	:	PLT® / Poultry Litter Treatment
Material uses	:	Poultry litter treatment. *Not intended for use in feed, food or drinking water.*
Supplier/Manufacturer	:	Jones Hamilton 30354 Tracy Road Walbridge, OHIO, 43465 Tel: (419) 666-9838 Fax: (419) 666-1817
Code	:	PLTCUN01
MSDS authored by	:	KMK Regulatory Services inc.
In case of emergency	:	CHEMTREC, U.S. : (800) 424-9300 International: (703) 527-3887
Product type	:	Solid.

2. Hazards identification

Emergency overview

Color	:	Off-white.
Physical state	:	Dry (Anhydrous) crystalline solid spherical shape beads.
Odor	:	Fresh to pungent.
Signal word	:	WARNING!
Hazard statements	:	Causes serious eye irritation. May cause respiratory irritation. May be harmful if swallowed.
Precautions	:	Do not get in eyes. Avoid contact with skin and clothing. Use only with adequate ventilation. Keep container tightly closed and sealed until ready for use. Wash thoroughly after handling. Material is non-flammable. Use extinguishing media suitable for surrounding materials.
OSHA/HCS status	:	This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Potential acute health effects

Inhalation	:	Inhalation of dust may irritate nose, throat and/or lungs.
Ingestion	:	Small amounts (tablespoonful) swallowed are not likely to cause injury; however, swallowing large amounts may irritate or burn digestive tract.
Skin	:	Prolonged exposure may cause skin irritation.
Eyes	:	Causes serious eye irritation.

Potential chronic health effects

Chronic effects	:	Contains material that may cause target organ damage, based on animal data.
Carcinogenicity	:	No known significant effects or critical hazards.
Mutagenicity	:	No known significant effects or critical hazards.
Teratogenicity	:	No known significant effects or critical hazards.
Developmental effects	:	No known significant effects or critical hazards.
Fertility effects	:	No known significant effects or critical hazards.
Target organs	:	Contains material which may cause damage to the following organs: mucous membranes, skin, eyes.

Over-exposure signs/symptoms

Inhalation	:	Adverse symptoms may include the following: respiratory tract irritation coughing
Ingestion	:	No specific data.
Skin	:	No specific data.

6. Accidental release measures

Personal precautions : Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Small spill : Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor.

Large spill : Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see section 1 for emergency contact information and section 13 for waste disposal.

7 . Handling and storage

Handling : Put on appropriate personal protective equipment (see section 8). Avoid breathing dusts. Wash thoroughly after handling.

Storage : Material is hygroscopic and will readily absorb moisture. DO NOT store dry product where exposed to moist conditions. Keep container tightly closed.

8. Exposure controls/personal protection

Canada

Occupational exposure limits		TWA (8 hours)			STEL (15 mins)			Ceiling			
Ingredient	List name	ppm	mg/m³	Other	ppm	mg/m³	Other	ppm	mg/m³	Other	Notations
No known value.											

Consult local authorities for acceptable exposure limits.

Recommended monitoring procedures : Personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.

Engineering measures : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. The engineering controls also need to keep gas, vapor or dust concentrations below any lower explosive limits.

Hygiene measures : Ensure that eyewash stations and safety showers are close to the workstation location. Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period.

Personal protection

Respiratory : In dusty atmospheres (>10 mg/m³), use a NIOSH-approved dust respirator.

Hands : Rubber gloves.

Eyes : Safety glasses or chemical goggles.

Skin : Cotton-blend coveralls.

Environmental exposure controls : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

14 . Transport information

DOT/TDG/MXT/IMDG/IATA : Not regulated.

15 . Regulatory information

United States

HCS Classification : Irritating material

U.S. Federal regulations : **United States inventory (TSCA 8b):** All components are listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: Sodium bisulfate
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: Sodium bisulfate: Immediate (acute) health hazard, Delayed (chronic) health hazard

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 accidental release prevention: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

Clean Air Act Section 112(b) Hazardous Air Pollutants (HAPs) : Not listed

Clean Air Act Section 602 Class I Substances : Not listed

Clean Air Act Section 602 Class II Substances : Not listed

DEA List I Chemicals (Precursor Chemicals) : Not listed

DEA List II Chemicals (Essential Chemicals) : Not listed

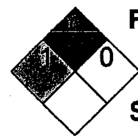
State regulations : **Connecticut Carcinogen Reporting:** None of the components are listed.
Connecticut Hazardous Material Survey: None of the components are listed.
Florida substances: None of the components are listed.
Illinois Chemical Safety Act: None of the components are listed.
Illinois Toxic Substances Disclosure to Employee Act: None of the components are listed.
Louisiana Reporting: None of the components are listed.
Louisiana Spill: None of the components are listed.
Massachusetts Spill: None of the components are listed.
Massachusetts Substances: None of the components are listed.
Michigan Critical Material: None of the components are listed.
Minnesota Hazardous Substances: None of the components are listed.
New Jersey Hazardous Substances: The following components are listed: Sodium bisulfate
New Jersey Spill: None of the components are listed.
New Jersey Toxic Catastrophe Prevention Act: None of the components are listed.
New York Acutely Hazardous Substances: None of the components are listed.
New York Toxic Chemical Release Reporting: None of the components are listed.
Pennsylvania RTK Hazardous Substances: None of the components are listed.
Rhode Island Hazardous Substances: None of the components are listed.

Canada

WHMIS (Canada) : Class D-2B: Material causing other toxic effects (Toxic).

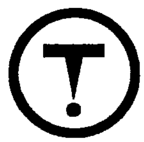
16 . Other information

National Fire Protection Association (U.S.A.) :



Canada

WHMIS (Canada) :



Date of issue (mm/dd/yyyy) : 06/15/2009
Date of previous issue : 04/15/2006
Version : 1.1

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.

Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

Subj: **Emailing: PAN Product Info for Plt.htm**
Date: 4/10/2014 4:30:30 P.M. Eastern Daylight Time
From: rhmathews51@comcast.net
To: Agrisys1@aol.com

PAN Pesticides Database - Pesticide Products

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Product Name: Plt

Note: See Working with the Information on this Page section below for important notes about this data.

This database and website are updated and enhanced by Pesticide Action Network North America (PANNA). The project is made possible by our Sponsors and by PANNA general funds. We need your support to maintain and improve this system. Please support the database and website — donate to PANNA.

Product ID	Identifying information, including U.S. EPA registration number, product registration status, formulation and warning label, as well as links to sources of product labels and MSDS information.
Toxicity	Summary of the toxicity properties of each active ingredient and the percent of each active ingredient in the product.
Uses	Approved uses for the product by general use type, pest, and crop or location.
Registration	Product registration history, including initial date registered, date cancelled (if applicable), and date registration was transferred (if applicable).
Company	Name, address, and identifying number of the company that registered the product. Name and address of the agent, if applicable.
Distributor Names	Complete list of names under which this product is sold. Often a company will register a single product and then sell the same product under many different brand names. The 'Distributor Name' list is a complete list of these names.

Product Identification for Plt

Top

Basic Identification Information About This Product

MSDS and Product Label	[Select Source V]
U.S. EPA Product Reg No	33907-3
Product Registration Status	Active
Formulation	Impregnated materials
Acute Hazard Warning Label	1 Danger
Restricted Use Product	No
PAN Bad Actor Product:	Yes
No. of names this product is sold under	1 (See bottom of page for complete list of products)

Toxicity for Plt

Top

Summary Toxicity Information for the Active Ingredients in this Product

For detailed chemical information click on the chemical names below

Active Ingredients Chemical Name	Percent	Carcinogen	Cholinesterase Inhibitor	Developmental or Reproductive Toxin	Endocrine Disruptor
Sodium bisulfate	93.2 %	?	No	?	?

Legend

Indicates high toxicity in the given toxicological category.

Indicates no available weight-of-the-evidence assessment. For additional information on toxicity from scientific journals or registration documents, see the "Additional Resources for Toxicity " section of the chemical detail page for each active ingredient.

Other Ingredients in this Product

By U.S. law, only active ingredients (AIs) are reported. In addition to active ingredients, pesticide products may contain one or more "inert" ingredients. Many "inert" ingredients in current use have known adverse human and environmental effects.

U.S. EPA statement on inerts U.S. EPA list of inerts NCAP Inerts Report (pdf)

Registered Uses in the U.S. for Plt

Top

Uses

Bacteriostat

Pests

Ammonia-producing bacteria , Animal pathogenic bacteria (g- and g+ vegetative)

Crops and Locations

Poultry brooder houses (enclosed premise treatment) , Poultry bldgs. (pullet h.) (enclosed premise treatment) , Poultry houses (enclosed premise treatment) , Poultry litter , Poultry droppings , Turkeys (enclosed premise treatment) , Poultry broiler house premises (enclosed premise treatment)

U.S. Product Registration History for Plt

Top

U.S. EPA Product Reg No: 33907-3 [U.S. State Registration Searches V]

Product Registration Status: Active

Approval Date: Jul 12, 2001

Company and Agent Information for Plt

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Manufacturer	Agent	Distributor
Jones-hamilton co 30354 tracey road Wallbridge, OH 43465 Company Number: 033907	No Agent, See Company Info.	No Additional Distributor, See Company Info.

Distributor Names for Plt

Top

Product names	Distributor	Product Type	Approval Date	Cancellation Date
Plt	Jones-hamilton co	Parent Product	Jul 12, 2001	Active

Working with the Information on this Page

Click on underlined terms for definitions or go to the Pesticide Tutorial overview page.

Any underlined term with a book icon has additional information.

To print this page, choose **Print.** To export this data, choose **Save As** 'HTML Source' and open it in Excel or equivalent program.

Citation: Kegley, S.E., Hill, B.R., Orme S., Choi A.H., *PAN Pesticide Database,* Pesticide Action Network, North America (San Francisco, CA, 2010), http:www.pesticideinfo.org.

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PLT® Research Trial JHL-2-98 Final Report

Summary

Evaluation of Poultry Litter Treatment-PLT®

This trial was conducted under controlled conditions simulating an average poultry production environment at Colorado Quality Research, Inc. (a FDA, Good Laboratory Practices (GLP) qualified facility) under the supervision of Dr. Carey L. Quarles.

Many chemicals have been used over the years as possible poultry litter treatments. Some of these products are composed primarily of substances known to be toxic or hazardous. Several references detail the toxic effects of these substances in poultry ("Poisons and Toxins" by Julian and Brown in 10th edition of Diseases of Poultry, B. W. Calnek editor, Iowa State Press; "Acute Sulfur Toxicity in Broiler Chicks" by Phillips, et al. in Proceedings of 44th Western Poultry Disease Conference; "Identification of ferrous sulfate toxicity in a commercial broiler flock" Avian Diseases 30, 1986; "Complex study of the physiologic role of aluminum and Aluminum tolerance test in broiler chickens" by Bokori, et. al. in Acta Vet Hung 41, 1993.) Some of these substances are considered as Hazardous Substances by the US EPA and Department of Transportation and other US government agencies (this information must be listed on a MSDS sheet). A MSDS sheet is attached to this report for PLT®. PLT® is not classified as a hazardous or toxic substance.

In this study, birds grown on litter treated with PLT® were evaluated in a pen study for any detrimental effects as compared to control birds grown on non-treated litter. A total of 1120 male broilers were used for this study with 5 replicates of each treatment. The treatments included litter with no amendment as control, and pens with 1 X, 5 X, and 10 X the recommended application rate of PLT®. Several parameters were examined to determine if there are any negative effects of PLT® at the various rates. These parameters included observations of bird behavior, pigmentation and feathering, mortality, examination of blood components, examination of tissues microscopically, necropsy, and comparison of bird weight and feed efficiency.

The results of this study show that PLT® did not prove to be detrimental to chickens when used at any rate of application up to 10 times the recommended rate.

PLT® Research Trial
Final Report

Project Number: JHL-2-98
Project Title: Evaluation of Poultry Litter Treatment-PLT®
Location: Colorado Quality Research, Wellington, Colorado
Duration: September, 1997 to January, 1998
Protocol Design: Drs. Carey Quarles and Mac Terzich
Investigators: Brent Kirn and Dr. Carey Quarles

Objective: This study was conducted to determine if broilers grown on litter treated with PLT® at 0, 1x, 5x, and 10x, application rates show any detrimental effects.

Protocol: In this pen trial, male broiler chickens were used and each pen contained 56 birds with a stocking density of .75 sq. ft. for each bird. Five replicates were conducted for each treatment. A total of 1120 birds were used for this trial. The following treatments were used: controls with no PLT® applied to the litter, PLT® at 1 x dose applied to the top of the litter at the rate of 5 lbs./ 100 sq. ft., PLT® at 5 x dose with 25 lbs./ 100 sq. ft., and PLT® at 10 x dose with 50 lbs./ 100 sq. ft. Used litter was used for this trial and the litter was not top dressed with new shavings. The litter was lightly wetted after the PLT® application to assure complete activation.

Each 42 sq. ft. pen has concrete floors and are housed in an environmentally controlled facility simulating commercial poultry production conditions including lighting, feed formulation and feeding, watering, etc. Birds were vaccinated with Marek's disease virus vaccine at the hatchery and with Newcastle disease virus vaccine and Infectious Bronchitis virus vaccine at 7 days of age via the drinking water.

Birds were observed daily for any abnormal behavior or signs other negative effects. Mortality was recorded and necropsied throughout the trial and a probable cause of death was determined. Body weights were recorded at 49 days of age at trial end. Blood samples were collected at day 0 and day 49 from 2 birds in each test pen for hematology assay including red blood cell count, hematocrit, white blood cell count and differential. Hematology samples were assayed by California Avian Laboratory in Citrus Heights, California. At the end of the trial, 2 birds from each treatment were completely necropsied and numerous tissues were collected for microscopic examination. These tissues included: bone and marrow, bursa, esophagus, kidneys, liver, spleen, and small intestine. Histopathology tissue evaluation was performed by a Board Certified Pathologist at Colorado Pathology Services in Fort Collins, Colorado.

At the end of the trial, all birds were necropsied and gross lesions were recorded. The following tissues were critically evaluated: bone and marrow, bursa, esophagus, heart, kidney, lung, pancreas, skin, testes, brain, airsacs, crop, intestine, muscle, crop, eye, liver, proventriculus, spleen, and trachea. Pigmentation and feathering were also evaluated visually.

Results:

Behavior, feathering, and pigmentation:

Based upon daily and end of study observations, there was no abnormal behavior in any of the birds housed on litter treated with any amount of PLT®. Bird behavior was critically evaluated in all pens and there were no differences between the behavior of birds in any of the treated pens and the control pens. Also, based upon study end observations there were no differences in skin pigmentation or feathering between the birds in any treatment pen and the control pens. From gross visual evaluation of bird behavior, pigmentation, or feathering, there appears to be no negative effects of treated litter with PLT® at rates up to 10 times the normally recommended rate of application under the conditions of this study.

Mortality and cause of death:

All mortality from day 0 to study end were recorded and necropsied to determine the probable cause of death. The following table summarizes, by treatment, the mortality and necropsy findings during this study. Two hundred and eighty birds were started for each treatment at the beginning of the study. Mortality levels and causes of mortality were similar in each treatment as compared to controls. There appears to be no difference in mortality rate or cause from any rate of PLT® application to the litter.

Based on mortality evaluation there appears to be no negative effects of PLT® at rates of application up to 10 times the normal rate.

Treatment	Birds Started	Total Mortality	% Mortality	% Cause of Death *
Control	280	25	8.93	ACT 40, SDS 24, BAC 12, UNK 16, SO 8
1 X PLT®	280	24	8.57	ACT 33, SDS 33, BAC 13, UNK 13, SO 8
5 X PLT®	280	18	6.43	ACT 39, SDS 22, BAC 5.5, UNK 28, SO 5.5
10 X PLT®	280	17	6.07	ACT 53, SDS 29, BAC 0, UNK 6, SO 6, INJ 6

* Causes of Death listed as percentages of following causes: ACT= ascites, SDS= sudden death syndrome, SO= starve out, BAC= bacterial infection, UNK= unknown, INJ= injury.

Hematology (examination of blood components):

To assess the effects of the varying rates of treatment, blood samples were collected from 2 birds in each pen of each treatment and control pen on days 0 and 50. A comparison is made between the day 0 (study beginning) blood values and the day 50 (study end) blood values. And a comparison is made between the blood samples from birds in control pens and the PLT® treated pens.

A standard avian hematology evaluation was performed on each sample by California Avian Laboratory in Citrus Heights, California. The hematology evaluation included the following components: White blood cells K/ul (WBC), % Heterophils (Het), % Lymphocytes (Lym), % Monocytes (Mono), % Basophils (Baso), % Eosinophils (Eos), Red Blood Cells M/ul (RBC), Hemoglobin g/dl (Hgb), Hematocrit % (Hct), Platelets K/ul (Plat), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC).

The following table of hematology results includes averages for all pens in each treatment and controls at the beginning of the study (day 0) and at the end of the study (day 50). Treatments listed at day 50 include: 0 = controls, and each level of PLT®, 1 X, 5 X, and 10 X the recommended application rate of 5 pounds/ 100 square feet of floor space.

Average Hematology Values
Data Represent Averages of Birds in 5 Pens/Treatment

Component	Normal Value*	Day 0	Study End			
			Control	1X	5X	10X
WBC	10-30	8.71	7.86	13.07	6.75	8.59
Het	15-40	64.84	70.95	66.52	69.19	71.98
Lym	45-70	33.81	27.80	29.65	30.44	29.18
Mono	1-10	1.22	0.90	3.41	0.22	1.16
Eos	2-8	0.44	0.10	0.04	0.03	0.07
Baso	0-5	0.39	0.23	0.39	0.12	0.29
RBC	2.5-4.5	2.47	2.90	3.00	2.77	3.01
Hgb	6.5-9.7	8.15	9.12	9.31	8.79	9.54
Hct	22-45	37.48	41.62	43.21	39.40	43.27
MCV	90-140	151.85	143.30	143.90	142.60	144.00
MCH	25-47	33.00	31.46	31.22	31.77	31.77
MCHC	21-35	21.75	21.95	21.70	22.30	22.09
Plat	20-40	41.33	5.53	4.73	5.40	5.61

*Normal Values from several published sources including Duke's Physiology of Domestic Animals. Swenson, M.J. 10th Ed., 1984; Anatomy of Domestic Birds. Nickel, R., 1977; Schalm's Veterinary Hematology. Jain, N.C., 4th Ed, 1986; and Avian Physiology. Sturkie, P.D., 4th Ed, 1986. **NOTE:** Actual day 0 values vary from published normal values. This may be due to several factors including the high altitude at which this trial was conducted. Also note that the published normal values do not specify differences between day old chicks and 50-day-old birds.

There appears to be no difference in tested blood values between the treatment and control groups at study end. This would indicate that PLT® application to the litter at the study rates of 1X, 5X, and 10X the recommended rate does not appear to cause any hematological changes in chickens grown on that litter.

Some blood values appear to be outside of the published normal range and this may be due to many factors including the management conditions of this study including altitude (study conducted in Colorado). The only parameter that appears to be significantly different from day 0 to day 50 is platelet levels. All treatment and control groups appear to have lower platelet levels at study end compared to the beginning value. Because the control groups had a similar study end value this appears to be an age change and certainly not an effect of treatment.

No evidence of detrimental effects were observed in the blood analysis of chickens grown on litter treated with PLT® at any rate in this study.

Histology (microscopic examination of tissues):

On day 50, two randomly selected birds from each pen of the 0 X (Control) and 10 X (highest rate) treatment groups were subjected to a complete gross necropsy. The following tissues were collected in formalin for preparation for microscopic examination: Bone and marrow from the tibia, Bursa of Fabricius, esophagus, kidneys, liver, spleen, and small intestine.

The tissues were examined and the following report was prepared by Dr. Donald N. Kitchen (Board Certified Veterinary Pathologist) of Colorado Pathology Services in Fort Collins, Colorado:

> " A study to determine if broilers grown on litter treated with 0, 1X, 5X, or 10X, of Poultry Litter Treatment (PLT®) showed any signs of negative effects. Male commercial broiler chickens were divided into 5 blocks of 4 pens each. Group 1 was the control group with no litter treatment. Groups 2, 3, and 4 were treated with 1X, 5X, and 10X of PLT. Histologic evaluation of tissues from Groups 1 and 4 were performed and is the basis of this report.
>
> No treatment-related findings were observed in the tissues examined. Miscellaneous findings included: hemorrhage or mucus accumulation in the bursa of Fabricius. Hemorrhage was seen in only one control animal whereas mucus accumulation was observed in 6 control birds and 5 in Group 4. The mucus was located in the crypts of the mucosal lining. This finding was considered to be a natural "background" lesion in these birds.
>
> **Based on the results of these histopathologic evaluations the PLT® did not, under the conditions of this study, cause any histomorphologic tissue alterations in the tissues examined."**

Bird Weight and Feed Efficiency:

Average Weight and Feed Efficiency
Data Represent Average of all Birds in All Pens for Each Treatment

Treatment	Average Weight (kg.)	Feed Efficiency
Controls	2.652	2.010
1 X PLT®	2.661	1.996
5 X PLT®	2.641	1.958
10 X PLT®	2.647	1.985

There appears to be no negative effects of PLT® at any rate in this study based upon differences in bird weight or feed efficiency.

Conclusion:

In this study, PLT® appears to have no adverse effects to chickens when used at application rates to the litter of up to ten times the recommended rate. PLT® is not classified as a toxic or hazardous product.

Notice:

This study and the final report are the sole property of Jones-Hamilton Co. This report may not be reproduced in whole or in part by any means without the express written consent of Jones-Hamilton Co.

There were no known circumstances that may have affected the data quality or integrity during this study. The report and data herein are accurate in that they represent the actual results of the study, and were collected in a manner that did not misrepresent the true effects of the test articles. A signed release statement is on file from the investigators and is available upon written request.

Test articles were used in a manner consistent this manufacturer's written publicly available instructions and was applied in a manner consistent with typical poultry industry standards. This study was conducted under conditions typical for commercial poultry production. The protocol and daily procedures during the trial were evaluated and monitored critically to fairly evaluate the test article.

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PLT® FIELD RESEARCH TRIAL

PRELIMINARY RESULTS

Project Number:	**JHF-2-96**
Project Title:	**Poultry Litter Treatment (PLT®) Effect of Breast Blisters and Downgrading of Turkey Carcasses**
Location:	**Canadian Turkey Farms Supervised by the University of Saskatchewan**
Duration:	**June 1996 to January 1998**
Protocol Design:	**Dr. Carlyle Bennett and Dr. Mac Terzich**

The study will investigate whether the incidence of breast lesions on turkey carcasses is affected by the chemical characteristics of the litter. The effect of using PLT® to reduce pH and ammonia levels in litter will be tested in a commercial turkey barn set up to accommodate research pens. The optimum level and number of applications of PLT® will be investigated. The ammonia, nitrogen, organic carbon, moisture, and pH of litter on commercial turkey tom farms with low and high levels of breast lesions will be monitored. To improve the method of analyzing ammonia production from litter in commercial barns, the use of a bag with a semi-permeable membrane to simulate the ability of ammonia to move from the litter and into a turkey's skin will be investigated. The results of the study will help determine the type of litter conditions that increase breast lesions.

Description of the Problem

Breast blisters are fluid filled nodes that must be trimmed off the keels of turkey carcasses, resulting in a significant loss in quality and value of the breast meat. Severe blistering can result in condemnation of a bird. Turkeys can also be downgraded because of small, round ulcers on the keel called breast buttons. It is unknown if breast blisters and buttons have the same cause although they can occur on the same carcass. Breast blisters have been a more severe problem in areas such as Minnesota and the Canadian Prairies while breast buttons have been more common in southern regions like North Carolina. A survey of turkey flocks marketed in Ontario indicated that 21% of toms had breast blisters or buttons while only 2% of hens and broilers were affected (McEwen and Barbut, 1992). Plant statistics from the Prairies reveal that 19% of toms have breast "cysts", (usually blisters but sometimes buttons), compared to 0.5% to 2% in broilers and hens. For turkey tom producers, downgrading due to blisters and buttons costs an average of 1 cent per kg shipped or approximately $750,000 annually. For consumers, toms with breast lesions can be undesirable even as utility birds because, while many will accept a utility bird with a wing or part of a leg trimmed off, they do not like a bird with a hole cut out of the middle of the breast. Finally, for further processors, the breast meat is the most valuable portion of the carcass and trimming breast lesions reduces the amount of breast meat that a carcass will yield.

Background

Breast blisters and buttons do not normally result from infection but instead appear to be caused by physical or chemical irritation of the breast. Individual birds with heavy feathering on the keel have a lower incidence of blisters and covering the keel with sheepskin can prevent breast blisters (Miner and Smart, 1975; Newberry, 1992). As toms reach weights over 13.5 kg, their breast becomes plump enough that the keel's contact with the litter is reduced and the incidence of breast blisters declines. Several possible sources of the irritation of the breast have been identified:

1. Breast lesions are increased in turkey flocks where many birds have difficulty walking, although the severely crippled birds are not the ones with the highest incidence of lesions (Warknick, 1979; Gonder and Barnes, 1989; Newberry, 1992). Birds with difficulty walking spend more time sitting and the increased contact with the litter may increase the problem. Those birds that are severely crippled, however, are underweight, have less contact pressure between their breast and the litter, and may avoid breast blisters. Use of lighting programs to improve bird health and mobility can reduce breast buttons (Newberry, 1992).

2. Turkeys on ranges with hard packed soil have more breast blisters than those with a soft, full grass cover (Dobson, 1969 and 1977). Sometimes "coarse" litter material in confinement barns is associated with breast buttons (Tilley et al 1990).

3. The role of litter wetness in breast lesions is difficult to determine. Wetting turkey ranges every third day in one research trial did not increase breast blisters and in one case birds on damp, caked litter actually had a lower incidence of blisters (Adams et al. 1967). Another researcher found that wetting the litter to very high levels of moisture, (60%-70%), did cause breast blisters (Martland 1984). Recent research from West Virginia, on the other hand, determined that turkeys in cool barns with damp litter had fewer breast blisters (Lerner 1996). Research from Minnesota has suggested that while high moisture can cause breast buttons, the effect on breast blisters may depend on litter type (Kamyab et al. 1995). In this recent research, high moisture decreased the incidence of blisters when toms were reared on fresh litter but increased it on reused litter.

4. The chemical characteristics of litter material are gaining increased attention as causes of breast lesions. Work done in West Virginia identified ammonia production in the litter as a major contributor of breast blisters (Lerner 1996). Similarly, some of the recent research in Minnesota has suggested that reducing ammonia and increasing acidity of the litter will help control breast blisters (Noll 1996). With respect to ammonia, it is the ammonia in the litter and not in the air that is considered important. At least in one research trial, treating litter with propionic acid has been shown to reduce breast blisters (Enos 1972).

Based on this previous research, a trial has been designed to investigate how litter characteristics could be altered to reduce breast lesions.

Trial A. At Hillcrest Turkey Research Barn

Objectives

The litter in a commercial barn will be top dressed with PLT®, to lower litter ammonia and pH, to determine if it will decrease breast blisters, reduce ammonia production in the litter and increase the fertilizer value of the litter.

Materials and Methods

Hillcrest Farms at Bruno, Saskatchewan has a commercial barn that can be divided into 8 pens of 300 toms, each pen having 1000 square feet. Half of the pens will be treated with 5lbs/100 sq. ft. of PLT® at 8 and 10 weeks of age. The litter ammonia, nitrogen, pH, moisture and carbon content will be tested at 8,10, 12 and 15 weeks of age. At the end of the flock, the litter will also be tested for phosphorous, potassium, sodium, sulfur, nitrates and rate of nitrogen release to determine its fertilizer value and potential as a source of water pollution.

A sample of 30 birds will be weighed in each pen at 8 and 15 weeks of age. The flock will be shipped at approximately 15 weeks of age and 12.5 kg body weight, the age and body weight at which breast blisters are most commonly found. The farm involved in this study averages approximately 15% breast blisters in its toms compared to 19% provincially. At the end of the flock, all of the birds on the untreated litter will be shipped one day and those on the treated litter would be shipped the next. The birds will be loaded by pen onto the truck so any incidence of breast blisters can be monitored pen by pen.

Trial B. Method of Applying PLT® to Litter (Hillcrest Farms)

Objectives

Normally, PLT® has been applied to the litter at a rate of 5lbs/100 sq. ft. with a drop type fertilizer spreader without raking or stirring the compound into the litter. The influence of 4 different methods of applying PLT® will be compared:

1. No top dressing
2. Top dressing with PLT® at 5lbs/100 sq. ft. without raking the product into the litter.
3. Top dressing with PLT® at 10lbs/100 sq. ft. without raking the product into the litter.
4. Top dressing with PLT® at 10lbs/100 sq. ft. with raking the product into the litter.

The change in the litter ammonia, pH and nitrogen content will be monitored over time with each method to determine which will provide the greatest and most long lasting change in litter conditions. This study will help determine if applying a high level of PLT® will reduce the number of ages at which it must be applied in the barn. It will also help decide if the change in litter conditions in response to a high level of applications is sufficient to warrant the extra expense.

Materials and Methods

The 4 methods of application of PLT® will be tested in a 200-foot long barn housing 2,400 toms when the birds reach 10 weeks of age. Each of the 4 application methods will be tested in 10 foot wide sections running across the barn, with 4 test sections for each method. Over a 4 -week period, the litter will be tested weekly for ammonia, nitrogen, organic carbon, pH and moisture.

Trial C. Survey of Litter Conditions in Commercial Farms

Objectives

The chemical character of the litter on 6 tom farms will be measured and related to the incidence of breast lesions on birds shipped from those farms. Two of the farms will typically have 5% breast lesions at the plant the others will average over 15%. The range of ammonia, nitrogen, organic carbon, moisture and pH found under commercial conditions will be determined. Knowing the typical levels found commercially will help to interpret whether litter conditions found to increase breast blisters in research trials are common on commercial farms.

Materials and Methods

The litter from 6 tom farms will be tested at 10 and 14 weeks of age to determine ammonia, nitrogen, organic carbon, moisture and pH. Grade information will be collected from the processing plant.

Trial D. Development of a Test to Simulate Ammonia Movement from Litter to Turkey Skin

Objective

A method of determining the movement of ammonia from litter into a bag with a semi-permeable membrane will be developed. Such a test will simulate the movement of ammonia from the litter into a turkey tom's skin, which is also a semi-permeable membrane. This technique will help determine which litter conditions promote movement of ammonia into the skin and not just those that increase total ammonia in the litter or air. A bag which trapped the ammonia released from the litter could also be easily moved around every few hours to different locations in a barn and the total ammonia trapped by the one sample would reflect average ammonia release from the litter, research costs could be reduced because fewer samples would need to be analyzed. A semi-permeable bag could also be used to detect ammonia release in specific areas such as near versus away from the drinkers and during specific time periods such as night versus day. Further more, it would be easier and quicker to test ammonia by moving the sample bag around the barn than digging up litter samples from many locations and then mixing and pooling them together.

Summary of Results of Breast Blister and Litter Treatment Trial

The birds in the pens treated with PLT® had a 25% lower incidence of breast blisters and abscesses. Very subjectively, the cysts appeared smaller in the birds from the treated pens. The overall incidence of the breast lesions was high in the flock, perhaps due to the use of small 300 bird pens with reduced walking distance. The reduction in breast lesions in the toms on the treated litter is encouraging, especially since the acidifying effect of the PLT® on the litter did not last the full two weeks between applications in the barn. Perhaps a more significant improvement would occur with larger or more frequent applications.

No negative effect of the litter treatment was seen in live bird performance, with similar growth rates, mortality and condemnations in toms from both the treated and untreated pens. Footpads appeared to be in good condition in both sets of birds.

	Untreated	Treated
Live Weight at 14 weeks, 3 days	11.66 kg	11.70kg
Live Weight at 15 weeks, 0 days	———	12.11kg
Live Weight at 15 weeks, 1 day	11.99kg	———
Mortality from 8 to 15 weeks %	7.2%	5.9%
Toms with breast cysts, %	34.8%	26.0%
Toms with abscesses, %	1.7%	1.3%
DOA's and Cyanosis, %	0.1%	0.3%
Other Condemnations, %	1.0%	0.3%

These results are encouraging enough to try another trial to see if the litter treatment will provide a consistent improvement in carcass quality.

A/7

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

Trisha Marsh Johnson[1], Brian Fairchild[2] and Casey W. Ritz[2].
[1]Veterinary and Environmental Technical Solutions, 125 Fox Trace, Athens, GA 30606, USA; [2]Department of Poultry Science, University of Georgia, Athens, GA 30602, USA.

Abstract

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

Introduction

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

This has left livestock and poultry producers with the need to implement effective best management practices to control both ammonia and VOCs emissions from animal housing and manure storage facilities (Dragosits, et al. 2002). This is also critical to European livestock & poultry producers as the BMPs implemented there were not enough to reach the emissions targets set in the Netherlands for the year 2000. It has been suggested that the only way to reach the target goals for NH_3 emissions (30GgNH_3/yr) set for 2030 in the Netherlands would be to completely eliminate all poultry & swine production and house all cattle in low-emission stables year-round (de Vries, et al. 2001). In addition, tremendous consumer focus on animal welfare has instituted strict limits on ammonia levels inside confinement animal facilities, mostly poultry & swine. Since the current management strategies often rely on being able to exhaust as much ammonia from the house as possible, alternatives are clearly needed (Ritz, et al. 2004).

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

Sodium Bisulfate Characteristics

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

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

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

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

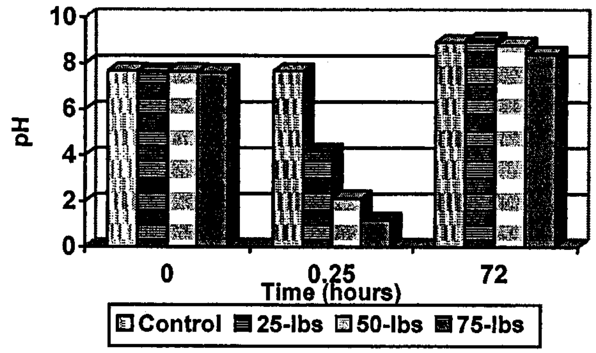


Figure 2. pH readings of dairy slurry treated with SBS (lbs/1000 sqft) over time.

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

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

SBS Use in Poultry- Literature Review

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

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

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

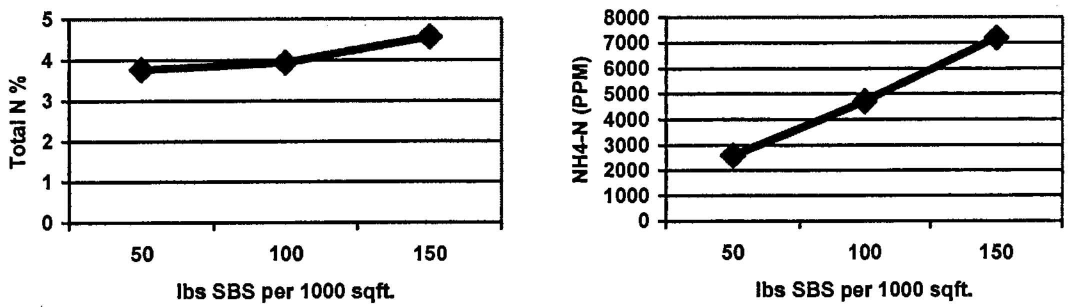
with a substantial return on investment that would support increased PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998;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

Current SBS Research in Poultry

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

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

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



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

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

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

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

Economics of SBS Use in Poultry

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

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

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

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

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

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

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

Summary

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

Footnote

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

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A 18

Effects of frequency of multiple applications of litter amendment on litter ammonia and live performance in a shared airspace

J. L. Purswell,*[1] J. D. Davis,† A. S. Kiess,‡ and C. D. Coufal§

**Poultry Research Unit, USDA-Agricultural Research Service, Mississippi State, MS 39762; †Agricultural and Biological Engineering Department, and ‡Poultry Science Department, Mississippi State University, Mississippi State 39762; and §Poultry Science Department, Texas A&M University, College Station 77843*

Primary Audience: Flock Supervisors, Researchers, Producers

SUMMARY

Mitigation of ammonia (NH_3) volatilization from litter is of particular interest given its effects on broiler health and production efficiency, as well as air and water quality concerns. Typical management guidelines recommend aerial NH_3 concentrations be limited to 25 ppm. However, concentrations in excess of this recommendation are common in winter months due to limited minimum ventilation to conserve heat. Litter amendments are an effective means to reduce ammonia volatilization and are applied to the litter before chick placement. In this study, we evaluated the effects of differing application frequencies of a sodium bisulfate-based litter amendment on bird performance and equilibrium litter NH_3 concentrations. Treatments consisted of no amendment application (negative control), initial application before placement (positive control), and varied application schedules at 14, 28, and 43 d at 0.49 kg/m^2 (100 lb/1,000 ft^2). Repeated application of litter amendment did not affect live performance or foot pad quality. More frequent application of litter amendment significantly reduced equilibrium litter NH_3 concentration when compared with the negative and positive controls. The most effective application program was biweekly, with significant reductions of 56.6 and 21.8% at d 42 and 57, respectively. Therefore, repeated application during growout can effectively mitigate ammonia volatilization from litter without incurring reductions in live performance or foot pad quality.

Key words: litter management, ammonia, air quality

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DESCRIPTION OF PROBLEM

Mitigation of aerial ammonia (NH_3) remains an important topic of interest in commercial poultry production due to its effects on bird health, well-being, and production efficiency, as well as the potential for environmental effects. Ocular and respiratory health can be compromised from chronic exposure to aerial NH_3 [1, 2]. Significant performance reductions occur as chronic exposure levels exceed 25 ppm, including reduced BW and poorer feed conversion [3]. Therefore, chronic exposure of poultry to aerial NH_3 can also have significant detrimental economic effect to poultry producers.

[1]Corresponding author: Joseph.Purswell@ars.usda.gov

Elevated NH_3 concentrations typically occur in commercial broiler houses as a result of recycled litter usage coupled with reduced ventilation rates for fuel conservation. With properly designed and operated ventilation systems, ventilation rates sufficient for moisture removal should remove air contaminants [4]. In lieu of reducing NH_3 production through reducing litter moisture via ventilation, the application of litter treatments, such as sodium bisulfate, aluminum sulfate, sulfuric acid, and ferric sulfate, to reduce NH_3 production [5, 6] and volatilization [7] through litter acidification has become a widespread management practice throughout the commercial broiler industry.

Application rates recommended by manufacturers range from 0.24 to 0.73 kg/m^2 (50 to 150 lb/1,000 ft^2) depending on the active ingredient (i.e., sodium bisulfate, alum, and so on) and previous litter management (e.g., in-house windrowing) [8]. Fairchild et al. [9] evaluated increased application rates for sodium bisulfate litter amendment (poultry litter treatment; **PLT**) to determine the lifespan of NH_3 mitigation ability. Overall aerial NH_3 concentrations were reduced as application rates increased from 0.24 to 0.73 kg/m^2 and extended NH_3 suppression for an additional week. In addition, more nitrogen was retained in the litter in the form of ammonium. Given the limited extensions of the duration of mitigation potential from increased initial application, another strategy to consider would be multiple applications over the life of the flock. Li et al. [10] evaluated weekly application of PLT in environmental chambers at application rates of 0.18 and 0.37 kg/m^2 (37.5 and 75 lb/1,000 ft^2). No significant differences in live performance were observed; however, NH_3 emission rates were significantly reduced.

The objective of this research was to evaluate the effects of application frequency of a sodium bisulfate litter amendment at the manufacturer's recommended rate on performance of broiler chickens and litter ammonia volatilization.

MATERIALS AND METHODS

A total of 920 straight-run broiler chickens [11] were obtained from a commercial hatchery for each trial and randomly allocated to 20 pens in a tunnel-ventilated research facility, resulting in 4 replicate pens per treatment. A total of 2,760 broilers were used over the 3 trials in the study. The first trial began in September 2011, and the time between each flock was kept at 14 d to mimic industry practice. Birds were housed in pens measuring 1.5 × 2.7 m (5 × 9 ft) to 56 d of age and stocked at 42 birds/pen. Each pen was equipped with tube feeders and nipple drinkers, and feed and water were available ad libitum. Ventilation was managed according to typical poultry housing guidelines [12, 13], with ventilation rates of 0.17 m^3/h per bird (0.10 ft^3/min per bird) and 0.42 m^3/h per bird (0.25 ft^3/min per bird) during wk 1 and 2, respectively, and to maintain temperature setpoints from wk 3 to 8.

The pens contained pine shavings litter that had been used with 1 previous flock. Treatments were held constant in each pen for all 3 trials to assess the effects of repeated amendment application over multiple flock cycles. A sodium bisulfate-based litter amendment [14] was used for each application in each trial. The litter amendment was applied to the surface of the litter according to the schedule in Table 1 at the manufacturer's recommended rate (0.48 kg/m^2; 100 lb/1,000 ft^2). Ammonia volatilization from the litter was assessed by measuring equilibrium NH_3 concentrations [15, 16] with a photoacoustic infrared gas analyzer [17] and a dynamic flux chamber [18] placed on the litter on d −1, 13, 27, and 42, and on d 57 after birds were removed from the pens. The dynamic flux chamber method was used to measure equilibrium NH_3 concentrations, as all pens shared a common airspace and emissions could not be measured directly. All equilibrium concentrations measurements were taken before the litter amendment application in 1 location near the center of each pen to avoid areas near the drinker line and feeder that typically have increased litter moisture and may increase the variability of equilibrium NH_3 concentrations. Chick placement was considered d 0 for each trial.

The following 4-phase feeding schedule was used: starter (placement to d 14), grower (d 15–29), finisher (d 30–43), and withdrawal (d 44–56). Diet compositions have previously been reported by Dozier et al. [19]. The weight of all birds in each pen and feed consumption were obtained on d 14, 29, 43, and 56. Foot pad quality was assessed on flocks 1 and 3; foot pad

Table 1. Litter amendment application frequency treatment schedule[1]

Treatment	Application schedule (d)
A	Negative control
B	−1 (positive control)
C	−1 and 28
D	−1, 14, 28, and 43
E	−1, 28, and 43

[1]Day −1 = the day before chick placement.

scores (FPS) were obtained for 6 birds per pen (3 male and 3 female) [20] per Nagaraj et al. [21] on d 56. All procedures were approved by the USDA-Agricultural Research Service Animal Care and Use Committee at the Mississippi State location.

For statistical analysis, a randomized complete block design was used, with trial serving as the blocking factor. All analyses were performed using PROC MIXED in SAS [22]. No treatment × trial interactions were observed, and data from all 3 trials were pooled for analysis. Means were separated using Fisher's LSD, with significance considered at $P \leq 0.05$.

RESULTS AND DISCUSSION

Live performance results are shown in Table 2. No significant differences in live performance were observed among treatment groups, indicating multiple applications of the litter amendment did not affect live performance or mortality. These findings agree with those of Li et al. [10]. The shared airspace in the current study precluded determinations of potential effects on performance due to changes in aerial NH_3 concentration resulting from repeated amendment application. Additionally, Li et al. [10] reported similar results from a larger scale study with a limited aerial NH_3 concentration at a maximum of 25 ppm, which may not realistically simulate typical commercial conditions.

Foot pad quality was generally improved through addition of litter amendment (Table 3), with treatment B having the best footpad quality. The negative control (treatment A) and application at d −1, 28, and 42 (treatment C) had fewer birds with no foot pad lesions (FPS = 0). The negative control also had a significantly higher incidence of lesions <1.5 cm (FPS = 1) when

Table 2. Live performance responses for straight-run broilers under different litter amendment application frequencies during growout to 56 d of age[1]

Treatment[2]	BW gain (g/bird)	FI[3] (g/bird)	FCR (g:g)	Mortality (%)
A	3,883	7,362	1.88	1.5
B	3,915	7,285	1.86	0.4
C	3,851	7,271	1.87	1.1
D	3,869	7,285	1.87	1.0
E	3,919	7,357	1.86	0.9
SEM	32	41	0.01	0.1
P-value	0.483	0.377	0.554	0.646

[1]Table values represent LSM for 12 pens (4 replicate pens × 3 trials) having 42 birds/pen at placement.

[2]Refer to Table 1 for treatment descriptions.

[3]FI = feed intake.

compared with the remaining treatments. Cumulative FPS for trials 1 and 3 are presented in Table 4; foot pad quality decreased significantly in trial 3 ($P \leq 0.0001$). Biweekly application (treatment E) and single application (treatment B) had the lowest cumulative FPS in trial 3; thus, reduced FPS does not appear to be correlated to frequency of application in this study. Nagaraj et al. [21] evaluated the effects of application rate of PLT on pododermititis and found no differences in FPS attributable to the addition of PLT. However, Li et al. [10] found significant improvements in FPS with weekly applications at

Table 3. Mean incidence (%) of broiler foot pad scores (FPS) for different litter amendment application frequencies during growout assessed at 56 d of age[1]

Treatment[2]	FPS[3] = 0 (%)	FPS = 1 (%)	FPS = 2 (%)
A	78.1[c]	20.8[a]	1.0
B	98.9[a]	1.0[b]	0.0
C	87.5[bc]	8.3[b]	4.2
D	92.7[ab]	2.1[b]	5.2
E	94.8[ab]	5.2[b]	0.0
SEM	3.6	3.1	1.8
P-value	0.0011	<0.0001	0.14

[a–c]Means within a column having different superscripts are significantly different at $P \leq 0.05$.

[1]Table values represent LSM for 8 pens (4 replicate pens × 2 trials) having 42 birds/pen at placement.

[2]Refer to Table 1 for treatment descriptions.

[3]Foot pad quality was assessed using a 3-point system where lesions were assigned the following scores according to severity: 0 = no lesions, 1 = lesions <1.5 cm, and 2 = lesions >1.5 cm.

Table 4. Mean cumulative foot pad scores for different litter amendment application frequencies during growout assessed at 56 d of age[1]

Treatment[2]	Trial 1[3]	Trial 3
A	0.15^{a}	0.31^{a}
B	0.00^{b}	0.02^{c}
C	0.00^{b}	0.33^{a}
D	0.00^{b}	0.25^{ab}
E	0.00^{b}	0.10^{bc}
SEM	0.02	0.07
P-value	<0.0001	0.0054

a–cMeans within a column having different superscripts are significantly different at $P \leq 0.05$.

[1]Table values represent least squares means for 4 pens/trial having 42 birds/pen at placement.

[2]Refer to Table 1 for treatment descriptions.

[3]Foot pad quality was assessed using a 3-point system where lesions were assigned the following scores according to severity: 0 = no lesions, 1 = lesions <1.5 cm, and 2 = lesions >1.5 cm.

both 0.18 and 0.37 kg/m^2 (37.5 and 75 lb/1,000 ft^2) when compared with no application.

Mean dynamic flux chamber equilibrium NH_3 concentrations are shown in Table 5. No significant differences in chamber equilibrium NH_3 concentrations were observed through d 27 for any treatment. All treatments resulted in reduced NH_3 concentration from d −1 to 14; this reduction is likely a product of increased NH_3 volatilization from heating and bird activity and low rates of feces deposition on the litter with young birds. Significant reductions were observed at d 42 (56.6% reduction) and 57 (21.8% reduction) for a 2-wk application frequency (treatment D) when compared with the negative control (treatment A). Significant reductions were also observed at d 42 (60.4% reduction) and 57 (31.1% reduction) for treatment D when compared with the positive control (treatment B).

Reductions in equilibrium NH_3 concentration over time are likely higher than those reported here, as measurements were taken at the end of each 2-wk period; Li et al. [10] noted increased reductions in emissions immediately after repeated applications of PLT. Whereas treatment E showed significant reductions at d 42 and 57 when compared with the positive control (39.6 and 9.0%, respectively), it was not different from the negative control. Treatments D and E were not significantly different, suggesting that application after the brooding period (i.e., d 14) is less critical than achieving a threshold amount of litter amendment applied for reduction of litter NH_3.

Significant reductions in performance have been observed when broilers were subjected to aerial NH_3 concentrations in excess of 25 ppm [3]; hence reductions in aerial NH_3 will likely translate into improved performance under commercial conditions [23]. As ventilation rates increase with bird age to control temperature during moderate and warm weather, aerial NH_3 concentrations are normally kept below 25 ppm, thus repeated application may not improve performance under these conditions, but will likely provide reductions in NH_3 emissions. However, this may not always be the case in periods of extremely cold weather, and mitigation of ammonia volatilization in the later stages of growout may result in improved broiler performance. Repeated application of the litter amendment in commercial-scale poultry production facilities will require development of distribu-

Table 5. Mean dynamic flux chamber equilibrium ammonia concentrations for different litter amendment application frequencies during broiler growout to d 56[1]

Treatment[2]	d −1 (ppm)	d 13 (ppm)	d 27 (ppm)	d 42 (ppm)	d 57 (ppm)
A	64.0	15.6	24.8	219.9^{ab}	255.8^{ab}
B	70.3	10.5	15.8	241.0^{a}	290.1^{a}
C	82.4	10.3	15.1	148.1^{abc}	243.3^{b}
D	64.0	12.7	11.8	95.4^{c}	199.9^{c}
E	80.1	13.8	11.9	132.8^{bc}	232.7^{bc}
SEM	18.2	2.2	3.5	36.5	14.8
P-value	0.920	0.396	0.074	0.038	0.003

a–cMeans within a column having different superscripts are significantly different at $P \leq 0.05$.

[1]Table values represent least squares means for 12 pens (4 replicate pens × 3 trials) having 42 birds/pen at placement.

[2]Refer to Table 1 for treatment descriptions.

tion systems; distribution system development should be focused on accurate placement of litter amendment to minimize equipment maintenance issues. Further studies under commercial-type ventilation and environment are warranted to determine how live performance may be affected, and the economic effect of repeated application.

CONCLUSIONS AND APPLICATIONS

1. Multiple applications of the sodium bisulfate litter amendment at the manufacturer's recommended rate (0.48 kg/m^2; 100 lb/1,000 ft^2) on a biweekly basis reduced litter ammonia concentrations by 56.6 and 21.8% at d 42 and 57, respectively.
2. Live performance was not affected by repeated additions of the sodium bisulfate litter amendment.
3. Further studies under commercial-type ventilation and environment are warranted to determine the effects of repeated litter amendment applications on live performance, equipment maintenance issues, and economic effect.

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A/13

Conforms to ANSI Z400.5-2004 Standard (United States, Canada, Mexico).

Material Safety Data Sheet

PLT® / Poultry Litter Treatment

1. Product and company identification

Product name	:	PLT® / Poultry Litter Treatment
Material uses	:	Poultry litter treatment. *Not intended for use in feed, food or drinking water.*
Supplier/Manufacturer	:	Jones Hamilton 30354 Tracy Road Walbridge, OHIO, 43465 Tel: (419) 666-9838 Fax: (419) 666-1817
Code	:	PLTCUN01
MSDS authored by	:	KMK Regulatory Services inc.
In case of emergency	:	CHEMTREC, U.S. : (800) 424-9300 International: (703) 527-3887
Product type	:	Solid.

2. Hazards identification

Emergency overview

Color	:	Off-white.
Physical state	:	Dry (Anhydrous) crystalline solid spherical shape beads.
Odor	:	Fresh to pungent.
Signal word	:	WARNING!
Hazard statements	:	Causes serious eye irritation. May cause respiratory irritation. May be harmful if swallowed.
Precautions	:	Do not get in eyes. Avoid contact with skin and clothing. Use only with adequate ventilation. Keep container tightly closed and sealed until ready for use. Wash thoroughly after handling. Material is non-flammable. Use extinguishing media suitable for surrounding materials.
OSHA/HCS status	:	This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Potential acute health effects

Inhalation	:	Inhalation of dust may irritate nose, throat and/or lungs.
Ingestion	:	Small amounts (tablespoonful) swallowed are not likely to cause injury; however, swallowing large amounts may irritate or burn digestive tract.
Skin	:	Prolonged exposure may cause skin irritation.
Eyes	:	Causes serious eye irritation.

Potential chronic health effects

Chronic effects	:	Contains material that may cause target organ damage, based on animal data.
Carcinogenicity	:	No known significant effects or critical hazards.
Mutagenicity	:	No known significant effects or critical hazards.
Teratogenicity	:	No known significant effects or critical hazards.
Developmental effects	:	No known significant effects or critical hazards.
Fertility effects	:	No known significant effects or critical hazards.
Target organs	:	Contains material which may cause damage to the following organs: mucous membranes, skin, eyes.

Over-exposure signs/symptoms

Inhalation	:	Adverse symptoms may include the following: respiratory tract irritation coughing
Ingestion	:	No specific data.
Skin	:	No specific data.

2 . Hazards identification

Eyes : Adverse symptoms may include the following:
pain or irritation
watering
redness

Medical conditions aggravated by over-exposure : Pre-existing disorders involving any target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

See toxicological information (section 11)

3. Composition/information on ingredients

United States

Name	CAS number	%
Sodium bisulfate	7681-38-1	>90

Canada

Name	CAS number	%
Sodium bisulfate	7681-38-1	>90

Mexico

Name	UN number	IDLH	Classification H	F	R	Special	CAS number	%
Sodium bisulfate	Not regulated.	-	1	0	0		7681-38-1	>90

There are no additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

4 . First aid measures

Eye contact : Immediately flush eyes with plenty of water for at least 20 minutes, occasionally lifting the upper and lower eyelids. If redness or irritation persists, get prompt medical attention.

Skin contact : In case of contact, immediately flush skin with plenty of water for at least 20 minutes. If skin irritation occurs, seek medical attention.

Inhalation : Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. If irritation or discomfort persists, seek medical attention.

Ingestion : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Call medical doctor or poison control center immediately.

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training.

5. Fire-fighting measures

Flammability of the product : No specific fire or explosion hazard.

Extinguishing media

Suitable : Use an extinguishing agent suitable for the surrounding fire.

Not suitable : None known.

Special exposure hazards : None known.

Hazardous thermal decomposition products : Decomposition products may include the following materials:
sulfur oxides

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

6. Accidental release measures

Personal precautions : Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Small spill : Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor.

Large spill : Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see section 1 for emergency contact information and section 13 for waste disposal.

7. Handling and storage

Handling : Put on appropriate personal protective equipment (see section 8). Avoid breathing dusts. Wash thoroughly after handling.

Storage : Material is hygroscopic and will readily absorb moisture. DO NOT store dry product where exposed to moist conditions. Keep container tightly closed.

8. Exposure controls/personal protection

Canada

Occupational exposure limits		TWA (8 hours)			STEL (15 mins)			Ceiling			
Ingredient	List name	ppm	mg/m³	Other	ppm	mg/m³	Other	ppm	mg/m³	Other	Notations
No known value.											

Consult local authorities for acceptable exposure limits.

Recommended monitoring procedures : Personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.

Engineering measures : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. The engineering controls also need to keep gas, vapor or dust concentrations below any lower explosive limits.

Hygiene measures : Ensure that eyewash stations and safety showers are close to the workstation location. Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period.

Personal protection

Respiratory : In dusty atmospheres (>10 mg/m³), use a NIOSH-approved dust respirator.

Hands : Rubber gloves.

Eyes : Safety glasses or chemical goggles.

Skin : Cotton-blend coveralls.

Environmental exposure controls : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

9 . Physical and chemical properties

Physical state	: Dry (Anhydrous) crystalline solid spherical shape beads.
Color	: Off-white.
Odor	: Fresh to pungent.
Molecular weight	: 120
Molecular formula	: $NaHSO_4$
pH	: <1 [Conc. (% w/w): 5%]
Melting/freezing point	: 177°C (350.6°F)
Specific gravity	: 1.28 g/cm^3
Solubility	: Partially soluble in the following materials: cold water and hot water.

10. Stability and reactivity

Chemical stability	: The product is stable.
Conditions to avoid	: DO NOT store dry product where exposed to moist conditions.
Materials to avoid	: Reactive or incompatible with the following materials: oxidizing materials, acids and alkalis. DO NOT MIX dry or concentrated solutions of this product with concentrated solutions of chlorine bleach, ammonia cleansers or similar products.
Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Possibility of hazardous reactions	: Under normal conditions of storage and use, hazardous reactions will not occur.
Hazardous polymerization	: Under normal conditions of storage and use, hazardous polymerization will not occur.

11. Toxicological information

Acute toxicity

Product/ingredient name	Result	Species	Dose	Exposure
Sodium bisulfate	LD50 Oral	Rat	2800 mg/kg	-

Chronic toxicity : No specific data.

12. Ecological information

Environmental effects	: This product readily dissolves in water to form a weak acid solution. A 0.05 percent or greater (by weight) solution of this product will likely be acutely harmful to aquatic life.
Other adverse effects	: No known significant effects or critical hazards.

13. Disposal considerations

Waste disposal	: The generation of waste should be avoided or minimized wherever possible. This material and its container must be disposed of in a safe way. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Empty containers or liners may retain some product residues. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor.

Disposal should be in accordance with applicable regional, national and local laws and regulations.

Refer to Section 7: HANDLING AND STORAGE and Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION for additional handling information and protection of employees.

14 . Transport information

DOT/TDG/MXT/IMDG/IATA : Not regulated.

15 . Regulatory information

United States

HCS Classification : Irritating material

U.S. Federal regulations : **United States inventory (TSCA 8b):** All components are listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: Sodium bisulfate
SARA 311/312 MSDS distribution - chemical inventory - hazard identification:
Sodium bisulfate: Immediate (acute) health hazard, Delayed (chronic) health hazard

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 accidental release prevention: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

Clean Air Act Section 112(b) Hazardous Air Pollutants (HAPs) : Not listed

Clean Air Act Section 602 Class I Substances : Not listed

Clean Air Act Section 602 Class II Substances : Not listed

DEA List I Chemicals (Precursor Chemicals) : Not listed

DEA List II Chemicals (Essential Chemicals) : Not listed

State regulations : **Connecticut Carcinogen Reporting:** None of the components are listed.
Connecticut Hazardous Material Survey: None of the components are listed.
Florida substances: None of the components are listed.
Illinois Chemical Safety Act: None of the components are listed.
Illinois Toxic Substances Disclosure to Employee Act: None of the components are listed.
Louisiana Reporting: None of the components are listed.
Louisiana Spill: None of the components are listed.
Massachusetts Spill: None of the components are listed.
Massachusetts Substances: None of the components are listed.
Michigan Critical Material: None of the components are listed.
Minnesota Hazardous Substances: None of the components are listed.
New Jersey Hazardous Substances: The following components are listed: Sodium bisulfate
New Jersey Spill: None of the components are listed.
New Jersey Toxic Catastrophe Prevention Act: None of the components are listed.
New York Acutely Hazardous Substances: None of the components are listed.
New York Toxic Chemical Release Reporting: None of the components are listed.
Pennsylvania RTK Hazardous Substances: None of the components are listed.
Rhode Island Hazardous Substances: None of the components are listed.

Canada

WHMIS (Canada) : Class D-2B: Material causing other toxic effects (Toxic).

15 . Regulatory information

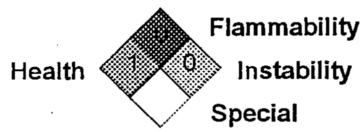
Canadian lists : **CEPA Toxic substances:** None of the components are listed.
Canadian ARET: None of the components are listed.
Canadian NPRI: None of the components are listed.
Alberta Designated **Substances:** None of the components are listed.
Ontario Designated **Substances:** None of the components are listed.
Quebec Designated **Substances:** None of the components are listed.

Canada inventory : All components are listed or exempted.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.

Mexico

Classification :



International regulations

International lists : Australia inventory **(AICS):** All components are listed or exempted.
China inventory (IECSC): All components are listed or exempted.
Japan inventory: All components are listed or exempted.
Korea inventory: All components are listed or exempted.
New Zealand Inventory of Chemicals (NZIoC): All components are listed or exempted.
Philippines inventory (PICCS): All components are listed or exempted.

Chemical Weapons Convention List Schedule I Chemicals : Not listed

Chemical Weapons Convention List Schedule II Chemicals : Not listed

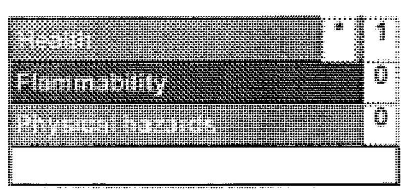
Chemical Weapons Convention List Schedule III Chemicals : Not listed

16 . Other information

United States

Label requirements : Warning - Causes serious eye irritation. May cause respiratory irritation. May be harmful if swallowed. Wear protective gloves and eye/face protection. Avoid breathing dust. Wash thoroughly after handling.

Hazardous Material Information System (U.S.A.) :

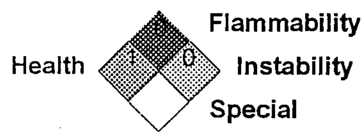


Caution: HMIS® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks Although HMIS® ratings are not required on MSDSs under 29 CFR 1910.1200, the preparer may choose to provide them. HMIS® ratings are to be used with a fully implemented HMIS® program. HMIS® is a registered mark of the National Paint & Coatings Association (NPCA). HMIS® materials may be purchased exclusively from J. J. Keller (800) 327-6868.

The customer is responsible for determining the PPE code for this material.

16 . Other information

National Fire Protection Association (U.S.A.) :



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1: Test Guideline 431: In Vitro Skin Corrosion - Reconstructed Human Epidermis Test Method 70%
... Based on In Vitro results 4 MTT Reducer 5 Physical State Category 1A In Vivo Corrosives Acrylic acid 79-10-7 organic acid 1A L Bromoacetic acid 79-08-3 organic acid 1A S Boron trifluoride dihydrate 13319-75-0 inorganic acid 1A 12 x 1A L Phenol 108-95-2 phenol 1A S Category 1B/1C In Vivo Corrosives Glyoxylic acid monohydrate 563-96-2 organic acid 1B and 1C S Lactic acid 598-82-3 organic acid 1B and 1C L N,N- Dimethylbenzylamine 103-83-3 organic base 1C Y L **Sodium bisulfate** monohydrate 10034-88-5 ...
http://ntp.niehs.nih.gov/iccvam/SuppDocs/FedDocs/OECD/OECD-TG431-2013-508.pdf
Size: 692KB

2: Chemical and Product Class Information for the Substances Tested in the HET-CAM Test Method: Appx B - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 70%
... - Inorganic - **Sodium** bisulfite 7631-90-5 - Inorganic - **Sodium** sulfite 7757-83-7 - Inorganic - **Sodium** chloride 7647-14-5 - Inorganic - **Sodium** cyanate 917-61-3 - Cyanate - **Sodium** disilicate 13870-28-5 Silane 69 Inorganic - **Sodium** hydrogen sulfate **7681-38-1 Sodium bisulfate** Inorganic - **Sodium** hydroxide 1310-73-2 - Alkali - **Sodium** lauryl ether sulfate 3088-31-1 Diethylene glycol monolauryl ether **sodium** sulfate - - **Sodium** lauryl sulfate 151-21-3 - Surfactant, Anionic Detergent **Sodium** ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcamAppB.pdf
Size: 281KB

N/A

3: TERADB.XLS Phys.-chem. Eigsch. Löslichk. 70%
... 20 2.2 11.6 nicht 132 n-Butanol 71-36-3 79 7 8.2 BD HK Öl 1.87 9.6 13 reizend 133 L-Lysin Monohydrat 39665-12-8 ### 10 9.5 BD HO 7.5 10 10.4 mäßig 134 Anisol 100-66-3 unlöslich k.A. 7.8 AP HK Öl 5 7.3 19.1 mäßig 135 Natriumhydrogensulfat **7681-38-1** ### 1.1 4.2 HK WA 1 18.8 19.2 st.reiz 136 Triisooctylamin 25549-16-0 0.5 7 7.5 BG MD Öl 100 0.8 14.1 nicht 137 p-Anisidin 104-94-9 21 8.8 8.1 AP BD 0.9 13.4 9.5 H3;K2;L1 H3;K1;L0 10%:ges. st.reizend 138 Asparaginsäure 56-84-8 4.3 3.4 5 BD BG ...
http://ntp.niehs.nih.gov/iccvam/pubcomment/ocucomm/3teradb.pdf
Size: 159KB

4: Comparison of In Vitro and In Vivo Data Sorted by Substance for IS(B)-10 Analysis Method: Appx D6 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 69%
... Tested Chemical Class In Vivo Physical Form Tested pH Property of Interest In Vivo (GHS) Classification 1 GHS Category 1 Subclass 2 In Vivo (EPA) Classification 3 In Vivo (EU)

Classification 4 In Vitro Classification (IS(B)-10) 5 Reference **Sodium** hydrogen sulfate **7681-38-1** 100%, 10%, and ITC Inorganic salt Solid 1.1 Category 1 4 SCNM SCNM Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 100%, 10%, and ITC Organic salt, Ester, Ether Unknown 8 SCNM SCNM SCNM Severe Spielmann et ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcamappD6.pdf

Size: 744KB

5: In Vitro Data for Substances Tested in HET-CAM Sorted by Substance for IS(A)-10 Analysis Method: Appx C7 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 69%
... 10.5 Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 BG 10% Solid 3.5 11.4 19.7 Severe Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 HK 10% Solid 3.5 11.4 20.7 Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** HK 10% Solid 1080 1.1 18.8 Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** WA 10% Solid 1080 1.1 16.7 Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 BG 10% Unknown soluble 8 10.5 Severe Severe ...
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Size: 1.1MB

6: In Vitro Data for Substances Tested in HET-CAM Sorted by Substance for Q-Score Analysis Method: Appx C8 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 69%
... 10.7 Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 BG 100% Solid 3.5 11.4 18.2 Severe Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 HK 100% Solid 3.5 11.4 16.6 Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** HK 100% Solid 1080 1.1 19.2 Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** WA 100% Solid 1080 1.1 18.1 Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 BG 100% Unknown soluble 8 17.9 Severe Severe ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcamappC8.pdf

Size: 1.5MB

7: Appendix H: ICCVAM Ocular Test Method Evaluation Report (2006) 69%
... Sigma-Aldrich Corp. Chemical Intermediate, Dye n.a. n.a. 154.1 ? ? 1 ? ? ? solid 63.0 n=1/1, CO=4 - 100 mg Cleaning Agent, Laboratory 0.1 mL or Chemical, Pesticide Category 1 4 **Sodium** hydrogen sulfate **7681-38-1** ZEBET n.a. Sigma-Aldrich Corp. Salt (inorganic) n.a. n.a. 120.1 ? ? 1 ? ? ? solid 8.0 n=1/1, CO=4 - 100 mg Caustic Agent, Chemical Category 1 Fisher Scientific Intermediate, Industrial Chemical, Pharmaceutical Intermediate, Reagent Grade soluble (1 "virtually International, Inc. 4 **Sodium** ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/OTeval/appH.pdf

Size: 696KB

8: Comparison of In Vitro and In Vivo Data Sorted by Substance for IS(B)-100 Analysis Method: Appx D7 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 69%
... cyanate 917-61-3 100% Inorganic salt Solid 10 SCNM Category III SCNM Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28- 5 100% Inorganic salt Solid 11.4 Category 1 4 SCNM SCNM Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** 100% Inorganic salt Solid 1.1 Category 1 4 SCNM SCNM Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 100% Organic salt, Ester, Ether Unknown 8 SCNM SCNM SCNM Severe Spielmann et al. (1996) **Sodium** monochloroacetat e 3926-62-3 ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcamappD7.pdf

Size: 1.1MB

9: Comparison of In Vitro and In Vivo Data Sorted by Reference: Appx D1 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 69%
... Ester Unknown ns Category 1 1 Category I R41 Slight Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 100%, 10%, and ITC Inorganic salt Solid 11.4 Category 1 4 SCNM SCNM Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** 100%, 10%, and ITC Inorganic salt Solid 1.1 Category 1 4 SCNM SCNM Severe Severe Spielmann et al. (1996) n-Acetyl-Methionine 1115-47-5 100%, 10%, and ITC Amide, Amino acid Solid 2.2 Category 1 4 SCNM R41 Severe Severe Spielmann et al. (1996) ...
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Size: 2.2MB

10: Section 7: ICCVAM HET-CAM BRD 68%

... Score IS(B)- 100 SD %CV for IS(B)-100 **Sodium** sulfite 7757-83-7 12.25 1.34 10.97 14.20 2.69 18.92 **Sodium** cyanate 917-61-3 12.65 3.04 24.04 9.45 1.77 18.71 **Sodium** disilicate 13870-28-5 20.20 0.71 3.50 17.40 1.13 6.50 **Sodium** hydrogen sulfate **7681-38-1** 17.75 1.48 8.37 18.65 0.78 4.17 **Sodium** lauryl ether sulfate 3088-31-1 14.10 5.09 36.11 18.45 0.78 4.22 **Sodium** monochloroacetate 3926-62-3 3.75 5.30 141.42 13.45 3.75 27.86 Sodiumpyrosulfite 7681-57-4 14.87 2.41 16.22 14.60 3.05 20.90 4-((2- ...
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11: In Vitro Data for Substances Tested in HET-CAM Sorted by Substance for IS(A)-10 Analysis Method: Appx C7 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 68%
... 10.5 Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 BG 10% Solid 3.5 11.4 19.7 Severe Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 HK 10% Solid 3.5 11.4 20.7 Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** HK 10% Solid 1080 1.1 18.8 Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** WA 10% Solid 1080 1.1 16.7 Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 BG 10% Unknown soluble 8 10.5 Severe Severe ...
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Size: 1.1MB

12: Analysis of the Estimated Underclassification and Overclassification Likelihoods of the Current In Vivo Rabbit Eye Test for Hazard Classification 68%
... Cat 1(pos1/3) nonirritant Cat2A Cat2A Cat 1(pos1/3) Cat2A Category 1 4 65 4-Amino-5-methoxy-2-methylbenzene- sulphonic acid 6471-78-9 ZEBET n.p. Cat 1(pos1/3) Category 1 4 66 **Sodium** hydrogen sulfate **7681-38-1** ZEBET n.p. Cat 1(pos1/3) Category 1 4 67 Methylpentynol 77-75-8 ZEBET n.p. Cat 1(pos1/3) Category 1 4 68 B-Resorcylic acid 89-86-1 ZEBET n.p. Cat 1(pos1/3) Category 1 4 69 4-Chloro-methanilic acid 98-36-2 ZEBET n.p. Cat 1(pos1/3) Category 1 4 70 Diphocars ZEBET n.p. Cat 1(pos1/3) Category 1 ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/classification/haserpt110405.pdf

Size: 6.3MB

Same as 6

13: In Vitro Data for Substances Tested in HET-CAM Sorted by Substance for Q-Score Analysis Method: Appx C8 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 68%
... 10.7 Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 BG 100% Solid 3.5 11.4 18.2 Severe Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 HK 100% Solid 3.5 11.4 16.6 Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** HK 100% Solid 1080 1.1 19.2 Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** WA 100% Solid 1080 1.1 18.1 Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 BG 100% Unknown soluble 8 17.9 Severe Severe ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcamappC8.pdf

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14: In Vitro Data for Substances Tested in HET-CAM Sorted by Reference: Appx C2 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 68%

... Score 3 S-Score Classification Overall S-Score Classification Q- Score 4 Q-Score Classification Overall Q- Score Classification IS(B)-10 5 IS(B)-10 Class. Overall IS(B)- 10 Class. IS(B)-100 5 IS(B) -100 Class. Overall IS(B)-100 Class. Reference **Sodium** hydrogen sulfate **7681-38-1** HK 100%, 10%, and ITC - n.p. 1080 1.1 18.8 Severe Severe 19.2 Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** WA 100%, 10%, and ITC - n.p. 1080 1.1 16.7 Severe 18.1 Severe Spielmann et al. (1996) ...
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15: Comparison of In Vitro and In Vivo Data Sorted by Substance for IS(B)-100 Analysis Method: Appx D7 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 68%

Same as 8

... cyanate 917-61-3 100% Inorganic salt Solid 10 SCNM Category III SCNM Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28- 5 100% Inorganic salt Solid 11.4 Category 1 4 SCNM SCNM Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** 100% Inorganic salt Solid 1.1 Category 1 4 SCNM SCNM Severe Spielmann et al. (1996) **Sodium** lauryl ether sulfate 3088-31-1 100% Organic salt, Ester, Ether Unknown 8 SCNM SCNM SCNM Severe Spielmann et al. (1996) **Sodium** monochloroacetat e 3926-62-3 ...
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16: Appendix H: ICCVAM Ocular Test Method Evaluation Report (2006) 68%

Same as 7

... Sigma-Aldrich Corp. Chemical Intermediate, Dye n.a. n.a. 154.1 ? ? 1 ? ? ? solid 63.0 n=1/1, CO=4 - 100 mg Cleaning Agent, Laboratory 0.1 mL or Chemical, Pesticide Category 1 4 **Sodium** hydrogen sulfate **7681-38-1** ZEBET n.a. Sigma-Aldrich Corp. Salt (inorganic) n.a. n.a. 120.1 ? ? 1 ? ? ? solid 8.0 n=1/1, CO=4 - 100 mg Caustic Agent, Chemical Category 1 Fisher Scientific Intermediate, Industrial Chemical, Pharmaceutical Intermediate, Reagent Grade soluble (1 "virtually International, Inc. 4 **Sodium** ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/OTeval/appH.pdf

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17: Comparison of In Vitro and In Vivo Data Sorted by Reference: Appx D1 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) 67%

Same as 9

... Ester Unknown ns Category 1 1 Category I R41 Slight Severe Spielmann et al. (1996) **Sodium** disilicate 13870-28-5 100%, 10%, and ITC Inorganic salt Solid 11.4 Category 1 4 SCNM SCNM Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** 100%, 10%, and ITC Inorganic salt Solid 1.1 Category 1 4 SCNM SCNM Severe Severe Spielmann et al. (1996) n-Acetyl-Methionine 1115-47-5 100%, 10%, and ITC Amide, Amino acid Solid 2.2 Category 1 4 SCNM R41 Severe Severe Spielmann et al. (1996) ...
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18: From: Zebet 67%

N/A

... 20 2.2 11.6 nicht 132 n-Butanol 71-36-3 79 7 8.2 BD HK Öl 1.87 9.6 13 reizend 133 L-Lysin Monohydrat 39665-12-8 ### 10 9.5 BD HO 7.5 10 10.4 mäßig 134 Anisol 100-66-3 unlöslich k.A. 7.8 AP HK Öl 5 7.3 19.1 mäßig 135 Natriumhydrogensulfat **7681-38-1** ### 1.1 4.2 HK WA 1 18.8 19.2 st.reiz 136 Triisooctylamin 25549-16-0 0.5 7 7.5 BG MD Öl 100 0.8 14.1 nicht 137 p-Anisidin 104-94-9 21 8.8 8.1 AP BD 0.9 13.4 9.5 H3;K2;L1 H3;K1;L0 10%:ges. st.reizend 138 Asparaginsäure 56-84-8 4.3 3.4 5 BD BG ...
http://ntp.niehs.nih.gov/iccvam/pubcomment/ocucomm/spielmann.pdf

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19: Section 7: ICCVAM HET-CAM BRD 67%

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... Score IS(B)- 100 SD %CV for IS(B)-100 **Sodium** sulfite 7757-83-7 12.25 1.34 10.97 14.20 2.69 18.92 **Sodium** cyanate 917-61-3 12.65 3.04 24.04 9.45 1.77 18.71 **Sodium** disilicate 13870-28-5 20.20 0.71 3.50 17.40 1.13 6.50 **Sodium** hydrogen sulfate **7681-38-1** 17.75 1.48 8.37 18.65 0.78 4.17 **Sodium** lauryl ether sulfate 3088-31-1 14.10 5.09 36.11 18.45 0.78 4.22 **Sodium** monochloroacetate 3926-62-3 3.75 5.30 141.42 13.45 3.75 27.86 Sodiumpyrosulfite 7681-57-4 14.87 2.41 16.22 14.60 3.05 20.90 4-((2- ...
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20: tr 488 60-HZ Magnetic Fields 67%

A magnetic Fields Study re Toxicology and Carcinogenesis

... as carrier b Calcium carbonate as carrier TABLE G2 Vitamins and Minerals in NTP-2000 Rat and Mouse Ration a Amount Source Vitamins A 4,000 IU Stabilized vitamin A palmitate or acetate D 1,000 IU D-activated animal sterol K 1.0 mg Menadione **sodium bisulfate** complex "-Tocopheryl acetate 100 IU Niacin 23 mg Folic acid 1.1 mg d-Pantothenic acid 10 mg d-Calcium pantothenate Riboflavin 3.3 mg Thiamine 4 mg Thiamine mononitrate B 12 Pyridoxine 52 µg 6.3 mg Pyridoxine hydrochloride Biotin 0.2 mg ...
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21: Analysis of the Estimated Underclassification and Overclassification Likelihoods of the Current In Vivo Rabbit Eye Test for Hazard Classification — 67%
... Cat 1(pos1/3) nonirritant Cat2A Cat2A Cat 1(pos1/3) Cat2A Category 1 4 65 4-Amino-5-methoxy-2-methylbenzene- sulphonic acid 6471-78-9 ZEBET n.p. Cat 1(pos1/3) Category 1 4 66 **Sodium** hydrogen sulfate **7681-38-1** ZEBET n.p. Cat 1(pos1/3) Category 1 4 67 Methylpentynol 77-75-8 ZEBET n.p. Cat 1(pos1/3) Category 1 4 68 B-Resorcylic acid 89-86-1 ZEBET n.p. Cat 1(pos1/3) Category 1 4 69 4-Chloro-methanilic acid 98-36-2 ZEBET n.p. Cat 1(pos1/3) Category 1 4 70 Diphocars ZEBET n.p. Cat 1(pos1/3) Category 1 ...
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22: In Vitro Data for Substances Tested in HET-CAM Sorted by Reference: Appx C2 - ICCVAM HET-CAM BRD (NIH Publication No. 06-4515) — 67%
... Score 3 S-Score Classification Overall S-Score Classification Q- Score 4 Q-Score Classification Overall Q- Score Classification IS(B)-10 5 IS(B)-10 Class. Overall IS(B)- 10 Class. IS(B)-100 5 IS(B) -100 Class. Overall IS(B)-100 Class. Reference **Sodium** hydrogen sulfate **7681-38-1** HK 100%, 10%, and ITC - n.p. 1080 1.1 18.8 Severe Severe 19.2 Severe Severe Spielmann et al. (1996) **Sodium** hydrogen sulfate **7681-38-1** WA 100%, 10%, and ITC - n.p. 1080 1.1 16.7 Severe 18.1 Severe Spielmann et al. (1996) ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcamappC2.pdf
Size: 6.8MB

Same as 14

23: NTP Technical Report 561: Toxicology and Carcinogenesis Studies of Tetralin (CAS No. 119-64-2) in F344/N Rats and B6C3F1 Mice and Toxicology Study of Tetralin in Male NBR Rats (Inhalation Studies) — 66%
... TABLE K2 Vitamins and Minerals in NTP-2000 Rat and Mouse Ration a Amount Source Vitamins A 4,000 IU Stabilized vitamin A palmitate or acetate D 1,000 IU D-activated animal sterol K 1.0 mg Menadione **sodium bisulfate** complex "-Tocopheryl acetate 100 IU Niacin 23 mg Folic acid 1.1 mg d-Pantothenic acid 10 mg d-Calcium pantothenate Riboflavin 3.3 mg Thiamine 4 mg Thiamine mononitrate B 12 52 µg Pyridoxine 6.3 mg Pyridoxine hydrochloride Biotin 0.2 mg d-Biotin Minerals Magnesium 514 mg Magnesium ...
http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/TR561.pdf
Size: 9.8MB

Not Applicable

24: — 66%

[TR-545: NTP TECHNICAL REPORT ON THE TOXICOLOGY AND CARCINOGENESIS STUDY OF GENISTEIN IN SPRAGUE-DAWLEY RATS (FEED STUDY)]
... corn gluten meal, corn oil, dicalcium phosphate, brewers dried yeast, calcium carbonate, and salt TABLE H1 Vitamins and Minerals in Purina 5K96 Rat Ration Vitamins Amount Source Carotene 1.6 ppm multiple sources Vitamin K 7.1 ppm menadione **sodium bisulfate** Thiamin Hydrochloride 26 ppm thiamine mononitrate Riboflavin 8.6 ppm riboflavin Niacin 91 ppm nicotinic acid Pantothenic acid 29 ppm calcium pantothenate Choline chloride 1,800 ppm choline chloride Folic acid 2.7 ppm folic acid Pyridoxine 10 ...
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25: TR-539:NTP TECHNICAL REPORT ON THE MULTIGENERATIONAL REPRODUCTIVE TOXICOLOGY STUDY OF GENISTEIN (CAS NO. 446-72-0) IN SPRAGUE-DAWLEY RATS (FEED STUDY) 66%
... INGREDIENTS OF PURINA 5K96 RAT RATION Ground wheat, ground corn, wheat middlings, ground oats, fish meal, casein, corn gluten meal, corn oil, dicalcium phosphate, brewers dried yeast, calcium carbonate, and salt TABLE N1 Vitamins and Minerals in Purina 5K96 Rat Ration Amount Source Vitamins Carotene 1.6 ppm multiple sources Vitamin K 7.1 ppm menadione **sodium bisulfate** Thiamin hydrochloride 26 ppm thiamine mononitrate Riboflavin 8.6 ppm riboflavin Niacin 91 ppm nicotinic acid Pantothenic acid 29 ...
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26: PDF Document (1782k) 66%
... 20 2.2 11.6 nicht 132 n-Butanol 71-36-3 79 7 8.2 BD HK Öl 1.87 9.6 13 reizend 133 L-Lysin Monohydrat 39665-12-8 ### 10 9.5 BD HO 7.5 10 10.4 mäßig 134 Anisol 100-66-3 unlöslich k.A. 7.8 AP HK Öl 5 7.3 19.1 mäßig 135 Natriumhydrogensulfat **7681-38-1** ### 1.1 4.2 HK WA 1 18.8 19.2 st.reiz 136 Triisooctylamin 25549-16-0 0.5 7 7.5 BG MD Öl 100 0.8 14.1 nicht 137 p-Anisidin 104-94-9 21 8.8 8.1 AP BD 0.9 13.4 9.5 H3;K2;L1 H3;K1;L0 10%:ges. st.reizend 138 Asparaginsäure 56-84-8 4.3 3.4 5 BD BG ...
http://ntp.niehs.nih.gov/iccvam/pubcomment/ocucomm/spielmann.pdf

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27: Background Review Document: Hen's Egg Test - Chrorioallantoic Membrane (Het-CAM) Test Method (NIH Publication No. 06-4515) 66%
... Score IS(B)- 100 SD %CV for IS(B)-100 **Sodium** sulfite 7757-83-7 12.25 1.34 10.97 14.20 2.69 18.92 **Sodium** cyanate 917-61-3 12.65 3.04 24.04 9.45 1.77 18.71 **Sodium** disilicate 13870-28-5 20.20 0.71 3.50 17.40 1.13 6.50 **Sodium** hydrogen sulfate **7681-38-1** 17.75 1.48 8.37 18.65 0.78 4.17 **Sodium** lauryl ether sulfate 3088-31-1 14.10 5.09 36.11 18.45 0.78 4.22 **Sodium** monochloroacetate 3926-62-3 3.75 5.30 141.42 13.45 3.75 27.86 Sodiumpyrosulfite 7681-57-4 14.87 2.41 16.22 14.60 3.05 20.90 4-((2- ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcambrd.pdf

Size: 6.7MB

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28: ICCVAM Test Method Evaluation Report on In Vitro Test Methods Proposed for Identifying Eye Injury Hazard Potential of Chemicals and Products (Vol. 2) 66%
... - Inorganic - **Sodium** bisulfite 7631-90-5 - Inorganic - **Sodium** sulfite 7757-83-7 - Inorganic - **Sodium** chloride 7647-14-5 - Inorganic - **Sodium** cyanate 917-61-3 - Cyanate - **Sodium** disilicate 13870-28-5 Silane 69 Inorganic - **Sodium** hydrogen sulfate **7681-38-1 Sodium bisulfate** Inorganic - **Sodium** hydroxide 1310-73-2 - Alkali - **Sodium** lauryl ether sulfate 3088-31-1 Diethylene glycol monolauryl ether **sodium** sulfate - - **Sodium** lauryl sulfate 151-21-3 - Surfactant, Anionic Detergent **Sodium** ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/InVitro-2010/TMER-Vol2.pdf

Size: 21.2MB

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29: ICCVAM Ocular Test Method Evaluation Report (2006) 66%
... Sigma-Aldrich Corp. Chemical Intermediate, Dye n.a. n.a. 154.1 ? ? 1 ? ? ? solid 63.0 n=1/1, CO=4 - 100 mg Cleaning Agent, Laboratory 0.1 mL or Chemical, Pesticide Category 1 4 **Sodium** hydrogen sulfate **7681-38-1** ZEBET n.a. Sigma-Aldrich Corp. Salt (inorganic) n.a. n.a. 120.1 ? ? 1 ? ? ? solid 8.0 n=1/1, CO=4 - 100 mg Caustic Agent, Chemical Category 1 Fisher Scientific Intermediate, Industrial Chemical, Reagent soluble (1 "virtually International, Inc. 4 **Sodium** hydroxide 1310-73-2 ECETOC ...

http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/OTeval/OTevalrpt.pdf

Size: 13.4MB

30: tr 488 60-HZ Magnetic Fields 66%

... as carrier b Calcium carbonate as carrier TABLE G2 Vitamins and Minerals in NTP-2000 Rat and Mouse Ration a Amount Source Vitamins A 4,000 IU Stabilized vitamin A palmitate or acetate D 1,000 IU D-activated animal sterol K 1.0 mg Menadione **sodium bisulfate** complex "-Tocopheryl acetate 100 IU Niacin 23 mg Folic acid 1.1 mg d-Pantothenic acid 10 mg d-Calcium pantothenate Riboflavin 3.3 mg Thiamine 4 mg Thiamine mononitrate B 12 Pyridoxine 52 µg 6.3 mg Pyridoxine hydrochloride Biotin 0.2 mg ...

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31: Background Review Document: Hen's Egg Test - Chrorioallantoic Membrane (Het-CAM) Test Method (NIH Publication No. 06-4515) 65%
... Score IS(B)- 100 SD %CV for IS(B)-100 **Sodium** sulfite 7757-83-7 12.25 1.34 10.97 14.20 2.69 18.92 **Sodium** cyanate 917-61-3 12.65 3.04 24.04 9.45 1.77 18.71 **Sodium** disilicate 13870-28-5 20.20 0.71 3.50 17.40 1.13 6.50 **Sodium** hydrogen sulfate **7681-38-1** 17.75 1.48 8.37 18.65 0.78 4.17 **Sodium** lauryl ether sulfate 3088-31-1 14.10 5.09 36.11 18.45 0.78 4.22 **Sodium** monochloroacetate 3926-62-3 3.75 5.30 141.42 13.45 3.75 27.86 Sodiumpyrosulfite 7681-57-4 14.87 2.41 16.22 14.60 3.05 20.90 4-((2- ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/ocubrd/hetcam/hetcambrd.pdf
Size: 6.7MB

Same as Table 10

32: NTP Technical Report 561: Toxicology and Carcinogenesis Studies of Tetralin (CAS No. 119-64-2) in F344/N Rats and B6C3F1 Mice and Toxicology Study of Tetralin in Male NBR Rats (Inhalation Studies) 65%
... TABLE K2 Vitamins and Minerals in NTP-2000 Rat and Mouse Ration a Amount Source Vitamins A 4,000 IU Stabilized vitamin A palmitate or acetate D 1,000 IU D-activated animal sterol K 1.0 mg Menadione **sodium bisulfate** complex "-Tocopheryl acetate 100 IU Niacin 23 mg Folic acid 1.1 mg d-Pantothenic acid 10 mg d-Calcium pantothenate Riboflavin 3.3 mg Thiamine 4 mg Thiamine mononitrate B 12 52 µg Pyridoxine 6.3 mg Pyridoxine hydrochloride Biotin 0.2 mg d-Biotin Minerals Magnesium 514 mg Magnesium ...
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33: TR-545: NTP TECHNICAL REPORT ON THE TOXICOLOGY AND CARCINOGENESIS STUDY OF GENISTEIN IN SPRAGUE-DAWLEY RATS (FEED STUDY) 65%
... corn gluten meal, corn oil, dicalcium phosphate, brewers dried yeast, calcium carbonate, and salt TABLE H1 Vitamins and Minerals in Purina 5K96 Rat Ration Vitamins Amount Source Carotene 1.6 ppm multiple sources Vitamin K 7.1 ppm menadione **sodium bisulfate** Thiamin Hydrochloride 26 ppm thiamine mononitrate Riboflavin 8.6 ppm riboflavin Niacin 91 ppm nicotinic acid Pantothenic acid 29 ppm calcium pantothenate Choline chloride 1,800 ppm choline chloride Folic acid 2.7 ppm folic acid Pyridoxine 10 ...
http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/TR545.pdf
Size: 2.7MB

Same as 24

34: 65%

Same as 25

TR-539:NTP TECHNICAL REPORT ON THE MULTIGENERATIONAL REPRODUCTIVE TOXICOLOGY STUDY OF GENISTEIN (CAS NO. 446-72-0) IN SPRAGUE-DAWLEY RATS (FEED STUDY)
... INGREDIENTS OF PURINA 5K96 RAT RATION Ground wheat, ground corn, wheat middlings, ground oats, fish meal, casein, corn gluten meal, corn oil, dicalcium phosphate, brewers dried yeast, calcium carbonate, and salt TABLE N1 Vitamins and Minerals in Purina 5K96 Rat Ration Amount Source Vitamins Carotene 1.6 ppm multiple sources Vitamin K 7.1 ppm menadione **sodium bisulfate** Thiamin hydrochloride 26 ppm thiamine mononitrate Riboflavin 8.6 ppm riboflavin Niacin 91 ppm nicotinic acid Pantothenic acid 29 ...
http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr539.pdf

Size: 5.6MB

35: ICCVAM Ocular Test Method Evaluation Report (2006) 65%

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... Sigma-Aldrich Corp. Chemical Intermediate, Dye n.a. n.a. 154.1 ? ? 1 ? ? ? solid 63.0 n=1/1, CO=4 - 100 mg Cleaning Agent, Laboratory 0.1 mL or Chemical, Pesticide Category 1 4 **Sodium** hydrogen sulfate **7681-38-1** ZEBET n.a. Sigma-Aldrich Corp. Salt (inorganic) n.a. n.a. 120.1 ? ? 1 ? ? ? solid 8.0 n=1/1, CO=4 - 100 mg Caustic Agent, Chemical Category 1 Fisher Scientific Intermediate, Industrial Chemical, Reagent soluble (1 "virtually International, Inc. 4 **Sodium** hydroxide 1310-73-2 ECETOC ...
http://ntp.niehs.nih.gov/iccvam/docs/ocutox_docs/OTeval/OTevalrpt.pdf

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ANNEX 1

PERFORMANCE STANDARDS FOR ASSESSMENT OF PROPOSED SIMILAR OR MODIFIED *IN VITRO* RECONSTRUCTED HUMAN *EPIDERMIS* (RHE) TEST METHODS FOR SKIN CORROSION[4]

INTRODUCTION

1. The purpose of Performance Standards (PS) is to provide the basis by which new or modified test methods, both proprietary (*i.e.* copyrighted, trademarked, registered) and non-proprietary can demonstrate to have sufficient reliability and relevance for specific testing purposes. The PS, based on valid and accepted test methods, can be used to evaluate the reliability and relevance of other analogous test methods (colloquially referred to as "me-too" test methods) that are based on similar scientific principles and measure or predict the same biological or toxic effect (9). On the other hand, modified test methods, which propose potential improvements to an approved test method, should be evaluated to determine the effect of the proposed changes on the test method's performance and the extent to which such changes affect the information available for the other components of the validation process. Depending on the number and nature of the proposed changes, the generated data and supporting documentation for those changes, they should either be subjected to the same validation process as described for a new test method, or, if appropriate, to a limited assessment of reliability and relevance using established PS (9).

2. Similar (me-too) or modified test methods proposed for use under this Test Guideline should be evaluated to determine their reliability and relevance using Reference Chemicals (Table 1) representing the full range of the TG 404 *in vivo* corrosivity scores, *i.e.*, Corrosive (UN GHS Category 1A and Category 1B and 1C) and non-corrosive chemicals (1). The proposed similar or modified test methods should have reliability, sensitivity, specificity and accuracy values which are comparable or better than those derived from the two VRM [EpiSkin™ (SM) and EpiDerm™ SCT (EPI-200)] and as described in paragraphs 6 to 10 of this Annex (Tables 2 and 3) (12) (13). The reliability of the new or modified test method, as well as its ability to correctly identify non-corrosive and corrosive chemicals, and possibly also to discriminate UN GHS Category 1A from Category 1B and 1C corrosive chemicals, should be determined prior to its use for testing chemicals.

3. These PS are based on the US-ICCVAM PS (8) for evaluating the validity of new or modified RhE test methods. The PS consists of (9): (i) essential test method components; (ii) recommended reference chemicals, and; (iii) defined reliability and accuracy values that the proposed test method should meet or exceed.

[4] Proposed new or modified test method following the PS of this Test Guideline should be submitted to the OECD for adoption and inclusion into the Test Guideline before being used for regulatory purposes.

ESSENTIAL TEST METHOD COMPONENTS

4. These consist of essential structural, functional, and procedural elements of a validated test method that should be included in the protocol of a proposed, mechanistically and functionally similar or modified test method. These components include unique characteristics of the test method, critical procedural details, and quality control measures. Adherence to essential test method components will help to assure that a similar or modified proposed test method is based on the same concepts as the corresponding VRMs (7). The essential test method components are described in detail in paragraphs 16 to 32 of the Test Guideline:

The general conditions (paragraph 16)

The functional conditions, which include:

- Viability (paragraph 17)
- Barrier function (paragraph 18)
- Morphology (paragraph 19)
- Reproducibility (paragraph 20)
- Quality control (paragraph 21)

The procedural conditions (paragraphs 22 to 32)

For specific parameters (*e.g.*, for Tables 2, 3, 4, 5, and 6), adequate values should be provided for any new similar or modified test method, these specific values may vary depending on the specific test method.

MINIMUM LIST OF REFERENCE CHEMICALS

5. Reference Chemicals are used to determine if the reliability and relevance of a proposed similar or modified test method, proven to be structurally and functionally sufficiently similar to the VRMs, or representing a minor modification of one of the VRMs, are comparable or better than those of the VRMs (12) (13). The 30 recommended Reference Chemicals listed in Table 1 include substances representing different chemical classes (*i.e.* chemical categories based on functional groups), and are representative of the full range of TG 404 *in vivo* scores. The substances included in this list comprise 10 UN GHS Category 1A, 10 UN GHS Category 1B and 1C (the *in vivo* data do not permit distinction between the two categories) and 10 non-corrosive substances. The substances listed in Table 1 are selected from the substances used in the validation study of the VRMs, with regard to chemical functionality and physical state (11) (12) (13). These Reference Chemicals represent the minimum number of chemicals that should be used to evaluate the reliability and relevance of a proposed similar or modified test method able to discriminate between Category 1A, Category 1B and 1C and non-corrosive substances and mixtures (1A vs. 1B and 1C vs. NC), in accordance with the UN GHS (1) . For similar or modified test method able to discriminate corrosive from non-corrosive substances and mixtures but not able to sub-categorize corrosive chemicals (C vs. NC), only 20 of the 30 substances listed in Table 1 (the ones not in *italics*) need to be evaluated (5 UN GHS Category 1A, 5 UN GHS Category 1B and 1C and 10 non-corrosive substances). The use of these Reference Chemicals for the development/optimization of new similar test methods should be avoided to the extent possible. In situations where a listed substance is unavailable, other substances for which adequate *in vivo* reference data are available could be used, primarily from the substances used in the validation study of the VRMs. If desired, additional substances representing other chemical classes and for which adequate *in vivo* reference data are available may be added to the minimum list of Reference Chemicals to further evaluate the accuracy of the proposed test method.

Table 1: **Minimum list of Reference Chemicals for determination of Reliability, Sensitivity, Specificity and Accuracy values for similar or modified *in vitro* RhE-based skin corrosion test methods. The 20 chemicals NOT *in italics* should be tested with similar or modified test methods proposed to discriminate Corrosive from Non-Corrosive chemicals (without sub-categorization). Extra reference should be tested only with similar or modified test methods proposed to discriminate between Cat. 1A, Cat.1 B-and-1C and Non Corrosive chemicals (sub-categorization performed) are indicated *in italics*.**

Chemical	CASRN	Performance Standard	Physical State	EpiDerm™	EpiSkin™	SkinEthic™
UN GHS Category NC based on *in vivo* results						
Phenyl Ethyl Bromide	103-63-9	Y	L	(3) NC	(3) NC	(3) NC
4-Amino-1,2,4-triazole	584-13-4	Y	S	(3) NC	(3) NC	(3) NC
4-(methylthio)-benzaldehyde	3446-89-7	Y	L	(3) NC	(3) NC	(3) NC
Lauric acid	143-07-7	Y	S	(3) NC	(3) NC	(3) NC
1,9-Decadiene	1647-16-1	Y	L	(3) NC	(3) NC	(3) NC
Benzylacetone	2550-26-7	Y	L	(3) NC	(3) NC	(3) NC
3,3-Dithiopropionic acid	1119-62-6	Y	S	(3) NC	(3) NC	(3) NC
Methyl palmitate	112-39-0	Y	S	(3) NC	(3) NC	(3) NC
2-Hydroxyiso-butyric acid	594-61-6	Y	S	(3) 1B-and-1C	(3) 1B-and-1C	(3) 1B-and-1C
Sodium undecylenate (33%)	3398-33-2	Y	L	(3) 1B-and-1C	(3) 1B-and-1C	(3) 1B-and-1C
UN GHS Cat. 1B-and-1C based on *in vivo* results						
Glyoxylic acid monohydrate	563-96-2	Y	S	(3) 1B-and-1C	(3) 1B-and-1C	(3) 1B-and-1C
Lactic acid	598-82-3	Y	L	(3) 1B-and-1C	(3) 1B-and-1C	(3) 1B-and-1C
Sodium bisulphate	7681-38-1	Y	S	(3) 1B-and-1C	(3) 1B-and-1C	(3) 1B-and-1C
Ethanolamine	*141-43-5*	*Y*	*Viscous*	*(3) 1B-and-1C*	*(3) 1B-and-1C*	*(3) 1B-and-1C*
60/40 Octanoic/ decanoic acid	68937-75-7	Y	L	(3) 1B-and-1C	(3) 1B-and-1C	(3) 1B-and-1C
Hydrochloric acid (14.4%)	*7647-01-0*	*Y*	*L*	*(3) 1B-and-1C*	*(3) 1B-and-1C*	*(3) 1B-and-1C*
Fluroboric acid	16872-11-0	Y	L	(3) 1A	(3) 1A	(3) 1A
Propionic acid	*79-09-4*	*Y*	*L*	*(3) 1A*	*(3) 1A*	*(3) 1A*
2-tert-Butylphenol	*88-18-6*	*Y*	*L*	*(3) 1A*	*(3) 1B-and-1C*	*(3) 1A*
Maleic anhydride	*108-31-6*	*Y*	*S*	*(2) 1B-and-1C (1) 1A*	*(3) 1B-and-1C*	*(2) 1B-and-1C (1) 1A*

Substances Used In HET-CAM Accuracy Analysis (Chemical and Product Classes)

Substance	CASRN	Synonyms	Chemical Class	Product Class
Silan 108	3069-40-7	Trimethoxyoctyl silane	Hydrocarbon; Ether	-
Silan 165	29055-11-6	Bis(3-trimethoxysilylpropyl)sulfide	Hydrocarbon; Ether; Sulfur containing	-
Silan 167	41453-78-5	3,3,14,14-Tetramethoxy-2,15-dioxa-7,8,9,10-tetrathia-3,14-disilahexadecane	-	-
Silan 253	18784-74-2	-	-	-
Silver nitrate	7761-88-8	-	Inorganic	-
Sodium bisulfite	7631-90-5	-	Inorganic	-
Sodium sulfite	7757-83-7	-	Inorganic	-
Sodium chloride	7647-14-5	-	Inorganic	-
Sodium cyanate	917-61-3	-	Cyanate	-
Sodium disilicate	13870-28-5	Silane 69	Inorganic	-
Sodium hydrogen sulfate	7681-38-1	Sodium bisulfate	Inorganic	-
Sodium hydroxide	1310-73-2	-	Alkali	-
Sodium lauryl ether sulfate	3088-31-1	Diethylene glycol monolauryl ether sodium sulfate	-	-
Sodium lauryl sulfate	151-21-3	-	Surfactant, Anionic	Detergent
Sodium monochloroacetate	3926-62-3	Sodium chloroacetate	Carboxylic acid	-
Sodium oxalate	62-76-0	-	Inorganic	-
Sodium perborate	10486-00-7	-	Inorganic	-
Sodiumpyrosulfite	7681-57-4	Sodium metabisufite	Inorganic	-
Stearyltrimethylammonium chloride	15461-40-2	-	Surfactant, Cationic	-
Styrene	100-42-5	-	Hydrocarbon	-
4-((2-sulfatoethyl)sulfonyl)-aniline	2494-89-5	2-Sulfanyl ethanol hydrogen sulfate	Amide	-

Substances Used In Accuracy Analysis (IS(B)-10 Analysis Method)

Substance Name	CASRN	*In Vitro* Conc. Tested	*In Vivo* Conc. Tested	Chemical Class	*In Vivo* Physical Form Tested	pH	Property of Interest	*In Vivo* (GHS) Classification[1]	GHS Category 1 Subclass[2]	*In Vivo* (EPA) Classification[3]	*In Vivo* (EU) Classification[4]	*In Vitro* Classification (IS(B)-10)[5]	Reference
Sodium hydrogen sulfate	7681-38-1		100%, 10%, and ITC	Inorganic salt	Solid	1.1		Category 1	4	SCNM	SCNM	Severe	Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1		100%, 10%, and ITC	Organic salt, Ester, Ether	Unknown	8		SCNM		SCNM	SCNM	Severe	Spielmann et al. (1996)
Sodium monochloroacetate	3926-62-3		100%, 10%, and ITC	Organic salt, Carboxylic acid salt	Solid	4.5		Category 2B		Category III	R36	Moderate	Spielmann et al. (1996)
Sodiumpyrosulfite	7681-57-4		100%, 10%, and ITC	Inorganic salt	Solid	4.6		SCNM		SCNM	SCNM	Severe	Spielmann et al. (1996)
4-((2-sulfatoethyl)sulfonyl)-aniline	2494-89-5		100%, 10%, and ITC	Amine, Organic sulfur compound, Ether	Unknown	7		Category 1	4	SCNM	R41	Severe	Spielmann et al. (1996)
Surfactant Based Formulation 1-HZA		10%	Undiluted	Formulation	Solution			Category 1	1	Category I	R41	Severe	Gettings et al. (1996)
Surfactant Based Formulation 2-HZB		10%	Undiluted	Formulation	Solution			Category 1	1	Category I	R41	Moderate	Gettings et al. (1996)
Surfactant Based Formulation 3-HZC		10%	Undiluted	Formulation	Solution			Category 1	1	Category I	R41	Severe	Gettings et al. (1996)
Surfactant Based Formulation 4-HZD		10%	Undiluted	Formulation	Solution			Category 2B		Category III	Nonirritant	Moderate	Gettings et al. (1996)
Surfactant Based Formulation 5-HZE		10%	Undiluted	Formulation	Solution			SCNM		Category I	SCNM	Severe	Gettings et al. (1996)
Surfactant Based Formulation 6-HZF		10%	Undiluted	Formulation	Solution			Category 1	1	Category I	R41	Severe	Gettings et al. (1996)
Surfactant Based Formulation 7-HZG		10%	Undiluted	Formulation	Solution			Category 1	1	Category I	R41	Moderate	Gettings et al. (1996)
Surfactant Based Formulation 8-HZH		10%	Undiluted	Formulation	Solution			Nonirritant		Category IV	Nonirritant	Slight	Gettings et al. (1996)
Surfactant Based Formulation 9-HZI		10%	Undiluted	Formulation	Solution			Category 1	1	Category I	R41	Severe	Gettings et al. (1996)
Surfactant Based Formulation 10-HZJ		10%	Undiluted	Formulation	Solution			Nonirritant		Category IV	Nonirritant	Moderate	Gettings et al. (1996)

Substance Name	CASRN	Test Lab	*In Vitro* Concentration Tested	*In Vitro* Physical Form Tested	Purity (%)	Solubility[1]	pH	IS(B)-10[2]	IS(B)-10 Classification	Overall IS(B)-10 Classification	Reference
Silan 167	41453-78-5	WA	10%	Unknown		soluble	n.s.	2.7	Slight	Slight	Spielmann et al. (1996)
Silan 167	41453-78-5	HO	10%	Unknown		soluble	n.s.	0.1	Nonirritant		Spielmann et al. (1996)
Silan 253	18784-74-2	BD	10%	Unknown		insoluble	<7	3	Severe	Severe	Spielmann et al. (1996)
Silan 253	18784-74-2	MD	10%	Unknown		insoluble	<7	3	Severe		Spielmann et al. (1996)
Sodium bisulfite	7631-90-5	AP	10%	Solid		readily soluble	4.5	12.7	Severe	Severe	Spielmann et al. (1996)
Sodium bisulfite	7631-90-5	MD	10%	Solid		readily soluble	4.5	13.9	Severe		Spielmann et al. (1996)
Sodium sulfite	7757-83-7	AP	10%	Solid		250	10	13.2	Severe	Severe	Spielmann et al. (1996)
Sodium sulfite	7757-83-7	BG	10%	Solid		250	10	11.3	Severe		Spielmann et al. (1996)
Sodium cyanate	917-61-3	MD	10%	Solid		110	10.4	14.8	Severe	Severe	Spielmann et al. (1996)
Sodium cyanate	917-61-3	WA	10%	Solid		110	10.4	10.5	Severe		Spielmann et al. (1996)
Sodium disilicate	13870-28-5	BG	10%	Solid		3.5	11.4	19.7	Severe	Severe	Spielmann et al. (1996)
Sodium disilicate	13870-28-5	HK	10%	Solid		3.5	11.4	20.7	Severe		Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	HK	10%	Solid		1080	1.1	18.8	Severe	Severe	Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	WA	10%	Solid		1080	1.1	16.7	Severe		Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	BG	10%	Unknown		soluble	8	10.5	Severe	Severe	Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	MD	10%	Unknown		soluble	8	17.7	Severe		Spielmann et al. (1996)

6

Substance Name	CASRN	Test Lab	Concentration Tested	Physical Form Tested	Purity (%)	Solubility[1]	pH	IS(B)-100[2]	IS(B)-100 Classification	Overall IS(B)-100 Classification	Reference
Sodium bisulfite	7631-90-5	AP	100%	Solid		readily soluble	4.5	20	Severe	Severe	Spielmann et al. (1996)
Sodium bisulfite	7631-90-5	MD	100%	Solid		readily soluble	4.5	16.8	Severe		Spielmann et al. (1996)
Sodium sulfite	7757-83-7	AP	100%	Solid		250	10	16.1	Severe	Severe	Spielmann et al. (1996)
Sodium sulfite	7757-83-7	BG	100%	Solid		250	10	12.3	Severe		Spielmann et al. (1996)
Sodium cyanate	917-61-3	MD	100%	Solid		110	10.4	8.2	Moderate	Severe	Spielmann et al. (1996)
Sodium cyanate	917-61-3	WA	100%	Solid		110	10.4	10.7	Severe		Spielmann et al. (1996)
Sodium disilicate	13870-28-5	BG	100%	Solid		3.5	11.4	18.2	Severe	Severe	Spielmann et al. (1996)
Sodium disilicate	13870-28-5	HK	100%	Solid		3.5	11.4	16.6	Severe		Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	HK	100%	Solid		1080	1.1	19.2	Severe	Severe	Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	WA	100%	Solid		1080	1.1	18.1	Severe		Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	BG	100%	Unknown		soluble	8	17.9	Severe	Severe	Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	MD	100%	Unknown		soluble	8	19	Severe		Spielmann et al. (1996)
Sodium monochloroacetate	3926-62-3	HO	100%	Solid		440	4.5	16.1	Severe	Severe	Spielmann et al. (1996)
Sodium monochloroacetate	3926-62-3	BD	100%	Solid		440	4.5	10.8	Severe		Spielmann et al. (1996)

GHS Classification	NICEATM Category / SubClass	Substance	CASRN	In Vivo Data Source	Substance Source	Commercial Availability	Chemical Class	Product Class	Conc. Tested	Amount Tested	Purity	MW	pH	Dermal Corrosivity	# of Animals Tested	Water Solubility	Log Kow	Color	Physical Form Tested	MMAS score	Corneal score	Iritis score
Category 1	4	beta-Resorcylic acid	89-86-1	ZEBET	n.a.	Sigma-Aldrich Corp.	Acid (organic) [carboxylic acid], Phenol	Chemical Intermediate, Dye	n.a.	0.1 mL or 100 mg	n.a.	154.1	?	?	1	?	?	?	solid	63.0	n=1/1, CO=4	-
Category 1	4	Sodium hydrogen sulfate	7681-38-1	ZEBET	n.a.	Sigma-Aldrich Corp.	Salt (inorganic)	Cleaning Agent, Laboratory Chemical, Pesticide	n.a.	0.1 mL or 100 mg	n.a.	120.1	?	?	1	?	?	?	solid	8.0	n=1/1, CO=4	-
Category 1	4	Sodium hydroxide	1310-73-2	ECETOC	Fisher Scientific International, Inc.	Sigma-Aldrich Corp.	Alkali	Caustic Agent, Chemical Intermediate, Industrial Chemical, Pharmaceutical Intermediate, Veterinary Chemical	10%	0.1 mL	Reagent Grade	40.0	12.7	R35 (5%)	1	soluble (1 g/0.9 mL)	"virtually 0"	?	liquid	108.0	n=1/1, CO=4	n=1/1, IR=2 D21
Category 1	4	Sodium oxalate	62-76-0	ECETOC	Sigma-Aldrich Corp.	Sigma-Aldrich Corp.	Acid (organic) [carboxylic acid]	Industrial Chemical, Laboratory Chemical	100%	100 mg	>99%	134.0	8.4	corrosive	3	soluble (37 g/L)	n.a.	?	solid	61.3	n=1/3, CO=4	n=1/3, IR=2 D14
Category 1	1	Sodium perborate tetrahydrate	10486-00-7	ECETOC	Dupont Corp.	Sigma-Aldrich Corp.	Boron Compound, Salt (inorganic)	Cleaning Agent	100%	60 mg	98.6%	153.9	10.0	noncorrosive	6	n.a.	n.a.	?	solid	38.5	n=4/6, CO>1 D21	-
Category 1	4	Di(2-ethylhexyl) sodium sulfosuccinate	98-89-9	NIHS-Ohno	Japanese Cosmetic Industry Assn.	Sigma-Aldrich Corp.	Ester, Salt (organic), Sulfur Compound (organic)	Adjuvant, Cleaner, Solubilizer, Wetting Agent	10%	0.1 mL	n.a.	444.6	6.5	noncorrosive	3	soluble (15 g/L)	n.a.	?	liquid	57.0	n=1/3, CO=4	-
Category 1	3	Dibenzoyl-L-tartaric acid	2743-38-6	ECETOC	n.a.	Sigma-Aldrich Corp.	Acid (organic) [carboxylic acid], Ester	Chemical Intermediate	100%	100 mg	98%	358.3	n.a.	noncorrosive	3	slightly soluble	n.a.	?	solid	36.7	n=3/3, CO=3	-
Category 1	4	Tetraethylene glycol diacrylate	17831-71-9	TSCA	Rhone-Poulenc, Inc.	Sigma-Aldrich Corp.	Ether, Nitro Compound	Chemical Intermediate, Industrial Chemical	100%	0.1 mL	n.a.	302.3	?	?	6	?	?	?	liquid	103.3	n=5/6, CO=4	n=6/6, IR=2 D14
Category 1	4	Tetrahydrofuran	109-99-9	TSCA	International Specialty Products Co.	Sigma-Aldrich Corp.	Ether, Heterocyclic Compound	Chemical Intermediate, Industrial Chemical, Pharmaceutical Intermediate, Solvent	100%	0.1 mL	n.a.	72.1	?	?	6	?	?	?	liquid	31.2	n=2/6, CO=4	-
Category 1	4	N,N,N',N'-Tetramethylethylenediamine	111-18-2	TSCA	Union Carbide Corp.	Sigma-Aldrich Corp.	Amine	Anti-Infective, Industrial Chemical, Laboratory Chemical	100%	0.005 mL	n.a.	172.3	?	?	6	?	?	?	liquid	96.0	n=6/6, CO=4	-
Category 1	0 (likely 4)	2-Nitro-4-thiocyanoaniline	54029-45-7	CRK	n.a.	Sigma-Aldrich Corp.	Amine, Nitro Compound, Sulfur Compound (organic)	Industrial Chemical	100%	0.1 mL or 100 mg	n.a.	195.2	?	?	1	?	?	?	solid	63.0	-	-
Category 1	1	TNO-35 (Propyl lactate)	616-09-1	TNO-Prinsen	n.a.	Cook Aromatics Ltd. (Bulk)	Alcohol, Ester	Cleaning Agent, Food Additive	n.a.	0.1 mL or 100 mg	n.a.	132.2	?	?	1	?	?	?	solid	63.0	n=1/1, CO>0 D21	n=1/1, IR>0 D21
Category 1	4	1,2,4-Triazole, sodium salt	41253-21-8	ECETOC	Elf Atochem, Inc.	Sigma-Aldrich Corp.	Heterocyclic Compound, Salt (organic)	Anti-Fungal	100%	100 mg	99%	91.1	n.a.	noncorrosive	1	soluble	n.a.	brown	solid	104.0	n=1/1, CO=4	n=1/1, IR=2
Category 1	4	Trichloroacetic acid	76-03-9	ECETOC	Fisher Scientific International, Inc.	Sigma-Aldrich Corp.	Acid (organic) [carboxylic acid]	Caustic Agent, Herbicide	30%	0.1 mL	Reagent Grade	163.4	0.7	R34 (0.6N); R35 (undiluted)	1	soluble (10 g/mL)	1.33	?	liquid	106.0	n=1/1, CO=4	n=1/1, IR=2 D21
Category 1	4	Trichloroacetyl chloride	76-02-8	TSCA	Rhone-Poulenc, Inc.	Sigma-Aldrich Corp.	Acyl Halide	Chemical Intermediate, Industrial Chemical	n.a.	0.1 mL	n.a.	181.4	?	?	4	?	?	?	liquid	91.0	n=4/4, CO=4	-
Category 1	4	Triton X-100	9002-93-1	TSCA	Union Carbide Corp.	Sigma-Aldrich Corp.	Ether	Surfactant (nonionic)	100%	0.1 mL	n.a.	250.4	n.a.	noncorrosive	6	soluble	n.a.	colorless	liquid	65.8	n=2/6, CO=4	-
Category 1(H)	-	Ammonia	7664-41-7	-	-	Sigma-Aldrich Corp.	Alkali	Anti-Fungal, Chemical Intermediate, Cleaning Agent, Fertilizer, Herbicide, Industrial Chemical, Refrigerant	-	-	-	17.0	-	-	-	n.a.	n.a.	?	Liquid	-	-	-
Category 1(H)	-	Chloroform	67-66-3	-	n.a.	Sigma-Aldrich Corp.	Hydrocarbon (acyclic)	Anesthetic, Chemical Intermediate, Cleaning Agent, Industrial Chemical, Pharmaceutical Intermediate, Solvent	-	-	-	119.4	-	-	-	n.a.	n.a.	?	liquid	-	-	-
Category 1(H)	-	Lime	1305-78-8	-	-	Sigma-Aldrich Corp.	Salt (inorganic)	Building Material, Chemical Intermediate, Cleaning Agent, Fertilizer, Industrial Chemical	-	-	-	56.1	-	-	-	n.a.	n.a.	white to grayish	solid	-	-	-
Category 1(H)	-	Magnesium hydroxide	1309-42-8	-	-	Sigma-Aldrich Corp.	Salt (inorganic)	Chemical Intermediate, Flame Retardant, Industrial Chemical, Pharmaceutical, Veterinary Agent	-	-	-	58.3	-	-	-	n.a.	n.a.	?	solid	-	-	-
Category 1(H)	-	Nitric acid	7697-37-2	-	-	Sigma-Aldrich Corp.	Acid, Salt (inorganic)	Chemical Intermediate, Industrial Chemical, Laboratory Reagent, Pharmaceutical Intermediate	-	-	-	63.0	-	-	-	n.a.	n.a.	colorless to yellow	liquid	-	-	-

Substance Name	CASRN	*In Vitro* Conc. Tested	*In Vivo* Conc. Tested	Chemical Class	*In Vivo* Physical Form Tested	pH	Property of Interest	*In Vivo* (GHS) Classification[1]	GHS Category 1 Subclass[2]	*In Vivo* (EPA) Classification[3]	*In Vivo* (EU) Classification[4]	*In Vitro* Classification (IS(B)-100)[5]	Reference
Silan 253	18784-74-2	100%		Organosilicon compound	Unknown	<7		SCNM		SCNM	SCNM	Severe	Spielmann et al. (1996)
Sodium bisulfite	7631-90-5	100%		Inorganic acid, Inorganic salt	Solid	4.5		Nonirritant		Category III	Nonirritant	Severe	Spielmann et al. (1996)
Sodium sulfite	7757-83-7	100%		Inorganic salt	Solid	10		SCNM		Category III	SCNM	Severe	Spielmann et al. (1996)
Sodium cyanate	917-61-3	100%		Inorganic salt	Solid	10		SCNM		Category III	SCNM	Severe	Spielmann et al. (1996)
Sodium disilicate	13870-28-5	100%		Inorganic salt	Solid	11.4		Category 1	4	SCNM	SCNM	Severe	Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	100%		Inorganic salt	Solid	1.1		Category 1	4	SCNM	SCNM	Severe	Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	100%		Organic salt, Ester, Ether	Unknown	8		SCNM		SCNM	SCNM	Severe	Spielmann et al. (1996)
Sodium monochloroacetate	3926-62-3	100%		Organic salt, Carboxylic acid salt	Solid	4.5		Category 2B		Category III	R36	Severe	Spielmann et al. (1996)
Sodium oxalate	62-76-0	100%	100%	Organic salt, Carboxylic acid salt	Solid			Category 1	4	Category I	R41	Severe	Gilleron et al. (1997)
Sodium perborate	10486-00-7	100%	100%	Inorganic salt, Boron containing compound	Solid			Category 1	4	Category I	R41	Severe	Gilleron et al. (1997)
Sodiumpyrosulfite	7681-57-4	100%		Inorganic salt	Solid	4.6		SCNM		SCNM	SCNM	Severe	Spielmann et al. (1996)
4-((2-sulfatoethyl)sulfonyl)-aniline	2494-89-5	100%		Amine, Organic sulfur compound, Ether	Unknown	7		Category 1	4	SCNM	R41	Severe	Spielmann et al. (1996)
TA 01946 Alkylsilan		100%		Unknown	Unknown	ns		Nonirritant		Category IV	Nonirritant	Severe	Spielmann et al. (1996)
Tetraaminopyrimidine sulfate	5392-28-9	100%	100%	Amine, Heterocycle	Solid			Nonirritant		Category III	Nonirritant	Slight	Gilleron et al. (1996); Gilleron et al. (1997)

Substance Name	CASRN	*In Vitro* Concentration Tested	*In Vivo* Concentration Tested	Chemical Class	Form Tested	pH	Property of Interest	*In Vivo* (GHS) Classification[2]	GHS Category I Subclass[3]	*In Vivo* (EPA) Classification[4]	*In Vivo* (EU) Classification[5]	*In Vitro* Classification (IS(A))[6]	*In Vitro* Classification (IS(B))[7]	*In Vitro* Classification (IS(B)-10)[8]	*In Vitro* Classification (IS(B)-100)[9]	*In Vitro* Classification (Q-Score)[10]	*IIn Vitro* Classification (S-Score)[11]	Reference
Di(2-ethylhexyl) sodium sulfosuccinate	577-11-7	10%	10%	Organic salt, Sulfur containing compound, Ester	Solution			Category 1	4	Category I	R36	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Diisopropanolamine	110-97-4	10%	10%	Amine, Alcohol	Solution			Nonirritant		Category III	Nonirritant	Moderate						Hagino et al. (1999)/Submitted Y. Ohno Data
Domiphen bromide	538-71-6	10%	10%	Organic salt, Onium, Ether	Solution			Category 1	4	Category I	R41	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Ethanol	64-17-5	10%	10%	Alcohol	Solution			Nonirritant		Category IV	Nonirritant	Slight						Hagino et al. (1999)/Submitted Y. Ohno Data
Ethanol	64-17-5	100%	100%	Alcohol	Liquid			SCNM		SCNM	SCNM	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Glycolic acid	79-14-1	10%	10%	Carboxylic acid, Alcohol	Solution			Category 2B		Category III	Nonirritant	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Lactic acid	50-21-5	10%	10%	Carboxylic acid, Alcohol	Solution			SCNM		Category III	SCNM	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Lactic acid	50-21-5	100%	100%	Carboxylic acid, Alcohol	Liquid			Category 1	4	Category I	R41	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Potassium laurate	10124-65-9	10%	10%	Organic salt, Carboxylic acid salt	Solution			Category 1	4	Category I	R41	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Stearyltrimethylammonium chloride	15461-40-2	10%	10%	Organic salt, Onium	Solution			Category 1	4	Category I	R41	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Triethanolamine	102-71-6	10%	10%	Amine, Alcohol	Solution			Nonirritant		Category IV	Nonirritant	Slight						Hagino et al. (1999)/Submitted Y.
Triethanolamine	102-71-6	100%	100%	Amine, Alcohol	Liquid			Nonirritant		Category III	Nonirritant	Moderate						Hagino et al. (1999)/Submitted Y. Ohno Data
Monoethanolamine	141-43-5	10%	10%	Amine, Alcohol	Solution			Category 2B		Category III	Nonirritant	Severe						Hagino et al. (1999)/Submitted Y. Ohno Data
Ethanol	64-17-5	10%		Alcohol	Unknown			Nonirritant		Category IV	Nonirritant	Slight						Kojima et al. (1995)
Potassium laurate	10124-65-9	10%		Organic salt, Carboxylic acid salt	Unknown			Category 1	4	Category I	R41	Severe						Kojima et al. (1995)
Sodium lauryl sulfate	151-21-3	10%		Organic salt, Carboxylic acid salt	Unknown			Category 1/Category 2A	4	Category I/Category II	R41/Nonirritant	Moderate						Kojima et al. (1995)
Stearyltrimethylammonium chloride	15461-40-2	10%		Organic salt, Onium	Unknown			Category 1	4	Category I	R41	Severe						Kojima et al. (1995)
Triton X-100	9002-93-1	10%		Ether	Unknown			Category 1		Category II	SCNM	Moderate						Kojima et al. (1995)
C12/C14-Glucoside		100%, 10%, and ITC		Alcohol, Ether	Unknown	9		Category 1	1	Category I	R41			Severe	Severe			Spielmann et al. (1996)
Isodecylglucoside		100%, 10%, and ITC		Alcohol, Ether	Unknown	9		SCNM		SCNM	SCNM			Severe	Severe			Spielmann et al. (1996)
Nitro-bis-octylamide		100%, 10%, and ITC		Alcohol, Ether	Unknown	ns		Nonirritant		Category III	Nonirritant			Slight	Moderate			Spielmann et al. (1996)
7-Acetoxyheptanal		100%, 10%, and ITC		Aldehyde, Ester	Unknown	ns		Category 1	1	Category I	R41			Slight	Severe			Spielmann et al. (1996)
Sodium disilicate	13870-28-5	100%, 10%, and ITC		Inorganic salt	Solid	11.4		Category 1	4	SCNM	SCNM			Severe	Severe			Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	100%, 10%, and ITC		Inorganic salt	Solid	1.1		Category 1	4	SCNM	SCNM			Severe	Severe			Spielmann et al. (1996)
n-Acetyl-Methionine	1115-47-5	100%, 10%, and ITC		Amide, Amino acid	Solid	2.2		Category 1	4	SCNM	R41			Severe	Severe			Spielmann et al. (1996)
Ambuphylline	5634-34-4	100%, 10%, and ITC		Amine, Heterocycle, Alcohol	Solid	9		Nonirritant		Category IV	Nonirritant			Severe	Severe			Spielmann et al. (1996)
4-Amino-5-methoxy-2-methylbenzenesulfonic acid	6471-78-9	100%, 10%, and ITC		Amine, Ether, Organic sulfur compound	Unknown	1.5		Category 1	4	SCNM	SCNM			Moderate	Severe			Spielmann et al. (1996)
Ammoniumpersulfate	7727-54-0	100%, 10%, and ITC		Inorganic salt	Solid	1.5		SCNM		SCNM	SCNM			Slight	Severe			Spielmann et al. (1996)
Anisole	100-66-3	100%, 10%, and ITC		Ether	Liquid	ns		SCNM		SCNM	SCNM			Moderate	Severe			Spielmann et al. (1996)
B 25		100%, 10%, and ITC		Unknown	Unknown	ns		Nonirritant		Category IV	Nonirritant			Nonirritant	Nonirritant			Spielmann et al. (1996)
n-Butanal	123-72-8	100%, 10%, and ITC		Aldehyde	Liquid	<7		Category 2B		Category III	Nonirritant			Moderate	Severe			Spielmann et al. (1996)

Substance Name[1]	CASRN	Mean IS(B)-10 Score	IS(B)-10 SD	%CV for IS(B)-10	Mean IS(B)-100 Score	IS(B)-100 SD	%CV for IS(B)-100
Sodium sulfite	7757-83-7	12.25	1.34	10.97	14.20	2.69	18.92
Sodium cyanate	917-61-3	12.65	3.04	24.04	9.45	1.77	18.71
Sodium disilicate	13870-28-5	20.20	0.71	3.50	17.40	1.13	6.50
Sodium hydrogen sulfate	7681-38-1	17.75	1.48	8.37	18.65	0.78	4.17
Sodium lauryl ether sulfate	3088-31-1	14.10	5.09	36.11	18.45	0.78	4.22
Sodium monochloroacetate	3926-62-3	3.75	5.30	141.42	13.45	3.75	27.86
Sodiumpyrosulfite	7681-57-4	14.87	2.41	16.22	14.60	3.05	20.90
4-((2-Sulfatoethyl)sulfonyl)-aniline	2494-89-5	19.05	1.48	7.79	-	-	-
TA 01946 Alkylsilan		8.80	1.70	19.28	13.10	4.38	33.47
Theophylline sodium acetate	8002-89-9	9.40	5.66	60.18	-	-	-
Tocla		16.30	4.81	29.50	16.95	4.88	28.78
Triisooctylamine	25549-16-0	0.40	0.57	141.42	9.05	7.14	78.91
2,2,3-Trimethyl-3-cyclo-pentene-1-acetaldehyde	4501-58-0	2.60	0.42	16.32	12.20	3.54	28.98
Trioxane	110-88-3	11.33	2.93	25.91	17.90	0.14	0.79
Wessalith Slurry		6.57	4.86	74.00	9.90	8.20	82.85
Xanthinol nicotinate	437-74-1	7.65	5.16	67.48	13.20	5.94	45.00
Mean %CV Value				**60.17**			**35.21**
Median %CV Value				**42.65**			**26.22**
Range %CVs				**0-141.42**			**0-141.42**
Mean %CV Value (Minus Substances Tested in 3 Laboratories)				**58.07**			**34.62**
Median %CV Value (Minus Substances Tested in 3 Laboratories)				**31.85**			**21.57**
Range %CVs (Minus Substances Tested in 3 Laboratories)				**0-141.42**			**0-141.42**

Abbreviations: CV = coefficient of variation; CASRN = Chemical Abstract Service Registry Number.
[1]Italicized substances represent chemicals that were tested in three testing laboratories. Data for these substances were removed to determine their impact on the calculated %CV values for this data set.

Hagino et al. (1999) and Ohno et al. (1999): The Japanese Ministry of Health and Welfare evaluated the HET-CAM test method in five different laboratories as part of a validation effort to assess alternative ocular irritation test method. Nine, 15, and 14 cosmetic ingredients were evaluated in the first, second, and third steps of the validation study, respectively. These studies used the IS(A) analysis method to assess potential irritancy classifications. Average individual laboratory results and standard deviations for tested substances were reported in Hagino et al. (1999). **Appendix F2** provides the average IS(A) values for each testing laboratory for each substance evaluated in this validation effort.

ABSTRACT

An analysis was conducted to estimate the likelihood of underclassifying ocular corrosives or severe irritants as nonsevere irritants or overclassifying ocular nonsevere irritants and nonirritants as ocular corrosives or severe irritants. The analysis used the current sequential three animal *in vivo* rabbit eye test method and the United Nations (UN) Globally Harmonized System (GHS) of Classification and Labeling of Chemicals. The distribution of individual rabbit responses within each hazard classification was used to estimate the likelihood of under- and over-classification likelihoods for a sequential testing strategy (using from one to three rabbits). Based on assumptions about the variability in rabbit responses among substances within each hazard classification, the estimated underclassification likelihoods, based on 723 rabbits tested in 181 studies, for corrosives/severe irritants (GHS Category 1) ranged from 4.30% to 13.24%. Analyses based on the physical form of the test substance indicated that underclassification likelihoods for solids were lower than for liquids (2.89%-8.31% vs. 5.36%-15.79%, respectively), although these differences are not statistically significant. Estimated underclassification likelihoods were higher when a corrosive/severe irritant classification was based solely on persistent lesions present at observation day 21. By chemical class, carboxylic acids had the highest underclassification likelihood (16.64%). Overclassification likelihoods of nonsevere and nonirritant substances as Category 1 substances, based on 2481 rabbits tested in 596 studies, were estimated to be 6.67% to 7.70% for Category 2A substances, 0.82% to 1.28% for Category 2B substances, and 0.00% for nonirritants. One limitation of this analysis is that it requires an *a priori* assignment of each chemical to a specific irritation category. Using the approach of Springer et al. (1993), the likelihood that an ocular corrosive or severe irritant will be underclassified can be estimated without an *a priori* assignment of each chemical to a specific hazard classification. Using a modified version of the Spring et al. approach, the overall estimated underclassification rate for all irritants was 13.40%, while the estimated overclassification rate for all nonirritants is 2.65%. These rates agree closely with the estimates based on using the previous approach.

	A	B	D	E	F	G	H	I	J	K	L	M
1	SUBSTANCE NAME	CASRN	SOURCE	CONCENTRATION	ANIMAL 1	ANIMAL 2	ANIMAL 3	ANIMAL 4	ANIMAL 5	ANIMAL 6	OVERALL CLASSIFICATION	SUBCLASSIFICATION
45	Surfonic HDL-1	9016-45-9	TSCA	100%	Cat 1(pos1/3)	Cat 1(pos2/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
46	2-Benzyl-4-chlorophenol	000120321	TSCA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
47	N,N,N',N'-Tetramethylhexanediamine	111-18-2	TSCA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
48	Antimony oxide	1309-64-4	TSCA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
49	Phosphorodicloridic acid, ethyl ester	1498-51-7	TSCA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
50	gamma-Aminopropyltriethoxy silane	919-30-2	TSCA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
51	Amway automatic dishwashing compound for soft water		Access Business Group	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
52	Amway concrete floor cleaner		Access Business Group	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
53	Amway Pursue disinfectant cleaner		Access Business Group	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
54	Ethylhexyl acid phosphate ester		ExxonMobil Biomedical Sciences	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
55	PROD-00153		FDA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
56	PROD-00157		FDA	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
57	Floor stripper (sample 18)		S.C. Johnson & Son, Inc.	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
58	Metal cleaner (sample 20)		S.C. Johnson & Son, Inc.	100%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
59	Dibenzoyl-L-tartaric acid	2743-38-6	Laboratoire National de la Sante	20%	Cat2B	Cat 1(pos1/3)	Cat2A				Category 1	4
60	Promethazine hydrochloride	58-33-3	Laboratoire National de la Sante	20%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)				Category 1	4
61	Diethylethanolamine	100-37-8	TSCA	25%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
62	Diethylethanolamine	100-37-8	TSCA	50%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
63	4-Tert-butylcatechol	98-29-3	TSCA	85%	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
64	Acid blue 40	6424-85-7	TSCA	n.a.	Cat 1(pos1/3)	nonirritant	Cat2A	Cat2A	Cat 1(pos1/3)	Cat2A	Category 1	4
65	4-Amino-5-methoxy-2-methylbenzene-sulphonic acid	6471-78-9	ZEBET	n.p.	Cat 1(pos1/3)						Category 1	4
66	Sodium hydrogen sulfate	7681-38-1	ZEBET	n.p.	Cat 1(pos1/3)						Category 1	4
67	Methylpentynol	77-75-8	ZEBET	n.p.	Cat 1(pos1/3)						Category 1	4
68	B-Resorcylic acid	89-86-1	ZEBET	n.p.	Cat 1(pos1/3)						Category 1	4
69	4-Chloro-methanilic acid	98-36-2	ZEBET	n.p.	Cat 1(pos1/3)						Category 1	4
70	Diphocars		ZEBET	n.p.	Cat 1(pos1/3)						Category 1	4
71	n-Butanol	71-36-3	ZEBET	n.p.	Cat 1(pos1/3)	nonirritant	Cat2A				Category 1	4
72	Polyhexamethylene guanidine	31961-54-3	ZEBET	n.p.	Cat2A	Cat2A	Cat 1(pos1/3)				Category 1	4
73	Sodium disilicate	13870-28-5	ZEBET	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)				Category 1	4
74	2-Hydroxyisobutyric acid	594-61-6	ZEBET	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)				Category 1	4
75	N-(2-Methylphenyl)-imidodicarbonimidic diamide	93-69-6	ZEBET	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)				Category 1	4
76	PROD-00138		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)				Category 1	4
77	Trichloroacetyl chloride	76-02-8	TSCA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)			Category 1	4
78	PROD-00062		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat2A	Cat 1(pos1/3)	nonirritant	Category 1	4
79	PROD-00072		FDA	n.p.	Cat 1(pos1/3)	Cat2A	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat2A	Category 1	4
80	Benzenesulfonyl chloride	98-0909	TSCA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos2/3)	Cat 1(pos1/3)	Category 1	4
81	Antimony trioxide	1309-64-4	TSCA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
82	Aluminum chloride	16603-84-2	TSCA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
83	PROD-00068		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
84	PROD-00074		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
85	PROD-00078		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
86	PROD-00098		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
87	PROD-00114		FDA	n.p.	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
88	Hydroxyethyl acrylate	818-1-1	TSCA	Undiluted	Cat 1(pos1/3)	Cat 1(pos2/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
89	T-1585		TSCA	Undiluted	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Cat 1(pos1/3)	Category 1	4
90	Promethazine hydrochloride	58-33-3	ECETOC	100%	Cat 1(pos2/3)	Cat 1(pos2/3)	Cat 1(pos2/3)				Category 1	3

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7.0 SUMMARY

This report estimates the potential for substances to be misclassified based on evaluating the variability in the observed rabbit responses. The two overall analyses that were conducted were: (1) an assessment of the underclassification likelihood of ocular corrosives/severe irritants being classified as nonsevere irritants/nonirritants; and (2) an assessment of the overclassification likelihood of ocular nonsevere irritants/nonirritants being classified as corrosives/severe irritants. The GHS classification system was used because it has been internationally harmonized through the UN and is expected to be implemented globally in the future. Within the first overall underclassification analysis, additional analyses were conducted to determine the impact of physical form, chemical class, and GHS criteria for classification on the underclassification likelihood of corrosives/severe irritants.

The estimated underclassification likelihoods obtained using the three different calculation methods that were based on the hazard classification category assigned to a test substances from the results of the *in vivo* rabbit eye test study are summarized in **Table 15**. As discussed previously, Calculation 1 assumes homogeneity of response within an irritancy category. While this simplifies the computation, it ignores the potentially significant contribution of animal variability to the underclassification likelihood. Calculation 2 assumes heterogeneity of response within an irritancy category, which leads to a higher estimated likelihood than determined by Calculation 1. One significant limitation of this approach is that the distribution of observed rabbit responses for each substance is based on a small number of rabbits. Calculation 3 attempts to incorporate aspects of both Calculation 1 and 2. Calculation 2 likely provides the most reasonable estimate of the underclassification likelihood for GHS Category 1 substances.

Using the three calculation methods, the estimated underclassification likelihoods for the total database ranged from 4.30% for Calculation 1 to 11.21% for Calculation 3 to 13.24% for Calculation 2. For all three calculation methods, the greatest contribution to the underclassification likelihood comes from a Category 1 substances being classified as a Category 2A (likelihoods range from 3.00% to 7.68% depending on the calculation method).

Substance Name	CASRN	Lab	In Vitro Conc. Tested	In Vitro Physical Form Tested	Purity (%)	Solubility[a]	pH	IS(A)[b]	IS(A) SD	IS(A) Classification	Overall IS(A) Classification	IS(B)[c]	IS(B) SD	IS(B) Classification	Overall IS(B) Classification	S-Score[d]	S-Score Classification	Overall S-Score Classification	Q-Score[e]	Q-Score Classification	Overall Q-Score Classification	IS(B)-10[f]	IS(B)-10 Class.	Overall IS(B)-10 Class.	IS(B)-100[f]	IS(B)-100 Class.	Overall IS(B)-100 Class.	Reference
Sodium hydrogen sulfate	7681-38-1	HK	100%, 10%, and ITC	-	n.p.	1000	1.1															18.8	Severe	Severe	19.2	Severe	Severe	Spielmann et al. (1996)
Sodium hydrogen sulfate	7681-38-1	WA	100%, 10%, and ITC	-	n.p.	1000	1.1															16.7	Severe		18.1	Severe		Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	BO	100%, 10%, and ITC	-	n.p.	soluble	8															10.5	Severe	Severe	17.9	Severe	Severe	Spielmann et al. (1996)
Sodium lauryl ether sulfate	3088-31-1	MD	100%, 10%, and ITC	-	n.p.	soluble	8															17.7	Severe		19	Severe		Spielmann et al. (1996)
Sodium monochloroacetate	3926-62-3	HO	100%, 10%, and ITC	-	n.p.	440	4.5															7.5	Moderate	Moderate	16.1	Severe	Severe	Spielmann et al. (1996)
Sodium monochloroacetate	3926-62-3	BD	100%, 10%, and ITC	-	n.p.	440	4.5															0	Nonirritant		10.8	Severe		Spielmann et al. (1996)
Sodiumpyrosulfite	7681-57-4	AP	100%, 10%, and ITC	-	n.p.	650	4.6															17.4	Severe	Severe	17.7	Severe	Severe	Spielmann et al. (1996)
Sodiumpyrosulfite	7681-57-4	BD	100%, 10%, and ITC	-	n.p.	650	4.6															13.6	Severe		11.6	Severe		Spielmann et al. (1996)
Sodiumpyrosulfite	7681-57-4	BKI	100%, 10%, and ITC	-	n.p.	650	4.6															14.6	Severe		14.5	Severe		Spielmann et al. (1996)
4-((2-sulfatoethyl)sulfonyl)-aniline	2494-89-5	AP	100%, 10%, and ITC	-	n.p.	soluble	7															18	Severe	Severe	18.4	Severe	Severe	Spielmann et al. (1996)
4-((2-sulfatoethyl)sulfonyl)-aniline	2494-89-5	HK	100%, 10%, and ITC	-	n.p.	soluble	7															20.1	Severe		n.p.	Severe		Spielmann et al. (1996)
TA 01946 Alkylsilan		AP	100%, 10%, and ITC	-	n.p.	0.014	n.a.															7.6	Moderate	Severe	16.2	Severe	Severe	Spielmann et al. (1996)
TA 01946 Alkylsilan		HK	100%, 10%, and ITC	-	n.p.	0.014	n.a.															18	Severe		19	Severe		Spielmann et al. (1996)
Theophylline sodium acetate	8002-89-9	AP	100%, 10%, and ITC	-	n.p.	50	11															13.4	Severe	Severe	4.9	Moderate	Moderate	Spielmann et al. (1996)
Theophylline sodium acetate	8002-89-9	HO	100%, 10%, and ITC	-	n.p.	50	11															5.4	Moderate		n.p.	Severe		Spielmann et al. (1996)
Tocla		BO	100%, 10%, and ITC	-	n.p.	40	6															12.9	Severe	Severe	13.5	Severe	Severe	Spielmann et al. (1996)
Tocla		HK	100%, 10%, and ITC	-	n.p.	40	6															19.7	Severe		20.4	Severe		Spielmann et al. (1996)
Triisooctylamine	25549-16-0	BO	100%, 10%, and ITC	-	n.p.	0.5	7															0.8	Nonirritant	Nonirritant	14.1	Severe	Severe	Spielmann et al. (1996)
Triisooctylamine	25549-16-0	MD	100%, 10%, and ITC	-	n.p.	0.5	7															0	Nonirritant		4	Slight		Spielmann et al. (1996)
2,2,3-Trimethyl-3-Cyclopentene-1-acetaldehyde	4501-58-0	BO	100%, 10%, and ITC	-	n.p.	< 2.5	2.3															2.9	Slight	Slight	9.7	Severe	Severe	Spielmann et al. (1996)
2,2,3-Trimethyl-3-Cyclopentene-1-acetaldehyde	4501-58-0	AP	100%, 10%, and ITC	-	n.p.	< 2.5	2.3															2.3	Slight		14.7	Severe		Spielmann et al. (1996)
Trioxane	110-88-3	HK	100%, 10%, and ITC	-	n.p.	172	n.a.															9.25	Severe	Severe	18	Severe	Severe	Spielmann et al. (1996)
Trioxane	110-88-3	WA	100%, 10%, and ITC	-	n.p.	172	n.a.															13.4	Severe		17.8	Severe		Spielmann et al. (1996)
Wessalith Slurry		BO	100%, 10%, and ITC	-	n.p.	readily soluble	11															3.13	Slight	Severe	4.1	Slight	Severe	Spielmann et al. (1996)
Wessalith Slurry		WA	100%, 10%, and ITC	-	n.p.	readily soluble	11															10	Severe		15.7	Severe		Spielmann et al. (1996)
Xanthinol nicotinate	437-74-1	WA	100%, 10%, and ITC	-	n.p.	250	6															4	Slight	Severe	9	Severe	Severe	Spielmann et al. (1996)
Xanthinol nicotinate	437-74-1	HK	100%, 10%, and ITC	-	n.p.	250	6															11.3	Severe		17.4	Severe		Spielmann et al. (1996)

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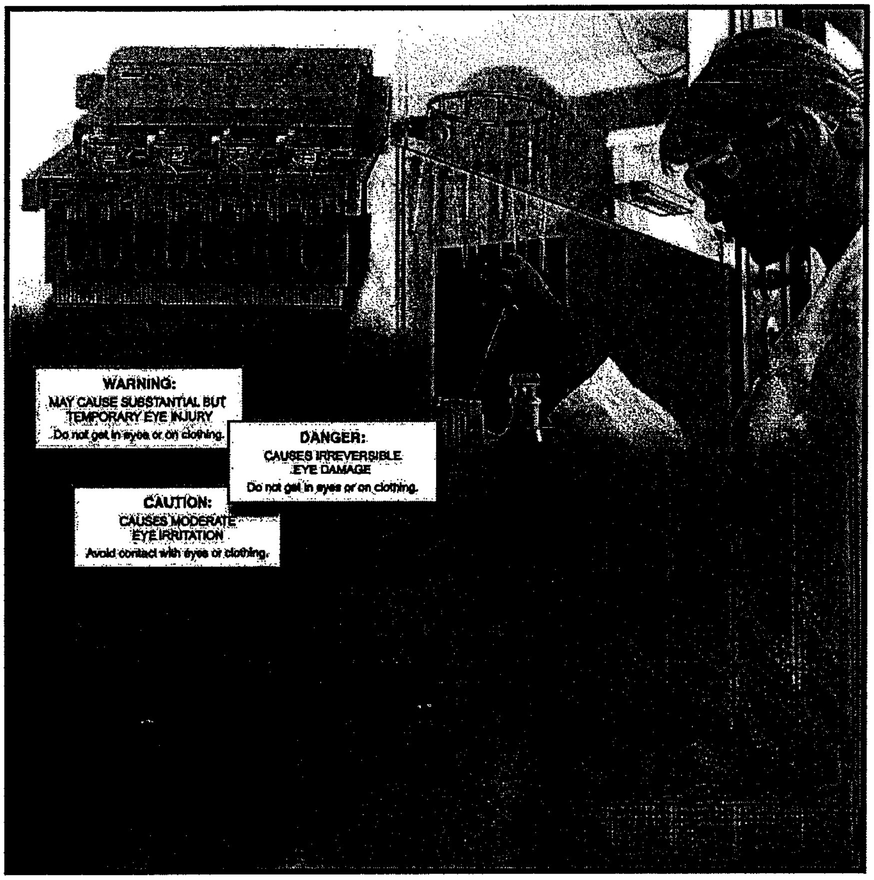

ICCVAM Test Method Evaluation Report: Current Validation Status of *In Vitro* Test Methods Proposed for Identifying Eye Injury Hazard Potential of Chemicals and Products

Volume 2 of 2

Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM)

National Toxicology Program (NTP) Interagency Center for the Evaluation of Alternative Toxicological Methods (NICEATM)

National Institute of Environmental Health Sciences
National Institutes of Health
U.S. Public Health Service
Department of Health and Human Services

Substances Used In HET-CAM Accuracy Analysis (Chemical and Product Classes)

Substance	CASRN	Synonyms	Chemical Class	Product Class
Silan 108	3069-40-7	Trimethoxyoctyl silane	Hydrocarbon; Ether	-
Silan 165	29055-11-6	Bis(3-trimethoxysilylpropyl)sulfide	Hydrocarbon; Ether; Sulfur containing	-
Silan 167	41453-78-5	3,3,14,14-Tetramethoxy-2,15-dioxa-7,8,9,10-tetrathia-3,14-disilahexadecane	-	-
Silan 253	18784-74-2	-	-	-
Silver nitrate	7761-88-8	-	Inorganic	-
Sodium bisulfite	7631-90-5	-	Inorganic	-
Sodium sulfite	7757-83-7	-	Inorganic	-
Sodium chloride	7647-14-5	-	Inorganic	-
Sodium cyanate	917-61-3	-	Cyanate	-
Sodium disilicate	13870-28-5	Silane 69	Inorganic	-
Sodium hydrogen sulfate	7681-38-1	Sodium bisulfate	Inorganic	-
Sodium hydroxide	1310-73-2	-	Alkali	-
Sodium lauryl ether sulfate	3088-31-1	Diethylene glycol monolauryl ether sodium sulfate	-	-
Sodium lauryl sulfate	151-21-3	-	Surfactant, Anionic	Detergent
Sodium monochloroacetate	3926-62-3	Sodium chloroacetate	Carboxylic acid	-
Sodium oxalate	62-76-0	-	Inorganic	-
Sodium perborate	10486-00-7	-	Inorganic	-
Sodiumpyrosulfite	7681-57-4	Sodium metabisufite	Inorganic	-
Stearyltrimethylammonium chloride	15461-40-2	-	Surfactant, Cationic	-
Styrene	100-42-5	-	Hydrocarbon	-
4-((2-sulfatoethyl)sulfonyl)-aniline	2494-89-5	2-Sulfanyl ethanol hydrogen sulfate	Amide	-

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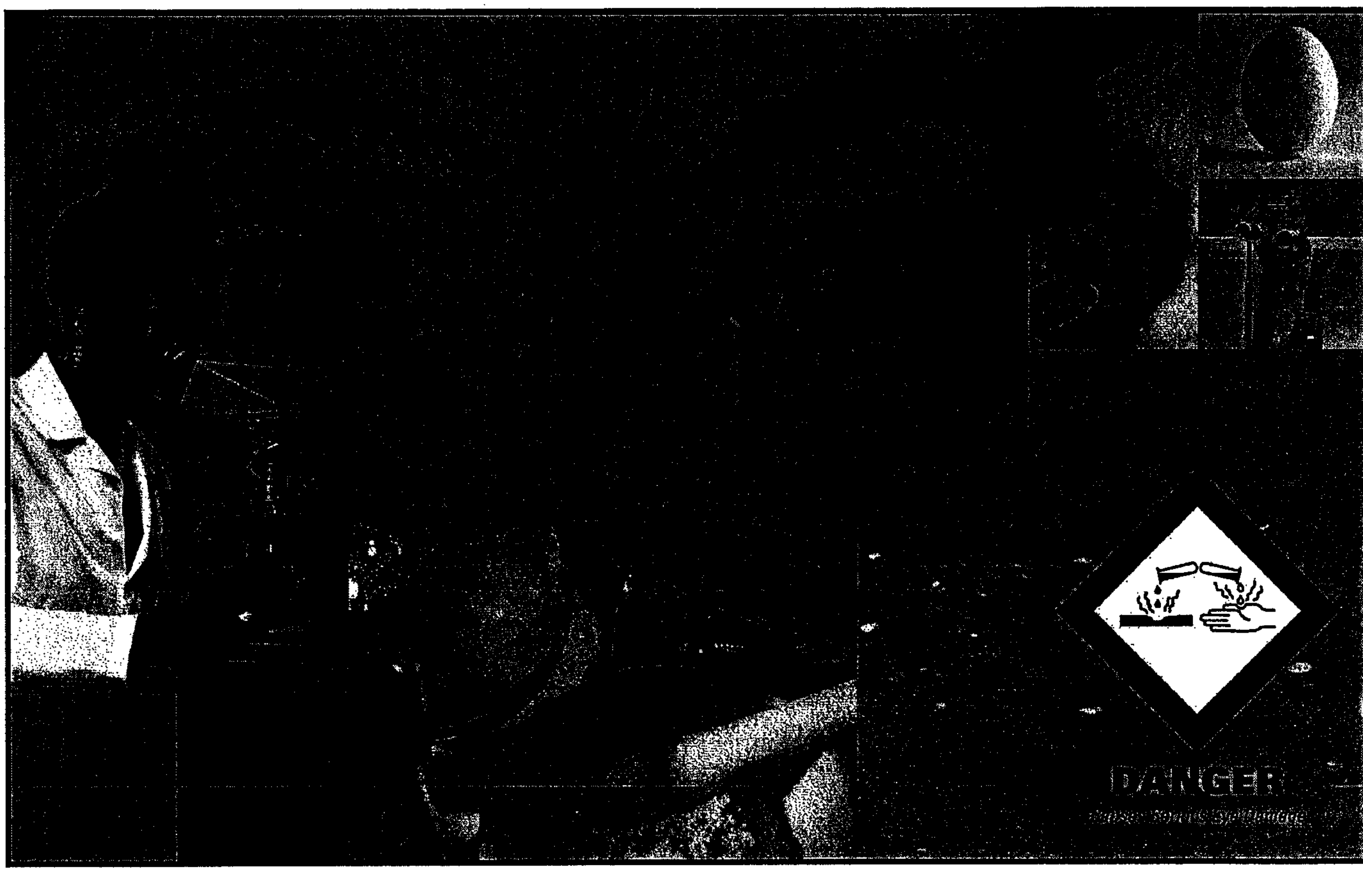

ICCVAM TEST METHOD EVALUATION REPORT

In Vitro Ocular Toxicity Test Methods for Identifying Severe Irritants and Corrosives

Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM)

National Toxicology Program (NTP) Interagency Center for the Evaluation of Alternative Toxicological Methods (NICEATM)

National Institute of Environmental Health Sciences
National Institutes of Health
U. S. Public Health Service
Department of Health and Human Services

GHS Classification	NICEATM Category 1 SubClass[1]	Substance	CASRN	In Vivo Data Source	Substance Source	Commercial Availability	Chemical Class	Product Class	Conc. Tested	Amount Tested[2]	Purity	MW	pH	Dermal Corrosivity	# of Animals Tested	Water Solubility	Log Kow	Color	Physical Form Tested	MMAS score	Corneal score	Iritis score
Category 1	4	beta-Resorcylic acid	89-86-1	ZEBET	n.a.	Sigma-Aldrich Corp.	Acid (organic) (carboxylic acid), Phenol	Chemical Intermediate, Dye	n.a.	0.1 mL or 100 mg	n.a.	154.1	?	?	1	?	?	?	solid	63.0	n=1/1, CO=4	-
Category 1	4	Sodium hydrogen sulfate	7681-38-1	ZEBET	n.a.	Sigma-Aldrich Corp.	Salt (inorganic)	Cleaning Agent, Laboratory Chemical, Pesticide	n.a.	0.1 mL or 100 mg	n.a.	120.1	?	?	1	?	?	?	solid	8.0	n=1/1, CO=4	-
Category 1	4	Sodium hydroxide	1310-73-2	ECETOC	Fisher Scientific International, Inc.	Sigma-Aldrich Corp.	Alkali	Caustic Agent, Chemical Intermediate, Industrial Chemical, Pharmaceutical Intermediate, Veterinary Chemical	10%	0.1 mL	Reagent Grade	40.0	13.7	R35 (5%)	1	soluble (1 g/0.9 mL)	"virtually 0"	?	liquid	108.0	n=1/1, CO=4	n=1/1, IR=2 D21
Category 1	4	Sodium oxalate	62-76-0	ECETOC	Sigma-Aldrich Corp.	Sigma-Aldrich Corp.	Acid (organic) (carboxylic acid)	Industrial Chemical, Laboratory Chemical	100%	100 mg	>99%	134.0	8.4	corrosive	3	soluble (37 g/L)	n.a.	?	solid	61.3	n=1/3, CO=4	n=1/3, IR=2 D14
Category 1	1	Sodium perborate tetrahydrate	10486-00-7	ECETOC	Dupont Corp.	Sigma-Aldrich Corp.	Boron Compound, Salt (inorganic)	Cleaning Agent	100%	60 mg	98.4%	153.9	10.0	noncorrosive	6	n.a.	n.a.	?	solid	20.5	n=4/6, CO>1 D21	-
Category 1	4	Di(2-ethylhexyl) sodium sulfosuccinate	98-09-9	NIHS-Ohno	Japanese Cosmetic Industry Assn.	Sigma-Aldrich Corp.	Ester, Salt (organic), Sulfur Compound (organic)	Adjuvant, Cleaner, Solubilizer, Wetting Agent	10%	0.1 mL	n.a.	444.6	6.5	noncorrosive	3	soluble (15 g/L)	n.a.	?	liquid	57.0	n=1/3, CO=4	-
Category 1	3	Dibenzoyl-L-tartaric acid	2743-38-6	ECETOC	n.a.	Sigma-Aldrich Corp.	Acid (organic) (carboxylic acid), Ester	Chemical Intermediate	100%	100 mg	98%	358.3	n.a.	noncorrosive	3	slightly soluble	n.a.	?	solid	36.7	n=3/3, CO=3	-
Category 1	4	Tetraethylene glycol diacrylate	17831-71-9	TSCA	Rhone-Poulenc, Inc.	Sigma-Aldrich Corp.	Ether, Nitro Compound	Chemical Intermediate, Industrial Chemical	100%	0.1 mL	n.a.	302.3	?	?	6	?	?	?	liquid	103.3	n=5/6, CO=4	n=6/6, IR=2 D14
Category 1	4	Tetrahydrofuran	109-99-9	TSCA	International Specialty Products Co.	Sigma-Aldrich Corp.	Ether, Heterocyclic Compound	Chemical Intermediate, Industrial Chemical, Pharmaceutical Intermediate, Solvent	100%	0.1 mL	n.a.	72.1	?	?	6	?	?	?	liquid	31.2	n=2/6, CO=4	-
Category 1	4	N,N,N',N'-Tetramethylhexanediamine	111-18-2	TSCA	Union Carbide Corp.	Sigma-Aldrich Corp.	Amine	Anti-Infective, Industrial Chemical, Laboratory Chemical	100%	0.005 mL	n.a.	172.3	?	?	6	?	?	?	liquid	96.0	n=6/6, CO=4	-
Category 1	0 (likely 4)	2-Nitro-4-thiocyanoaniline	54029-45-7	GSK	n.a.	Sigma-Aldrich Corp.	Amine, Nitro Compound, Sulfur Compound (organic)	Industrial Chemical	100%	0.1 mL or 100 mg	n.a.	195.2	?	?	1	?	?	?	solid	63.0	-	-
Category 1	1	TNO-35 (Propyl lactate)	616-09-1	TNO-Prinsen	n.a.	Cook Aromatics Ltd. (Bulk)	Alcohol, Ester	Cleaning Agent, Food Additive	n.a.	0.1 mL or 100 mg	n.a.	132.2	?	?	1	?	?	?	solid	63.0	n=1/1, CO>0 D21	n=1/1, IR>0 D21
Category 1	4	1,2,4-Triazole, sodium salt	41253-21-8	ECETOC	Elf Atochem, Inc.	Sigma-Aldrich Corp.	Heterocyclic Compound, Salt (organic)	Anti-Fungal	100%	400 mg	99%	91.1	n.a.	noncorrosive	1	soluble	n.a.	brown	solid	104.0	n=1/1, CO=4	n=1/1, IR=2
Category 1	4	Trichloroacetic acid	76-03-9	ECETOC	Fisher Scientific International, Inc.	Sigma-Aldrich Corp.	Acid (organic) (carboxylic acid)	Caustic Agent, Herbicide	30%	0.1 mL	Reagent Grade	163.4	0.7	R34 (0.6N); R35 (undiluted)	1	soluble (10 g/mL)	1.33	?	liquid	106.0	n=1/1, CO=4	n=1/1, IR=2 D21
Category 1	4	Trichloroacetyl chloride	76-02-8	TSCA	Rhone-Poulenc, Inc.	Sigma-Aldrich Corp.	Acyl Halide	Chemical Intermediate, Industrial Chemical	n.a.	0.1 mL	n.a.	163.4	?	?	4	?	?	?	liquid	71.0	n=4/4, CO=4	-
Category 1	4	Triton X-100	9002-93-1	TSCA	Union Carbide Corp.	Sigma-Aldrich Corp.	Ether	Surfactant (nonionic)	100%	0.1 mL	n.a.	250.4	n.a.	noncorrosive	6	soluble	n.a.	colorless	liquid	65.0	n=2/6, CO=4	-
Category 1(H)	-	Ammonia	7664-41-7	-	-	Sigma-Aldrich Corp.	Alkali	Anti-Fungal, Chemical Intermediate, Cleaning Agent, Fertilizer, Herbicide, Industrial Chemical, Refrigerant	-	-	-	17.0	-	-	-	n.a.	n.a.	?	Liquid	-	-	-
Category 1(H)	-	Chloroform	67-66-3	-	n.a.	Sigma-Aldrich Corp.	Hydrocarbon (acyclic)	Anesthetic, Chemical Intermediate, Cleaning Agent, Industrial Chemical, Pharmaceutical Intermediate, Solvent	-	-	-	119.4	-	-	-	n.a.	n.a.	?	liquid	-	-	-
Category 1(H)	-	Lime	1305-78-8	-	-	Sigma-Aldrich Corp.	Salt (inorganic)	Building Material, Chemical Intermediate, Cleaning Agent, Fertilizer, Industrial Chemical	-	-	-	56.1	-	-	-	n.a.	n.a.	white to grayish	solid	-	-	-
Category 1(H)	-	Magnesium hydroxide	12141-81-6	-	-	Sigma-Aldrich Corp.	Salt (inorganic)	Chemical Intermediate, Flame Retardant, Industrial Chemical, Pharmaceutical, Veterinary Agent	-	-	-	41.3	-	-	-	n.a.	n.a.	?	solid	-	-	-
Category 1(H)	-	Nitric acid	7697-37-2	-	-	Sigma-Aldrich Corp.	Acid, Salt (inorganic)	Chemical Intermediate, Industrial Chemical, Laboratory Reagent, Pharmaceutical Intermediate	-	-	-	63.0	-	-	-	n.a.	n.a.	colorless to yellow	liquid	-	-	-

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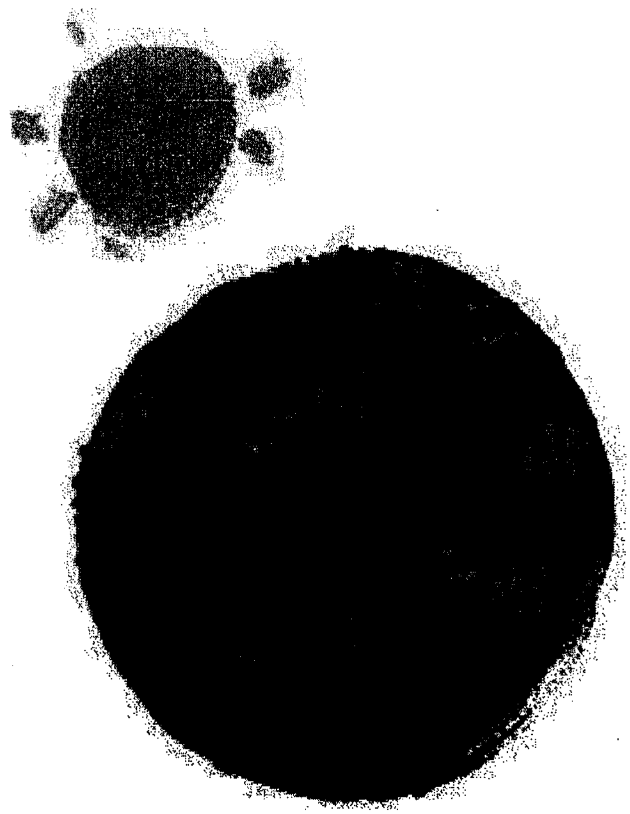
HTML

NIH Publication No: 06-4515



BACKGROUND REVIEW DOCUMENT

Current Status of *In Vitro* Test Methods for Identifying Ocular Corrosives and Severe Irritants:

Hen's Egg Test - Chorioallantoic Membrane Test Method

National Toxicology Program (NTP) Interagency Center for the Evaluation of
Alternative Toxicological Methods (NICEATM)

National Institute of Environmental Health Sciences
National Institutes of Health
U.S. Public Health Service
Department of Health and Human Services

Substance Name[1]	CASRN	Mean IS(B)-10 Score	IS(B)-10 SD	%CV for IS(B)-10	Mean IS(B)-100 Score	IS(B)-100 SD	%CV for IS(B)-100
Sodium sulfite	7757-83-7	12.25	1.34	10.97	14.20	2.69	18.92
Sodium cyanate	917-61-3	12.65	3.04	24.04	9.45	1.77	18.71
Sodium disilicate	13870-28-5	20.20	0.71	3.50	17.40	1.13	6.50
Sodium hydrogen sulfate	7681-38-1	17.75	1.48	8.37	18.65	0.78	4.17
Sodium lauryl ether sulfate	3088-31-1	14.10	5.09	36.11	18.45	0.78	4.22
Sodium monochloroacetate	3926-62-3	3.75	5.30	141.42	13.45	3.75	27.86
Sodiumpyrosulfite	7681-57-4	14.87	2.41	16.22	14.60	3.05	20.90
4-((2-Sulfatoethyl)sulfonyl)-aniline	2494-89-5	19.05	1.48	7.79	-	-	-
TA 01946 Alkylsilan		8.80	1.70	19.28	13.10	4.38	33.47
Theophylline sodium acetate	8002-89-9	9.40	5.66	60.18	-	-	-
Tocla		16.30	4.81	29.50	16.95	4.88	28.78
Triisooctylamine	25549-16-0	0.40	0.57	141.42	9.05	7.14	78.91
2,2,3-Trimethyl-3-cyclo-pentene-1-acetaldehyde	4501-58-0	2.60	0.42	16.32	12.20	3.54	28.98
Trioxane	110-88-3	11.33	2.93	25.91	17.90	0.14	0.79
Wessalith Slurry		6.57	4.86	74.00	9.90	8.20	82.85
Xanthinol nicotinate	437-74-1	7.65	5.16	67.48	13.20	5.94	45.00
Mean %CV Value				**60.17**			**35.21**
Median %CV Value				**42.65**			**26.22**
Range %CVs				**0-141.42**			**0-141.42**
Mean %CV Value (Minus Substances Tested in 3 Laboratories)				**58.07**			**34.62**
Median %CV Value (Minus Substances Tested in 3 Laboratories)				**31.85**			**21.57**
Range %CVs (Minus Substances Tested in 3 Laboratories)				**0-141.42**			**0-141.42**

Abbreviations: CV = coefficient of variation; CASRN = Chemical Abstract Service Registry Number.
[1]Italicized substances represent chemicals that were tested in three testing laboratories. Data for these substances were removed to determine their impact on the calculated %CV values for this data set.

Hagino et al. (1999) and Ohno et al. (1999): The Japanese Ministry of Health and Welfare evaluated the HET-CAM test method in five different laboratories as part of a validation effort to assess alternative ocular irritation test method. Nine, 15, and 14 cosmetic ingredients were evaluated in the first, second, and third steps of the validation study, respectively. These studies used the IS(A) analysis method to assess potential irritancy classifications. Average individual laboratory results and standard deviations for tested substances were reported in Hagino et al. (1999). **Appendix F2** provides the average IS(A) values for each testing laboratory for each substance evaluated in this validation effort.

Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing

T. Marsh Johnson[1] and Bernard Murphy[2]
Veterinary & Environmental Technical Solutions, PC[1]; Jones-Hamilton Co.[2]

Species: Poultry (broiler, layer & turkey), cattle, and horses
Use Area: Animal Housing
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Ammonia & Volatile Organic Carbons

Description:

Ammonia (NH_3), volatile organic compounds (VOCs) and greenhouse gases (GHG) of animal manure origin are produced by microbial activity on the nitrogen and carbon compounds not utilized by the animals for either maintenance or growth and excreted in the feces and /or urine (Carey, et al., 2004; Mutlu, et al. 2005). The release of ammonia from animal manure is dependent upon the amount of ammoniacal nitrogen present, pH, surface area, temperature, and the amount of urease present (Mutlu, et al., 2005; Gay and Knowlton, 2005). Therefore, for any emissions intervention to be effective, it must exploit at least one of these avenues to prevent NH_3 release into the atmosphere (Jongebreur and Monteny, 2001). VOCs are mostly derived from the bacterial degradation of manures soon after excretion (Mitloehner, 2005). Decreasing the bacterial activity in freshly excreted manures should then reduce the production & subsequent emissions of VOCs.

Ammonia emission from animal housing is calculated by multiplying ammonia concentration by airflow. Research and extensive commercial application show that the use of Sodium Bisulfate reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. The amount of emissions reduction can be tailored to a specific location by varying the rate, timing, and surface area of SBS application. Other documented benefits are as follow:

- Fuel savings through reduced ventilation
- Improved bird performance i.e. weight, feed conversion, and livability
- Improved animal welfare through better air quality and paw quality
- Reduced respiratory lesions
- Reduced Salmonella & campylobacter incidence of broilers
- Fly control in layer, equine, and calf housing
- Reduction in environmental mastitis
- Substantial return on investment.

Mitigation Mechanism:

Sodium bisulfate (SBS) is a dry, granular acid salt that has been used for many years as a pH reducer in a variety of agricultural, industrial, and food applications. The anti-bacterial properties of sodium bisulfate have been exploited in its application as a toilet-bowl sanitizer (i.e. EPA Reg. #1913-24-AA) and as a preservative in EPA method #5035 "Closed-System Purge-and-Trap & Extraction for Volatile Organics in Soil & Waste Samples," to prevent microbial activity leading to VOC release. These properties along with the safety and ease of use of SBS have led to its use for ammonia binding (Fig.1) and bacterial reduction in poultry, dairy, and equine manure and bedding materials (Ullman, et al., 2004; Blake and Hess, 2001; Sweeney, et al., 1996; Harper, 2002). The use of SBS reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. Sodium bisulfate is hygroscopic. As water is adsorbed into the SBS bead from the humidity in the air, the SBS is dissolved into its Na^+, H^+, and $SO_4^=$ constituents.

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

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

The hydrogen ion reduces the pH of the litter and protonates the ammonia molecule. The resulting ammonium is then bound by the sulfate component. This formation of ammonium sulfate is non reversible therefore the nitrogen in the litter is not released as the pH increases (Ullman, et al., 2004). The sodium and hydrogen ions of SBS exert negative pressure on the bacterial populations of the litter; decreasing total aerobic population counts 2-3 logs (Pope and Cherry, 2000). This may also serve to decrease urease concentration in the litter for additional ammonia reductions

(Ullman, et al., 2004). Once the ammonia concentration at bird level has been reduced, the poultry houses can be minimally ventilated for relative humidity control as they were designed rather than over-ventilated for NH_3 removal (Czarick and Lacey, 1998). In an ongoing emissions study being conducted at North Carolina State University, the value of whole house application and higher rates of application of SBS on reducing emissions are being demonstrated. In houses using an industry standard rate of 75-lbs/1000 sqft, emissions from brood chamber only application totaled 32.52 kg-NH3 per house for the 14 day brooding period compared to 23.96 kg-NH3 for a whole house application at the same rate for the same time period. Houses receiving 150-lbs of SBS per 1000 sqft in a whole house application had an average total emission for the 14-day brooding period of only 4.9-kg of ammonia.

Applicability:

Sodium bisulfate is suited to a wide variety of animal housing types. SBS has been used successfully in commercial applications in dry litter in both broiler, turkey, and layer facilities, deep bedding of horses, swine, and cattle, and free-stall and dry lot dairy housing systems. Due to the safety of SBS, it can be broadcast in the presence of animals at any time during production unlike most other amendments. This flexibility allows for each operation to tailor SBS usage rate and application timing to meet its unique needs. Any application scheme of SBS will reduce interior ammonia and ventilation rates, thereby reducing ammonia emissions. Specific application rates and application timing are necessary for reduction of food-borne pathogens and fly control purposes.

Reduction of ambient ammonia levels in broiler housing has been demonstrated in a variety of studies. Ammonia levels were 90% lower post PLT application with an average of 6.2 PPM of NH_3 in the treated houses and 62.3 PPM in the control houses. Two weeks after application, the ammonia levels in the treated houses were still reduced by 50% compared to control houses. Two hundred commercial broiler houses were studied in Delaware and Maryland by Terzich (1997) with 100 houses treated with PLT® and 100 houses serving as control. Ammonia levels averaged 127 PPM pre-treatment and were all 0 PPM post-treatment (Table 1). Consequent to the improved air quality, bird performance was significantly improved in the treated houses with better mortality rates, average weights, average daily gain, and percentage of respiratory lesions at processing compared to controls. Fuel usage was also reported to be 43% less in the treated houses. At a cost of $120/house for the PLT® litter treatment, the resulting production increases and fuel savings provided the producer with a substantial return on investment that would support increased

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

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

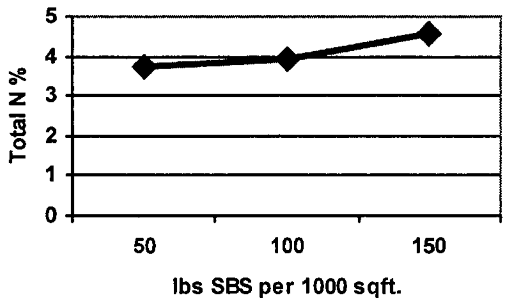
PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998; Terzich et al, Apr 1998).

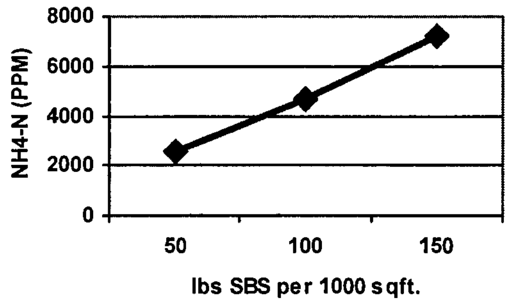
By converting ammonia into ammonium sulfate, the use of SBS increases fertilizer value of litter and displaces phosphorus resulting in improved nitrogen to phosphorus ratio. In a study at the University of Georgia, a linear increase is evident in both N and NH_4-N retained in the litter as the amount of PLT applied is increased (Fig. 3 & 4).

Similar results were observed in a commercial egg layer high-rise house where the higher rate of PLT showed the most consistent decrease in ammonia emissions (Patterson et al, 2006). As in the UGA study, manure ammonium (NH_4^+) nitrogen and P_2O_5 were positively altered by treatment group with the high-rate treatment group having the highest level of retained nitrogen and the lowest level of P_2O_5 (table 2).

Limitations:

Sodium bisulfate is only limited by the amount of product applied. Because of the hygroscopic nature of SBS, greater longevity of ammonia reductions will occur at interior housing humidity of 75% or less. This is consistent with the normal and proper ventilation of poultry houses for relative humidity control.





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

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

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

Cost:

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

A commercial broiler complex in the Southeast raising both a large (7.0 lb. or 3.2 kg) and small (4.5 lb. or 2.05 kg) bird evaluated the economic and performance benefits of using litter amendments from January – August 2000. Contract growers were given a choice of either using PLT® or an alum litter amendment (Al+Clear, General Chemical Corp., Parsippany, NJ) at the rate of 2.27 kg/9.29m² (50 lbs. /1000 sq ft) in the brood chamber (10,000 sq ft). Eighty-seven percent of the big bird growers and eighty-two percent of small bird growers chose PLT. The remaining thirteen percent of the big-bird and eighteen percent of the small-bird growers chose to use alum in an identical manner to the PLT. A total of 43.9 million birds were evaluated in this demonstration. The variety of housing and management types were similar between the treatment groups. Both the small and large bird groups raised on PLT substantially out performed the birds raised on alum (table3). In a complex of this size, the general rule of thumb used in the U.S. poultry industry is that an improvement in feed conversion of 0.01 lbs. of weight gain / lb. of feed consumption is worth $1 Million per year (Agrimetrics Associates, Inc., Midlothian, VA). The large birds raised on PLT had a feed conversion improved by 0.02 and the feed conversion of the small birds was improved by 0.04 over the birds raised on alum. This reduced performance shown by the birds raised on alum is consistent with production losses due to ammonia exposure reported in the literature (Miles, et al., 2004). This resulted in a net return of $2.7 million /yr over the cost of PLT ($305,000) on improved feed conversion alone in that complex. Additional economic benefit would have also been realized by the grower and the poultry integrator from the increases in weight and livability observed in this trial. Similar results were achieved in another complex in the South-Central part of the U.S. where the same rate of PLT application was compared with untreated litter (table 4). The economic viability of the use of PLT for reducing ammonia emissions is the reason why so many poultry growers have voluntarily adopted this BMP.

Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial additional return on investment.

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

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

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

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

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

Implementation:

The rate and timing of SBS application are dependent upon the type of housing to be treated, the age of the bedding material in the house, and the age of the animals being housed. Application rates begin at 0.32 kg/m^2 (50-lbs/1000 sqft) for new bedding and litter up to 3-4 flocks old. As the bedding material ages or the manure load increases, the application rate is increased accordingly. Rates of 0.64-0.96 kg/m^2 (100-150-lbs/1000 sqft) are commonly used in commercial field applications. The two drivers of ammonia release from the litter or bedding material are temperature and surface area. Because there is no choice but to have the proper floor temperatures to brood chicks, surface area of the litter particles needs to be minimized to reduce ammonia release from the litter. The amount of SBS needed for a particular grow-out is dependent on the amount of ammonia in the litter and how readily that ammonia is released. The older the birds raised on a farm and the higher the number of flocks raised on the litter, the more fecal material that is present. In other words, 3 flock litter from a house of 45-day-old 1.8-kg birds will have much less ammonia in it than 3 flock litter from a house of 4.2-kg roasters. Also, litter that has been aggressively handled and has maximum surface area will release far more ammonia than litter that has been crusted correctly. Because the amount of amendment used has to be matched to the ammonia load in a particular location, it is important to follow the manufacturer's recommendations when deciding upon the correct rate to use for a specific location and animal type.

In poultry housing, SBS is routinely applied prior to bird placement using a broadcast spreader of some type. Both professional application with a truck mounted spreader and hand application with a push spreader are used depending on farmer preference. Applications in the presence of animals are often done for bacterial or fly control purposes. Because of the safety and efficacy of SBS, producers have maximum flexibility to meet their needs.

Technology Summary:

Sodium bisulfate reduces ammonia and VOC emissions from animal housing areas. SBS binds ammonia converting it to ammonium sulfate thereby retaining nitrogen and increasing fertilizer value of the litter. Total phosphorus is reduced through dilution. Fuel savings and increased animal performance and welfare are realized allowing the mitigation to pay for itself. Research and commercial field studies indicate a 60-90% reduction of ammonia flux form the bedding surface. Application rates vary from 0.32-1.95 kg/m2 depending on the litter age and concentration of manure in the bedding. Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial return on investment. Additional benefits include reduced incidence of food-borne pathogens, fewer respiratory lesions and ascites, and improved paw quality.

Additional Resources:

SBS & Horses http://www3.vet.upenn.edu/labs/equinebehavior/publixs/Papers/96effect.pdf
Ammonia & Foals http://animalscience.ag.utk.edu/horses/pdf/foalammo.pdf
Sodium Bisulfate as a Litter Treatment http://www.aces.edu/pubs/docs/A/ANR-1208/

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Point of Contact:

Dr. Bernard Murphy
Jones-Hamilton Co.
[illegible] Tracy Road
Walbridge, OH 43465
[illegible]-379-2243
[illegible]@jones-hamilton.com

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PRODUCTION, MODELING, AND EDUCATION

The Use of Refused Tea as Litter Material for Broiler Chickens

N. S. B. M. Atapattu[1] and K. P. Wickramasinghe

Department of Animal Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka

ABSTRACT A completely randomized design experiment was conducted to determine the suitability of refused tea (RT) as a litter material for broiler chickens. Physiochemical properties of RT were compared with paddy husk (PH). Subsequently, broilers were raised on RT- or PH-based litter to compare the performances and litter qualities. Twenty-day-old broiler chicks (n = 150) were randomly allocated into 6 deep litter pens so that each treatment had 3 replicates. Chicks received 0.8 ft^2 of floor spacing until d 28 and 1.3 ft^2 thereafter. Each cage had a feeder and a drinker. Litter materials and litter samples taken on 28, 35, and 39 d were analyzed for bulk density, moisture, ash, and N. Chick mortality was low (1.3%) and similar on 2 types of litters. Live weights on d 28, 35, 39, and weight gains, feed intakes, dressing percentages, and feed conversion ratios were not affected by the type of litter material. The bulk density, moisture level, and pH of the RT were comparable with PH. Even though the water-holding capacity of PH (213%) was significantly higher ($P < 0.01$) than RT (70%), the latter material had significantly higher ($P < 0.01$) water-releasing capacity compared with the former (17.9 vs. 13.6%). Throughout the experiment the RT litter had around 10% units higher moisture level than PH litter. By d 39, the moisture content of the RT litter was (48%) significantly higher ($P = 0.05$) than PH litter (37%). The N contents of RT litter were higher ($P < 0.05$) than those of PH on d 28, 35, and 39, being 8.1, 7.8, and 7% and 3.4, 3.6, and 3%, respectively. It was concluded that RT could be successfully used as an alternative litter material for broilers. A higher N content in RT-based spent broiler litter would make it be a better organic fertilizer and ruminant feed compared with PH-based litter.

Key words: litter, paddy husk, refused tea

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INTRODUCTION

The deep litter system is probably the most popular broiler management system throughout the world. The suitability of a range of materials such as wood shavings (Brake et al., 1992), shredded paper (Griffith, 1993), saw dust, corn cobs (Chaloupka et al., 1967), recycled paper (Lien et al., 1992), paddy husk (Hester et al., 1985, 1987), refined gypsum (Wyatt and Goodman, 1992), and leaves (Willis et al., 1997) as litter materials for poultry has been studied. The quality of litter material directly affects the performance, health, carcass quality, and welfare of the poultry (Malone et al., 1982, 1983; Malone and Chaloupka, 1983; Veltman et al., 1984). An ideal litter material should be dry with higher water-holding capacity (**WHC**) but should also be able to release the absorbed moisture quickly. Under Sri Lankan conditions, paddy husk (**PH**) is the most widely used litter material for poultry. The physiochemical properties of PH make it an ideal litter material, and performance trials have also shown that PH to be the best litter material for poultry [http://www.agric.nsw.gov.au/reader/poultry/alt-litter (last accessed Dec. 2006)]. In Sri Lanka, in recent years, PH has become a highly sought material by many other industries to be used as a fuel. Consequently, in many areas of the country, poultry farmers find it increasingly difficult to get PH to be used as a litter material. The price of PH is also rising, incurring an additional cost on farmers. In this context, alternative litter materials for poultry industry are important. Refused tea (**RT**) or tea waste is a by-product of black tea processing. Generally, 4 to 5 kg of RT is produced for every 100 kg of green leaves processed. Annual RT production of Sri Lanka is estimated to be around 20 to 25 million tonnes (Tea Research Institute of Sri Lanka, 2004). The objective of the present study was to determine the suitability of RT as a litter material for broilers.

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[1]Corresponding author: Mahindaatapattu1@yahoo.com

MATERIALS AND METHODS

Chick Performance Assay

One-day-old broiler chicks were purchased from a local commercial hatchery. Chicks were brooded on an electric floor brooder for 2 wk and were fed with a commercial broiler starter diet (Nutrina Feeds, Sri Lanka) until they were 20 d old. The PH and RT litters were randomly allocated to 6 cages, resulting in 3 replicates per treatment. On d 20, chicks were individually weighed and allocated into 6 deep litter cages so that between cage weight variation was minimum. Each cage housed 25 birds. Each cage had a feeder and a bell-shaped drinker. A commercial broiler finisher diet (Nutrina Feeds) was fed from d 21 to 39. From d 21 to 28 chicks were given 0.8 ft^2 of floor space per chick and 1.3 ft^2 thereafter. Ad libitum feeding and watering was done every day. Lighting was continuous. Chicks were weighed on d 28, 35, and 39 and killed on d 40. Three birds were randomly selected from each cage for manual processing. Crop contents were examined for the presence of RT or PH particles. Weights of the liver and gizzard and dressed carcasses were recorded.

Litter Materials and Sample Analysis

The RT was obtained from a local tea factory. The RT and PH samples were analyzed for moisture content, pH, WHC, and bulk density (**BD**) by using methods adopted by Brake et al. (1992). The WHC was expressed on a fresh matter basis. To determine the water-releasing capacity, each litter material was placed in pans at 3 cm of depth. Then pans were filled with water and allowed to stand for 30 min. After draining the excess water for 3 min, the weights of the litter samples were determined. Then, the pans were weighed 1.5, 3, 4.5, and 24 h after draining. Moisture loss at each time point was expressed as a percentage of the initial wet weight of the sample. Three random litter samples were taken from each cage on d 28, 35, and 39. The BD (Brake et al., 1992), moisture content (at 105°C for 24 h), ash (at 550°C for 12 h), and N (AOAC 1990) were determined.

Statistical Analysis

Data were analyzed by using GLM procedure of Minitab Inc. (11.12, State College, PA). Performance criteria [live weight, weight gain, feed intake, and feed conversion ratio] and total litter production data were analyzed using pen means as replicates. For carcass and litter quality data analysis there were 9 replicates each, resulting from 3 randomly selected litter samples from each cage, respectively. Effects were considered statistically significant when $P < 0.05$.

RESULTS AND DISCUSSION

Physiochemical Properties

The particle size, freedom from dust, BD, thermal conductivity, drying rate, and compressibility make the PH an ideal litter material for poultry. Performance trials have also shown PH as the best litter material for broilers [http://www.agric.nsw.gov.au/reader/poultry/alt-litter (last accessed Dec. 2006)]. Therefore the physiochemical properties of RT and the performance of the broilers on RT-based litter and the properties of the litter were compared with those of PH. Physiochemical properties of RT and PH are given in Table 1. Bulk density of RT (84 kg/m^3) was not significantly different from PH (94 kg/m^3). Bulk densities of PH and RT were lower than the bulk densities of other litter materials such as pine wood shaving (192 kg/m^3) and hard wood bark (403 kg/m^3; Brake et al., 1992). Low BD of these materials indirectly reflect the high porosity and thus are conducive for better water-holding ability, air circulation through the litter, and release of moisture.

Table 1. Comparison of some physiochemical properties of paddy husk (PH) and refused tea (RT)

	Litter type		
Item[1]	PH	RT	ANOVA
Bulk density (kg/m^3)	97 ± 0.9	84 ± 0.9	NS
Moisture (%)	10.3 ± 0.9	12.6 ± 1.6	NS
WHC (%)	213 ± 18	70 ± 8	NS
WRC (%)			
1.5 h	1.3 ± 0.4	1.5 ± 0.3	NS
3 h	2.5 ± 0.5	3.1 ± 0.5	*
4.5 h	3.7 ± 0.3	6.4 ± 0.5	*
24 h	13.6 ± 0.8	17.9 ± 0.7	**
pH	6.1	6.3	
N (%)	0.37 ± 0.04	0.69 ± 0.07	***
Ash (%)	0.36 ± 0.02	0.21 ± 0.04	**

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[1]WHC =water-holding capacity; WRC = water-releasing capacity.

The moisture content of the RT (12.6%) was comparable with that of PH (10.3%). An ideal litter material should not have too high a moisture level because it would increase the risk of pathogenic microbial growth and increases the ammonia production (Carlile, 1984). Due to increased dustiness, too dry litter materials make the poultry more susceptible to respiratory diseases. The pH of the RT (6.3) was also not statistically different from that of PH (6.1). For a litter material, it is an added advantage to have a lower pH level because the conversion of excretory uric acid into ammonia is reduced at acidic pH levels (Moore et al., 1996).

Ruszler and Carson (1974) pointed out that moisture-releasing capacity was the most important characteristic in the evaluation of litter materials, whereas Molone et al. (1982) concluded that moisture absorbability was more important. Moisture absorbability and the moisture-releasing capacity of PH and RT were different. The WHC of PH (213%) was around 3 times higher than that of RT (70%) and significantly ($P < 0.001$) higher. This is contrary to the findings of Ruszler and Carson (1968) who found that litter materials with smaller particle size absorbed less moisture than larger litter materials. Obviously, not only the particle size, but also the other physiochemical properties may affect the WHC of litter materials. Contrary to WHC, water-releasing capacity of RT (17.9%) was significantly higher than that of PH (13.6%). An ideal litter material should be able to absorb the moisture of the feces and spilled water from the drinkers. Also, it should be able to release the absorbed moisture quickly to prevent the litter getting too wet. As discussed later (Table 2), the moisture content of the RT-based litter was

Table 2. Growth performers of broiler chicks reared on paddy husk (PH) or refused tea (RT) litter from d 21 to 39 and the properties of the litter

Item	Litter type		ANOVA
	PH	RT	
Growth performance			
Mortality (%)	1.3	1.3	
Live weight (g)			
D 21	635 ± 16	643 ± 26	NS
D 39	2,058 ± 116	2,012 ± 76	NS
Weight gain (g)	1,422 ± 106	1,369 ± 63	NS
Feed intake (g/d)	139 ± 7	133 ± 10	NS
Feed conversion ratio	1.80 ± 0.12	1.78 ± 0.01	NS
Water intake[1] (mL/d)	380 ± 134	353 ± 161	NS
Water:feed	3.1 ± 0.2	2.9 ± 0.23	NS
Litter quality			
Bulk density (kg/m^3)			
D 28	188 ± 2	140 ± 1	NS
D 35	240 ± 4	220 ± 9	NS
D 39	210 ± 0.07	180 ± 3	NS
Litter weight (kg)			
D 21	18	22	NS
D 39	46 ± 8	41 ± 11	NS
Litter weight/kg of LW	0.92 ± 0.28	0.82 ± 0.12	NS
Litter moisture (%)			
D 28	45 ± 5.7	51 ± 6	NS
D 35	42 ± 5.7	51.6 ± 2.3	NS
D 39	37 ± 4	48 ± 5	*
Litter ash (%)			
D 28	0.98 ± 0.2	0.48 ± 0.1	*
D 35	1.1 ± 0.4	0.6 ± 0.1	NS
D 39	1.5 ± 0.2	0.62 ± 0.3	*
Litter N (%; DM basis)			
D 28	3.4 ± 0.8	8.1 ± 0.55	**
D 35	3.6 ± 0.3	7.8 ± 0.7	*
D 39	3.5 ± 0.6	7.00 ± 0.5	*

[1]From d 35 to 39.

*$P<0.05$; **$P < 0.01$; ***$P < 0.001$.

significantly higher than that of PH. This indicates that higher water-releasing capacity of RT has not been effective in maintaining a lower litter moisture level when it was used as a litter material. Litter caking was increased with RT compared with PH. This feature may probably have reduced the release of moisture by evaporation and explains why RT-based litter contained more moisture though the water-releasing capacity was higher than that of PH.

Performance of the broiler chicks raised on PH- or RT-based litters is shown in Table 2. Chick mortality in each treatment (1.3%) was within acceptable limits. Several authors (Malone et al., 1983; Peacock et al., 1984; Brake et al., 1992) have found that broiler chicks ate smaller litter materials like saw dust. We also found a few RT particles in the crop contents of 2 chicks dissected on d 40. Higher particle size might have limited the consumption of RT. Wyatt and Goodman (1992) also found that broiler chicks did not eat fir wood shaving.

None of the growth parameters were statistically different ($P > 0.05$) between the treatments. The weight, weight gain, feed intake, and feed conversion ratio values of the chicks raised on RT-based litter were comparable with those of PH at each growth stage. Several other studies (Peacock et al., 1984; Brake et al., 1992; Lien et al., 1992; Wyatt and Goodman, 1992) have also found that growth performances were not affected by the litter types such as recycled paper, pine shaving, refined gypsum, and hardwood bark. No clear health abnormalities or behavioral differences were observed between the chicks raised on 2 types of litter materials.

Dressing percentage and the weight of the liver and gizzard were also not affected by the type of litter. No carcass grading was done in the present experiment. However, there were no clear visible abnormalities of the carcasses of the broilers raised on RT. Our findings are in agreement with those of Brake et al. (1992), Lien et al. (1992), and Willis et al. (1997).

Water intake was also not affected by the type of the litter used. However, in general the water intake per bird and per unit weight of the feed ingested were higher than the values reported by NRC (1994). We used bell-drinkers to provide water. Nicholson et al. (2004) showed that spillage of water from bell drinkers was higher than from nipple drinkers. Also, the higher ambient temperature and high relative humidity might have increased the actual water intake. In some previous experiments conducted in our laboratory under hot humid conditions, we (Atapattu and Gamage, 2006) have found comparatively higher water intake values for broilers. Water:feed ration was also not affected by the type of litter but was higher than typical values reported by NRC (1994).

Litter Characters

Though the performance and carcass characters were not significantly affected by the type of litter used, the characters of 2 types of litters were significantly different with respect to several important parameters (Table 2). The BD of the 2 types of litters were increased until d 35 and then declined. No significant difference in BD was observed between 2 litters at any time of the experiment, and throughout the experiment the BD of PH litter was higher than that of RT. It must be noted that BD of the PH before being used as a litter was higher than RT. This may be due to higher silica contents of the PH. The total litter production and litter production per kilogram of live weight produced were also not significantly affected by the kind of litter used. In general, approximately 1 kg of litter was produced from d 21 to 40, per kilogram of live weight.

Throughout the 19-d experimental period, the moisture level of RT-based litter was higher than that of PH-based litter. On d 28, the moisture levels of 2 litters were not significantly different, though RT-based litter had higher moisture level. By d 35, there was a trend to have (P = 0.07) higher moisture level in RT litter. By d 39, the moisture level in RT litter was higher (P = 0.05) than PH-based litter.

The reported moisture contents of various kinds of litters vary widely. For example, Wyatt and Goodman (1992) found as low as 6.5% litter moisture level when recycled gypsum was used as a litter material, whereas Brake et al. (1992) reported high moisture level as 44% for pine shaving litter. Compared with our findings, Andrew and McPherson (1963) reported lower (34%) moisture level in PH litter after 8 wk of growing period. Carr et al. (1990) recommended that it is desirable to maintain litter moisture below 30% for ammonia control. The high litter moisture levels we observed may be attributed to several factors. The use of bell-shaped drinkers as observed by Nicholson et al. (2004) has increased the water spillage from drinkers and the litter moisture levels. The water intake was also high in this experiment, probably due to high ambient temperature and relative humidity. At the same time humid conditions might have reduced drying capacity of the litters.

Because the drying capacity of RT was significantly higher than PH, it was expected that RT litter would dry more quickly than PH. However, the moisture levels of the 2 types of litter suggest that it was not the case. It was observed that the litter cake formation in RT litter was higher than PH-based litter. Consequently, frequent raking was required to minimize the cake formation in RT litter. Formation of cakes might have reduced the air circulation through the RT particles and reduced the release of moisture.

The moisture level (Malone et al., 1982) as well as the physical appearance of the material (Lien et al., 1992) affect the degree of litter cake formation. The RT, being longer and more fibrous than PH, can form cake easily. However, as suggested by Lien et al. (1992), although RT-based litter contains more moisture and tends to form more cakes, it may still be used as an alternative litter material because RT did not affect the broiler performance and health.

Apart from the N contained in the litter material, the litter is enriched with N due to excretory N as well as feed spillage. Meanwhile, a part of litter N is continuously converted to ammonia and lost to the atmosphere. The N content of RT (0.69% on dry matter basis) was significantly higher ($P < 0.001$) than the N content of PH (0.39%). Wijesekara (2004) reported that N content of RT could be as high as 1.7%. The N contents of the RT-based litter on d 28, 35, and 39 were 8.1, 7.8, and 7.1%, respectively. The respective values for PH-based litter were 3.4, 3.6, and 3.5%, which were significantly lower than RT-based litter. Over the 19-d broiler rearing period, the N content of PH was increased 9.45-fold (from 0.37 to 3.5%), whereas the N content of RT increased 10.14-fold from 0.69 to 7%. Higher litter moisture levels promote the loss of N as ammonia (Moore et al., 1996). Because RT-based litter contained higher litter moisture levels throughout the experiment, the litter N level of RT-based litter would have been low compared with that of PH-based litter. However, that was not the case in the present experiment. We assume that it may be a possibility that RT binds some ammonia, preventing volatilization. Further investigations are in progress in our laboratory to test this hypothesis.

The N content of PH-based litter was lower than the typical litter N level (0.45%) reported by Elwinger and Svensson (1996). Interestingly, throughout the experiment, the N content of the RT-based litter was at least 1.6 times higher than the N level reported by Elwenger and Svensson (1996). Spent poultry litter is widely used as an organic fertilizer and as a ruminant feed resource. It is concluded that RT could successfully be used as an alternative litter material for broilers. Having higher N content than conventional litter materials, the value of RT-based spent poultry litter as an organic fertilizer and ruminant feed may be higher.

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Poult Sci. 2007 May;86(5):968-72.

The use of refused tea as litter material for broiler chickens.

Atapattu NS[1], Wickramasinghe KP.

Author information

Abstract

A completely randomized design experiment was conducted to determine the suitability of refused tea (RT) as a litter material for broiler chickens. Physiochemical properties of RT were compared with paddy husk (PH). Subsequently, broilers were raised on RT- or PH-based litter to compare the performances and litter qualities. Twenty-day-old broiler chicks (n = 150) were randomly allocated into 6 deep litter pens so that each treatment had 3 replicates. Chicks received 0.8 ft(2) of floor spacing until d 28 and 1.3 ft(2) thereafter. Each cage had a feeder and a drinker. Litter materials and litter samples taken on 28, 35, and 39 d were analyzed for bulk density, moisture, ash, and N. Chick mortality was low (1.3%) and similar on 2 types of litters. Live weights on d 28, 35, 39, and weight gains, feed intakes, dressing percentages, and feed conversion ratios were not affected by the type of litter material. The bulk density, moisture level, and pH of the RT were comparable with PH. Even though the water-holding capacity of PH (213%) was significantly higher ($P < 0.01$) than RT (70%), the latter material had significantly higher ($P < 0.01$) water-releasing capacity compared with the former (17.9 vs. 13.6%). Throughout the experiment the RT litter had around 10% units higher moisture level than PH litter. By d 39, the moisture content of the RT litter was (48%) significantly higher ($P = 0.05$) than PH litter (37%). The N contents of RT litter were higher ($P < 0.05$) than those of PH on d 28, 35, and 39, being 8.1, 7.8, and 7% and 3.4, 3.6, and 3%, respectively. It was concluded that RT could be successfully used as an alternative litter material for broilers. A higher N content in RT-based spent broiler litter would make it be a better organic fertilizer and ruminant feed compared with PH-based litter.

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Comparison of ammonia emission rates from three types of broiler litters.

Atapattu NS[1], Senaratna D, Belpagodagamage UD.

Author information

Abstract

The objective of this study was to compare the emission of NH(3) from 3 types of broiler litters. Three litter materials (refused tea, RT; sawdust, SDT; and paddy husk, PH) were randomly assigned into 18 cages. Twenty-day-old broiler chicks (n = 216) were randomly allocated into cages and were fed a commercial broiler finisher diet from 21 to 42 d. Three litter samples were taken from each cage on 36 and 42 d. Three subsamples taken from each cage were pooled and analyzed for moisture, pH, and N. Litter samples were incubated for 5 h, and the emitted NH(3) was trapped with boric acid and then titrated with HCl to determine the NH(3) emissions. The emission of NH(3) from RT litter (13.2 mg/kg of litter per h) on d 36 was 61% less than that from SDT and PH. The NH(3) emission rate of RT litter on d 42 (13.0 mg/kg per h) was very similar to that on d 36 (13.2 mg/kg per h). However, emission rates of SDT and PH on d 36 increased by 57.8 and 33%, respectively, when determined on d 42. Emission of NH(3) from RT litter on d 42 (13.0 mg/kg per h) was significantly (P < 0.05) less than that from SDT (54 mg/kg per h) and PH (44 mg/kg per h) litters. When the emission rate was computed as grams of NH(3)/hour/animal unit (AU), the emission rates of RT litter on d 36 (3.4 g/h per AU) and 42 (5.1 g/h per AU) were significantly (P <

0.05) less than that of SDT and PH. The N contents of the RT litter on 36 and 42 d were 6.6 and 6.7%, respectively, and were significantly ($P < 0.001$) greater than the respective values of SDT and PH. It was concluded that emission of NH_3 from poultry houses could be reduced substantially by using RT as a litter material.

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Effectiveness of Litter Treatments for Reduction of Ammonia Volatilization in Broiler Production

J.P. Blake, J.B. Hess, and K.S. Macklin
Department of Poultry Science, Auburn University

Species: Poultry (Broiler)
Use Area: Animal Housing
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Ammonia

Description:

In commercial broiler production, a little over one ton of litter is produced per 1,000 birds and during the course of a year this could lead to 125 tons produced per 20,000 bird house. Built-up litter propagates higher in-house ammonia levels, which can adversely affect poultry health by making the birds more susceptible to respiratory diseases. Techniques to reduce ammonia levels and pathogenic microbes include changes in management practices and use of litter treatments. Most litter treatments are typically effective for only 3-4 weeks; whereas, broilers are housed for six or more weeks prior to slaughter. Information to be presented summarizes a series of experiments that evaluated six litter treatment strategies applied at three levels in reducing ammonia volatilization during broiler production: Poultry Litter Treatment (PLT™), granulated aluminum sulfate (Al-Clear™), Poultry Guard™, hydrated lime, liquid acidified aluminum sulfate (A-7™), and concentrated sulfuric acid.

Mitigation Mechanism:

Interest in the use of litter treatments has steadily increased over the last decade as growers and technical personnel alike recognize the health and productivity benefits of improving the broiler house environment. It is known that high ammonia levels make birds more susceptible to respiratory diseases. Numerous laboratory and field studies have shown how ammonia levels as low as 10 ppm affect bird health and performance (Carlile, 1984). Ammonia levels above 25 ppm in the poultry house can damage the bird's respiratory system and allow infectious agents to become established, leading to declining flock health and performance. Resistance to respiratory disease may be decreased and *E. coli* bacteria can be significantly increased in the lungs, air sacs and livers of birds exposed to ammonia because of damage that occurs to the tracheal cilia. In addition, body weight, feed efficiency and condemnation rate may be compromised in birds exposed to levels of ammonia exceeding 10 ppm.

Most litter treatments used in the broiler industry involve chemical reduction of litter pH so that bacteria associated with ammonia release are either inactivated, reduced in number or both. The volatilization of ammonia has been attributed to microbial decomposition of nitrogenous compounds, principally uric acid, in poultry house litter. Once formed, free ammonia will be in one of two forms: as the uncharged form of NH_3 (ammonia) or the ammonium ion (NH_4), depending on litter pH. Ammonia volatilization remains low when litter pH is below 7.0, but can be substantial when above 8.0. Uric acid decomposition is most favored under alkaline (pH>7) conditions. Uricase, the enzyme that catalyzes uric acid breakdown, has maximum activity at a pH of 9. As a result, uric acid breakdown decreases linearly for more acid than alkaline pH values. One principal ureolytic bacterium, *Bacillus pasteurii*, cannot grow at neutral pH, but thrives in litter above pH 8.5. Typically, litter pH in a broiler house ranges between 9-10.

Gaseous emission of NH_3 can be inhibited if converted to NH_4^+ (ammonium); which can be accomplished by lowering litter pH. In general, an effective litter treatment results in the production of hydrogen ions (H^+) when it dissolves and the hydrogen ions produced by this reaction will attach to ammonia to form ammonium, which further reacts with sulfate ions to form ammonium sulfate $(NH_4)_2SO_4$. Ammonium sulfate is a water-soluble fertilizer. As a result of these acid-based reactions, the amount of ammonia emitted from the litter will be reduced; which should increase the nitrogen (N) content of the litter.

Applicability:

The main goal in using a litter treatment is to effectively reduce ammonia emissions from poultry facilities, which will have a direct effect on improving litter management, nutrient enrichment, and reducing ammonia volatilization from poultry house litter. Recent research completed in the Department of Poultry Science at Auburn University has focused on a series of litter treatment experiments to evaluate six litter treatments at three application levels to evaluate their ability to prolong litter usage and to reduce ammonia volatilization and pathogenic microorganisms associated with this material. Poultry Litter Treatment (PLT™), granulated aluminum sulfate (Al-Clear™) (GA), Poultry Guard™ (PG), and Hydrated Lime (HL), were applied at 24.4, 48.8, or 73.2 kg/100 m^2 (50, 100, or 150 lbs/1000 ft^2); a liquid acidified aluminum sulfate (A-7™) (LA), was applied at 81.4, 162.8, and 227.1 L/100m^2 (20, 40 or 60 gal/1000 ft^2); and concentrated sulfuric acid (98% H_2SO_4) (SA) was applied at 9.75, 19.50, and 29.26 kg/100m^2 (20, 40, or 60 lb/1000 ft^2) on new pine sawdust bedding and tested against a non-treated control (CON).

In each experiment, a total of 1120 commercial broiler chicks (Cobb X Ross) were obtained from a commercial hatchery and were randomized with 70 birds assigned to each of 16 enclosed chambers (2.44 x 2.44 x 2.44 m; 8 x 8 x 8 ft). Birds were fed a corn-soybean meal starter (0.68 kg/bird; 22% CP, 3087 kcal/kg ME), grower (1.36 kg/bird; 20% CP, 3131 kcal/kg ME), finisher (1.81 kg/bird; 17.5% CP, 3197 kcal/kg ME) and withdrawal (c.a. 1.36 kg/bird; 16.5% CP, 3219 kcal/kg ME) to meet or exceed NRC (1994) requirements. New pine shavings (54.42 kg; 120 lbs) were placed in each pen at the start of each experiment. Feed and water were provided *ad libitum* with 24 hr light. Birds and feed were weighed at 21, 42 and 49 d to determine growth and feed performance. Litter and air quality samples were obtained for analysis initially and weekly through day 49. Ammonia measurements were conducted using a closed container of specified dimension (46 x 36 x 12 cm; 21 x 15.5 x 5 in) inverted over the litter bed and determined using a Drager CMS Analyzer equipped with a remote air sampling pump and appropriate ammonia sampling chip (0.2-5, 2-50, or 10-150 ppm). The tube from the sampling pump was located in the top center of the container. The sampling pump was evacuated (calibrated) for 60 seconds followed by a measurement period of up to 300 seconds. Most readings were usually achieved with 60 seconds following evacuation. Litter was collected weekly, starting the day prior to chick placement and continued through day 49. Collection was performed in each pen by using the grab sampling technique. Individual litter samples (3g) were mixed with 60 ml distilled water for pH measurement. Data from these experiments was analyzed by analysis of variance using the General Linear Models procedure of the Statistical Analysis System (SAS Institute, 1997). When significant ($P<0.05$), means were separated by Tukey's HD multiple comparison procedure.

There were no differences ($P>0.05$) in growth performance in any experiment attributed to type or level of litter treatment. Initial litter pH was significantly lower ($P<0.05$) for PLT, GA, PG, LA, and SA treated pens as compared to CON (ca 2.3 vs. 6.4) and was influenced by level of application. Results indicated that PLT, GA, and LA significantly ($P<0.05$) reduced ammonia volatilization as compared to CON through day 42 at the intermediate and highest application rates. SA significantly ($P<0.05$) reduced ammonia volatilization through day 35 at only the highest application rate as compared to CON. Although PG exhibited the ability to lower pH, it failed to elicit a significant ($P>0.05$) reduction in ammonia. Conversely, HL elevated litter pH initially as compared to CON (12.8 vs. 6.3), but this effect disappeared after day 21. HL failed to support any reduction in ammonia volatilization. Litter analysis results did not indicate a significant ($P>0.05$) increase in amount of nutrients retained due to treatment. Results indicate that PLT, GA, LA, and SA were capable of reducing ammonia volatilization during broiler production. Results show that higher levels of litter treatments can extend ammonia control and may contribute to improvements in bird health. In these trials, ammonia levels were often controlled at the intermediate and highest application levels for up to 42 days (starting with new pine shavings litter).

Limitations:

Litter treatments, by nature, can be corrosive and hazardous to work with and appropriate measures as defined by the manufacturer should be observed during handling and application procedures. As with any acid-based material, gloves, eye protection and appropriate clothing should be used. In some cases the litter treatment may be applied by a professional applicator, thus reducing hazards to the producer during handling and application.

Cost:

The delivered cost of a litter treatment is highly dependent upon transportation costs and competitive pricing offered among manufacturers and distributors. Also, costs for transporting, handling, and applying dry versus liquid products should also be considered. Due to the competitive nature of pricing for the various litter treatment products it is difficult to provide a reasonable and consolidated cost for the treatments tested in these experiments. However, it can be concluded that low levels (50 lb/1000 ft^2) only provide ammonia control during the brooding period (maybe for 3 weeks); whereas higher application rates will extend the effective period for ammonia control, but the producer must balance the cost of applying a higher level of litter treatment with benefits associated with longer ammonia control.

Implementation:

Originally, litter treatments were placed at a relatively low level (generally 50 lb/1000 ft^2) to give early ammonia control during the brooding period. More recently, higher levels have been suggested as the industry becomes more comfortable with the performance benefits associated with improving air quality in the broiler house with litter treatment use. Broiler growers must balance the cost of applying extra amounts of a litter treatment and benefits associated with longer ammonia control. In general, though, improved bird health normally translates into improved broiler weights and improved feed efficiency.

A principal question for those involved in poultry production is: "What is the best litter treatment?" Unfortunately, this most frequently asked question has no general answer and the difficulties in addressing this question may be complicated and numerous. There has never been an experimental study evaluating the various litter treatment products under various management conditions. Litter moisture, brooding and lighting programs, ambient temperature, strain type, ventilation management, litter management, and disease challenge are only a few of the variables that have a potential impact on product selection, efficacy and potential return on investment.

In selecting a litter treatment product, one must identify the goals for application. Litter treatments may be cost-effective and justifiable under one or more of the following situations:

- high fuel prices
- extreme cold weather
- short layout periods
- persistent disease challenges
- severe vaccination reactions
- reduction of ammonia-related stress
- prolonged litter reuse
- increased bird density
- address marginal management or housing situations

In general, control of house ammonia level is the primary purpose for using a litter treatment. In recent years, reasons for using a litter treatment and any potential benefits from its use have expanded to include improvements in performance and environmental concerns. Some litter treatments may be used to enhance the composition of the litter as a fertilizer or as part of a best management practice to reduce food-borne pathogens. Ammonia-reducing litter treatments offer a potentially better in-house environment for the birds. They may also play a role in reducing ammonia and odor emissions from poultry facilities. Although different litter treatments vary in their ability to control ammonia, each offers a unique set of characteristics that need to be considered in selecting the appropriate product to meet an individual's needs. The litter treatment that offers the best return on investment will depend on the user's ability to select the product that best meets application goals.

To maximize the effectiveness of any litter treatment, one must properly prepare and apply the litter treatment in addition to managing the house and litter. Prior to application of any litter treatment, the house needs to be de-caked or tilled. Afterwards, the litter treatment can be broadcast at the chosen level using a drop or cyclone spreader or spray applied. Before birds are placed in the house, spills or concentrated areas should be raked into the litter to prevent consumption by the young birds. As with any litter treatment product, the rate selection for an individual's operation will be dependent on current management practices and needs based on such factors as ventilation control and litter moisture levels. Higher rates may be recommended when high ammonia conditions prevail. Litter treatments have become a common means of improving the broiler house environment throughout much of the broiler industry. It is likely that the use of these products will continue as growers manage reused litter to their best advantage.

Technology Summary:

Recently, poultry producers have come under increased regulatory scrutiny regarding the amount and type of emissions exhausted from poultry housing during the course of normal house ventilation. Ammonia and dust have both been discussed as potential problems with poultry house exhausts. The main goal in using a litter treatment is to effectively reduce ammonia emissions from poultry facilities, which will have a direct effect on improving litter management, nutrient enrichment, and reducing ammonia volatilization from poultry house litter. Research completed by the Department of Poultry Science at Auburn University indicates that increased levels of litter treatments can extend their ammonia control usefulness and most worked well with the exception of lime. In these experiments, ammonia levels were often controlled at the intermediate and highest level of application for 35 to 42 days. If more strict environmental regulations are put into effect regarding ammonia emissions from poultry facilities, litter treatments may become an important technique to allow producers to remain compliant.

The delivered cost of a litter treatment is highly dependent upon transportation costs and market competitiveness among manufacturers and distributors. Also, costs for transporting, handling, and applying dry versus liquid products should also be considered. Due to the competitive nature of pricing for the various litter treatment products it is difficult to provide a reasonable and consolidated cost for the treatments tested in these experiments. However, it can be concluded that low levels only provide ammonia control during the brooding period (maybe for 3 weeks); whereas higher application rates will extend the effective period for ammonia control, but the producer must balance the cost of applying a higher level of litter treatment with benefits associated with longer ammonia control.

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Point of Contact:

John P. Blake
Auburn University
Department of Poultry Science
Auburn, AL 36849
USA
334-844-2640
blakejp@auburn.edu
www.auburn.edu/poultry

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Reduction of Ammonia Emission from Stored Poultry Manure Using Additives: Zeolite, Al+clear, Ferix-3 and PLT

Hong Li
Iowa State Unviersity

Hongwei Xin
Iowa State University, hxin@iastate.edu

Robert T. Burns
Iowa State University

Yi Liang
United States Department of Agriculture

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Reduction of Ammonia Emission from Stored Poultry Manure Using Additives: Zeolite, Al^{+}clear, Ferix-3 and PLT

Hong Li, Hongwei Xin, Robert T. Burns

Dept. of Agricultural & Biosystems Engineering, Iowa State University, Ames, IA

Yi Liang

USDA-ARS-PWA, Pendleton, OR

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Abstract. *Manure storage can be a significant source of ammonia emission that impacts the environment. Ammonia emission from manure storage can be controlled by using physical, chemical and/or biological methods. Five treatment agents, including zeolite, liquid Al^{+}Clear (aluminum sulfate), granular Al^{+}Clear (aluminum sulfate), and granular Ferix-3 (ferric sulfate), and PLT (sodium hydrogen sulfate) were topically applied to stored fresh layer manure. Each agent was tested at three application rates, i.e., low, medium and high. Manure was stored in 19-litter Teflon-lined vessels under a constant ambient temperature of 23 °C with a constant airflow of 3 liter per minute. The ammonia concentrations and emissions from the vessels were measured and ammonia emission reductions by the treatment regimens were evaluated as compared to the control. Reduction of ammonia emission as a result of topical application of the tested manure treatment agents, when compared to the control, over a 7-day manure storage period was as following: A) 68%, 81% or 96%, respectively, for zeolite applied at 2.5%, 5% or 10% of the manure weight; B) 63%, 89%, or 94%, respectively, for liquid Al^{+}Clear applied at 1, 2, or 4 kg m^{-2} of manure surface area; C) 81%, 93%, or 94%, respectively, for dry granular Al^{+}Clear applied at 0.5, 1.0, or 1.5 kg m^{-2}; D) 82%, 86%, or 87%, respectively, for Ferix-3 applied at 0.5, 1.0, or 1.5 kg m^{-2}; and E) 74%, 90%, or 92%, respectively, for PLT applied at 0.5, 1.0, or 1.5 kg m^{-2}.*

Keywords. Laying hen, belt house, manure storage, ammonia emission, additives.

Introduction

Ammonia (NH_3) volatilization from intensive livestock operation not only reduces fertilizer nitrogen (N) value when manure is applied to agricultural land, but also contributes to environmental pollution. Effective technologies that reduce ammonia loss during animal housing, manure storage and land application would have positive economic and environmental benefits.

Laying hen manure is typically either stock-piled in the lower level of high-rise houses or removed from belt cage layer houses to manure storage facilities once to seven times a week. Various mechanisms are involved in conserving N in poultry manure during storage, including immobilization of ammonium through addition of easily decomposable, N-poor materials, adsorption of ammonium (NH_4^+) and NH_3 on suitable amendments, and pH regulation of the manure solution (Kirchmann and Witter, 1989).

Numerous additives have been investigated to reduce NH_3 volatilization from livestock manure. McCroy and Hobbs (2001) published a comprehensive review of a wide range of additives, i.e., acidifying agents, absorbing agents, and bacterial additives, for reducing ammonia from livestock wastes. Natural zeolite is a cation-exchange medium that has high affinity and selectivity for NH_4^+ ions due to its crystalline, hydrated properties resulted from its infinite, 3-dimentional structures (Mumpton and Fishman, 1977). It has been widely used as amendment to poultry litter (Maurice et al., 1998; Nakaue and Koelliker, 1981b), in anaerobic digesters treating cattle manure (Borja et al., 1996), during composting of pig slurry and poultry manure (Bernal et al., 1993; Kithome et al., 1999), air scrubber packing material to improve poultry house environment (Koelliker et al., 1980), and as a filtration agent in deep-bedded cattle housing (Milan et al., 1999). Kithome et al. (1998) investigated the kinetics of NH_4^+ adsorption and desorption by natural zeolite clinopilolite [(Na_4K_4) (Al_8Si_{40}) $O_{96} \cdot 24H_2O$] for its ability to adsorb N in its NH_4^+ form at various pH values and initial NH_4^+ concentrations.

The volatilization of ammonia has been attributed to microbial decomposition of nitrogenous compounds, principally uric acid, in poultry manure. Manure pH plays an important role in ammonia volatilization. Ammonia concentration tends to increase with increasing pH. Ammonia release remains small when pH is below 7.0, but can be substantial when pH is above 8.0. Uric acid decomposition is most favored under alkaline (pH>7) conditions. Uricase, the enzyme that catalyzes uric acid breakdown, has maximum activity at a pH of 9 with uric acid decreasing linearly for more acid or alkaline pH values. The NH_3 emission can be inhibited by acidulants, which can lower manure pH and reduce conversion of ammonium to ammonia. The acidulants also inhibit the activities of bacteria and enzymes that are involved in the formation of ammonia, reducing ammonia production. Liquid Al+Clear and dry granular Al$^+$Clear (aluminum sulfate), Ferix-3 (ferric sulfate) and PLT (sodium hydrogen sulfate) are acidulants that produce hydrogen ions (H^+) when they dissolve, and the hydrogen ions produced by this reaction will attach to ammonia to form ammonium. Because of these reactions, the amount of ammonia emitted from the manure will be reduced, which will increase the nitrogen (N) content of the manure. Al$^+$Clear and PLT had been applied to poultry litter control ammonia volatilization (Moore et al., 1995, 1996; Kithome et al., 1999; Lefcourt and Meisinger, 2001, Armstrong et al., 2003). Ferix-3 usually is used for industrial and municipal water and wastewater treatment over a wide pH range. Uses include color removal, organics removal, phosphorous removal, bacteria reduction, arsenic removal, sludge conditioning, turbidity reduction, COD/BOD reduction, enhanced coagulation, and heavy metals removal. It performs very well in soil remediation applications. However, information on the three acidulants efficacies on ammonia mitigation with laying hen manure is meager.

Materials and Methods

Air Emission Vessels

Eight emission vessels were designed and built for the study (Fig. 1). The vessels were placed in an environment-controlled room with a constant temperature 23 °C at the Livestock Environment and Animal Physiology (LEAP) Lab II of Iowa State University. The vessels were made of 19-liter (5-gal) plastic containers. To prevent potential interference of the vessel material with ammonia emission measurement, each vessel was lined with Teflon FEP100 film (200A, DuPont Teflon ® Films, Wilmington, DE). Both air inlet and outlet were located in the air-tight lid. Teflon tubing (1/4″ diameter) and manifold, along with PVC compression fittings, were used in constructing the emission vessel system.

The vessels were operated under positive pressure. A diaphragm pump (Model DOA-P104-AA, Gast Manufacturing, Inc., Benton Harbor, MI) was used to supply fresh air to the emission vessels. Flow rate of the fresh supply air was controlled and measured with an air mass flow controller (0 to 30 LPM, stainless steel wetted part, AAlborg Instruments and Control Inc., Orangeburg, N.Y.). The supply air was connected to a distribution manifold where air was further divided via eight identical flowmeters (0.2 to 4 LPM, stainless steel valve, VFB-65-SSV, Dwyer Instruments, Inc., Michigan City, Indiana). A flow rate of 3 LPM was introduced into each vessel, resulting in an air exchange rate of 11 air changes per hour (ACH). Each vessel was equipped with a small stirring fan (12VDC, Radio Shack) located 6 cm below the lid for uniform mixing of the headspace. Gas exhausted from the vessels was connected to a common 5 cm PVC pipe that was routed to the building vent outlet. A photographical view of the experimental setup is shown in Figure 2.

Samples of the exhaust air from each of the eight vessels, the supply air, and the room air were sequentially taken at 6-min intervals, with the first 4 minutes for stabilization and the last 2 min for measurement. This yielded a measurement cycle of one hour for each vessel. The sequential sampling was achieved by controlled operation of eight solenoid valves (Type 6014, 24V, stainless steel valve body, Burkert Contromatic USA, Irvine, CA). A Teflon filter was placed in front of each solenoid valve. A photoacoustic infrared (IR) ammonia gas analyzer (Chillgard RT Refrigerant Monitor, MSA, Pittsburg, PA) was used to measure the NH_3 concentrations. The analyzer uses an internal pump to draw sample air at a flow rate of approximately 1.0 LPM. Manure temperature was measured with type T thermocouples (0.2 °C resolution). Air temperature and relative humidity of the room were monitored with a temp/RH data logger (HOBO Pro RH/Temp, Onset Computer Corporation, Bourne, MA). Analog outputs from the thermocouples, NH_3 analyzer, and the mass flow meter were logged at 20-s intervals into a measurement and control module (Model CR10, Campbell Scientific, Inc., Logan, UT).

Laying Hen Manure and Mitigation Options Tested

Hen manure that accumulated on belt for less than a day in a commercial manure-belt layer house was used in the evaluation of the treatment agents. Manure samples with an initial weight of 2.5 kg were used as the experimental units. The 2.5 kg sample was placed either in a 3.8-liter (1-gal) container (surface area of 0.02 m^2) that was further placed inside the 19-liter (5-gal) emission vessel or directly into the emission vessel (surface area of 0.05 m^2).

Five treatment additives at various application rates were tested, including natural zeolite, two forms (liquid and dry) of Al^+Clear, Ferix-3, and PLT. The treatment agents were topically applied to the manure samples at 2.5%, 5% or 10% of the manure weight for zeolite; 1, 2, or 4 kg m^{-2} of manure surface area for liquid Al^+Clear; and 0.5, 1.0, or 1.5 kg m^{-2} for dry granular Al^+Clear, Ferix-3, and PLT. The application rates of Al⁺Clear, Ferix-3, and PLT referred to the application rates of alum on the broiler litter (Armstrong et al., 2003). Properties of the four chemicals tested are listed in Table 1.

Each treatment regime had 4 to 6 replications. The trials with the four chemical agents' treatment lasted 7 days. In the case of zeolite treatment, three trials were conducted. The first two trials examined the effects of single application at one of the afore-mentioned three rates on ammonia emissions over a 14-day storage period, where the third trial examined the effect of multiple applications (every two days, coinciding with manure loading) at the 5% application rate on ammonia emission during a 14-day test. Manure samples were taken from the top 2.5 cm and their physical and chemical properties were analyzed by a certified commercial analytical laboratory.

Results and Discussion

Effect of Topical Application of Zeolite on NH_3 Emission from Hen Manure

Surface-applied zeolite on fresh manure substantially decreased NH_3 emission during 14-d storage period and the effect were generally proportional to the application rates. Daily NH_3 emissions of zeolite on manure in batch trials were illustrated in Figure 3. The adsorption of NH_3/NH_4^+ took effect right after its application at Day 0 and resulted in largest ER reduction on Day 1. Ammonia emissions were reduced by 66, 91 and 96% at the end of Day 1, with application rates of 2.5, 5 and 10%, respectively. Daily ammonia emission of the Ctrl vessels became stabilized after day 3, whereas emissions of the Trt vessels continued to increase with the Trt2.5 being most obvious. Ammonia emissions of Trt5 and Trt10 were significantly lower than that of the Ctrl ($P<0.01$) throughout the 14-d trial period, whereas this was true for the Trt2.5 regimen during the first 7 d ($P<0.01$). Addition of two or more layers of manure did not seem to increase NH_3 emission on a per vessel basis (g d^{-1} or g $m^{-2}d^{-1}$), largely due to the same emitting surface area in the vessel. However, on a per unit manure mass basis, daily ER decreased progressively with the addition of manure (Fig. 4).

Table 2 summarizes the effects of single or multiple topical applications of zeolite at the three dosages on NH_3 emission reduction. Cumulative NH_3 ER reductions at the end of Day 7 and Day 14 were 68% and 20% for Trt2.5, 81% and 50% for Trt5, and 96% and 77% for Trt10. Fourteen-day daily average NH_3 ERs were 0.231, 0.185, 0.116 and 0.053 g d^{-1} kg^{-1} initial manure for control, Trt2.5, Trt5 and Trt10, respectively.

Kithome et al. (1999) reported that NH_3 loss was decreased by 44% when composting poultry manure over 56 days with a surface application of 38% zeolite. Bernal et al. (1993) also reported that more than 90% of N-loss was trapped by placing 12% (by weight) zeolite in air stream over 13-day composting of pig slurry and chopped straw mixture. Zeolite additions at 2.5% and 6.25% into dairy slurry reduced NH_3 emissions by 22% and 47%, respectively, over 4-d storage period (Lefcourt and Meisinger, 2001).

Effects of Al⁺Clear, Ferix-3, and PLT Treatment on NH_3 Emission from Layer Manure

Surface-applied liquid and granular Al⁺Clear, Ferix-3, and PLT on fresh manure substantially decreased NH_3 emission during 7-d storage period. Daily NH_3 emissions from all treatment and control were illustrated in Figure 3. Ammonia emissions for each regimen, emission reduction by the treatment as compared to the control, and manure properties are summarized in Table 3. Reduction of ammonia emission as a result of topical application of the tested manure treatment agents, when compared to the control, over a 7-day manure storage period was as following: A) 63%, 89%, or 94%, respectively, for liquid Al⁺Clear applied at 1, 2, or 4 kg m^{-2} of manure surface area; B) 81%, 93%, or 94%, respectively, for powder Al⁺Clear applied at 0.5, 1.0, or 1.5 kg m^{-2}; C) 82%, 86%, or 87%, respectively, for Ferix-3 applied at 0.5, 1.0, or 1.5 kg m^{-2}; and D) 74%, 90%, or 92%, respectively, for PLT applied at 0.5, 1.0, or 1.5 kg m^{-2}. Ammonia emission reduction from each of the three application rates (denoted as low, medium and high) was significantly lower than that of the control ($P<0.001$). After 7 days, the NH_3 emission reductions from all low application rates were lower than the higher application rates ($P<0.001$).

Daily NH_3 ER of control vessels became stabilized after Day 3, while those of medium and high application treatment vessels stayed with very low NH_3 ERs (Fig. 5). Ammonia ERs (<0.01 g NH_3 kg^{-1} initial manure) of medium and high application rate on every single day were not different ($P>0.70$) during the 7 days. Ammonia ERs of low application rate vessels started to increase from the 3rd, 5th, 6th and 7th day for liquid Al⁺Clear, dry granular Al⁺Clear, Ferix-3, and PLT, respectively.

Results of the manure properties in Table 2 showed that manure samples receiving the higher application rates had lower pH, lower TAN, and higher total N in the top 2.5 cm manure after the 7-day storage period. The average TAN from the controls, low, medium and high application rate vessel were 11.3, 9.9, 8.2, and 6.9 g kg^{-1} (as-is), respectively. The average pH values from the controls, low, medium, and high application rate vessel were 7.6, 7.4, 7.1 and 6.6 respectively. The average total N from the controls, low, medium, and high application rate vessel were 18.5, 18.6, 21.6, and 22.9 g kg^{-1} (as-is), respectively. The more nitrogen was conserved in the manure with higher application rate.

Conclusions

Surface-applying fresh layer manure with zeolite, Al⁺Clear, Ferix-3 and PLT is an effective means to reduce NH_3 emission during storage. Reduction of ammonia emission as a result of topical application of the tested manure treatment agents, when compared to the control, over a 7-day manure storage period was as following: A) 68%, 81% or 96%, respectively, for zeolite applied at 2.5%, 5% or 10% of the manure weight; B) 63%, 89%, or 94%, respectively, for liquid Al⁺Clear applied at 1, 2, or 4 kg m^{-2} of manure surface area; C) 81%, 93%, or 94%, respectively, for dry granular Al⁺Clear applied at 0.5, 1.0, or 1.5 kg m^{-2}; D) 82%, 86%, or 87%, respectively, for Ferix-3 applied at 0.5, 1.0, or 1.5 kg m^{-2}; and E) 74%, 90%, or 92%, respectively, for PLT applied at 0.5, 1.0, or 1.5 kg m^{-2}.

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Table 1.Physical and chemical properties of Al⁺Clear, Ferix-3 and PLT

	Liquid Al⁺Clear	Dry Al⁺Clear	Ferrix-3	PLT
Molecular formula	$Al_2(SO_4)_3{\cdot}14H_2O$	$Al_2(SO_4)_3{\cdot}14H_2O$	$Fe_2(SO4)_3{\cdot}9H_2O$	$NaHSO_4$
Molecular weight	594	594	562	120
pH	2.0 (approx)	3.5 (1% solution)	1.02 (10% solution)	<1 (5% solution)
Appearance	Clear	White granules	Yellowish granules	Off-white granules
Physical state	48.5% in water	Dry solid	Dry solid	Dry solid
Odor	Odorless	Odorless	Slight	Odorless

Table 2. Effects of topical application of zeolite at various rates on reduction of ammonia emission from laying hen manure storage. The application rates, expressed in % of manure weight, were 0% (Ctrl), 2.5% (Trt2.5), 5% (Trt5), and 10% (Trt10), respectively.

		Single Application (in 1-gal emission vessels)				Four Layers (5-gal vessels)	
		Ctrl	Trt2.5	Trt5	Trt10	Ctrl	Trt5
Amount of manure, kg		2.5				2.5 kgx4 = 10	
Surface area of manure, m^2 (ft^2)		0.02 (0.22)				0.05 (0.54)	
Application rate	$kg\ m^{-2}$	0	3.125	6.25	12.5	0	2.55
	$lb\ ft^{-2}$	0	0.639	1.277	2.555	0	0.52
Number of zeolite application		Once - at the beginning				Four - once per layer	
Trial/treatment duration, day		14				14	
Avg. daily ER per unit of manure weight or surface area over trial period	$g\ kg^{-1}d^{-1}$	0.231	0.185	0.116	0.053	0.137	0.069
	$g\ m^{-2}d^{-1}$	29.9	24.0	15.0	6.9	16.1	9.7
7-d cumulative emission, $g\ kg^{-1}$		1.6	1.0	0.62	0.14	-	-
7-d emission reduction rate		-	68%	81%	96%	-	33% [b]
Total cumulative emission, $g\ kg^{-1}$ [a]		3.0	2.5	1.4	0.7	1.7	1.0
Total cumulative emission reduction		-	20%	50%	77%	-	44%
8-d emission reduction rate [c]		-	-	-	-	-	54%

[a] comparison tests lasted 14 days for vessel trials

[b] represents cumulative emission reduction over 7 days following the last-layer addition of hen manure

[c] represents cumulative emission reduction during first 8 days of manure additions

$$\text{Emission Reduction Rate} = \frac{CumuEmission_{Treament}}{CumuEmission_{Control}} \times 100\%$$

Table 3. Effects of topical application of liquid Al⁺Clear, dry granular Al⁺Clear, Ferix-3 and PLT at different rates on reduction of ammonia emission from laying hen manure storage

		Liquid Al^{+}Clear, kg m^{-2}				Dry Al^{+}Clear, kg m^{-2}				Ferix-3, kg m^{-2}				PLT, kg m^{-2}			
		Ctrl	1	2	4	Ctrl	0.5	1.0	1.5	Ctrl	0.5	1.0	1.5	Ctrl	0.5	1.0	1.5
Amount of manure, kg		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Surface area, m^2		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Application rate	kg m^{-2}	0	1.0	2.0	4.0	0	0.5	1.0	1.5	0	0.5	1.0	1.5	0	0.5	1.0	1.5
	lb ft^{-2}	0	0.20	0.41	0.82	0	0.10	0.20	0.31	0	0.10	0.20	0.31	0	0.10	0.20	0.31
Avg. daily ER over trial period	g $kg^{-1}d^{-1}$	0.187	0.070	0.020	0.011	0.150	0.029	0.011	0.009	0.075	0.014	0.011	0.010	0.144	0.037	0.014	0.012
	g $m^{-2}d^{-1}$	21.1	7.87	2.30	1.27	17.0	3.23	1.23	1.07	8.41	1.56	1.19	1.09	16.3	4.18	1.57	1.38
Cumulative emission [€]	g kg^{-1}	1.31	0.49	0.14	0.08	1.05	0.20	0.08	0.07	0.52	0.10	0.07	0.07	1.01	0.26	0.10	0.09
	g m^2	148	55.1	16.1	8.90	119	22.6	8.62	7.48	58.8	10.9	8.33	7.60	114	29.2	11.0	9.64
Reduction Rate [ϕ]		-	63%[b]	89%[a]	94%[a]	-	81%[b]	93%[a]	94%[a]	-	82%[b]	86%[a]	87%[a]	-	74%[b]	90%[a]	92%[a]
Dry content		28.1	29.9	31.1	30.8	27.1	27.9	27.1	30.8	28.3	34.1	31.9	33.9	27.0	29.0	30.5	32.3
Total N, g kg^{-1} (as-is)		17.6	16.5	21.0	24.1	18.5	18.8	20.0	19.1	21.1	23.0	23.5	24.9	16.6	16.2	21.9	23.4
Total N, gkg^{-1} (dry base)		62.6	55.2	67.5	73.5	68.3	67.4	73.8	62.0	74.6	67.4	73.7	73.5	61.5	55.9	71.8	72.4
TAN, g kg^{-1} (as-is)		10.5	9.8	6.0	5.4	11.1	12.5	12.3	10.4	13.2	8.6	7.1	5.6	10.5	8.6	7.3	6.0
TAN, g kg^{-1} (dry base)		37.4	32.8	19.3	16.5	41.0	44.8	45.4	33.8	46.6	25.2	22.3	16.5	38.9	29.7	23.9	18.6
pH		7.6	7.53	7.01	6.42	7.68	7.65	7.65	6.82	7.37	7.2	6.92	6.55	7.6	7.3	6.8	6.7

[€] Comparison tests lasted 7 days for vessel trials

[ϕ] Represents cumulative emission reduction during 7 days

$$\text{Emission Reduction Rate} = \frac{CumuEmission_{Treament}}{CumuEmission_{Control}} \times 100\%$$

[ϕ] Values of emission reduction rate for each agent followed by the same superscript letters are not significantly different (P>0.05).

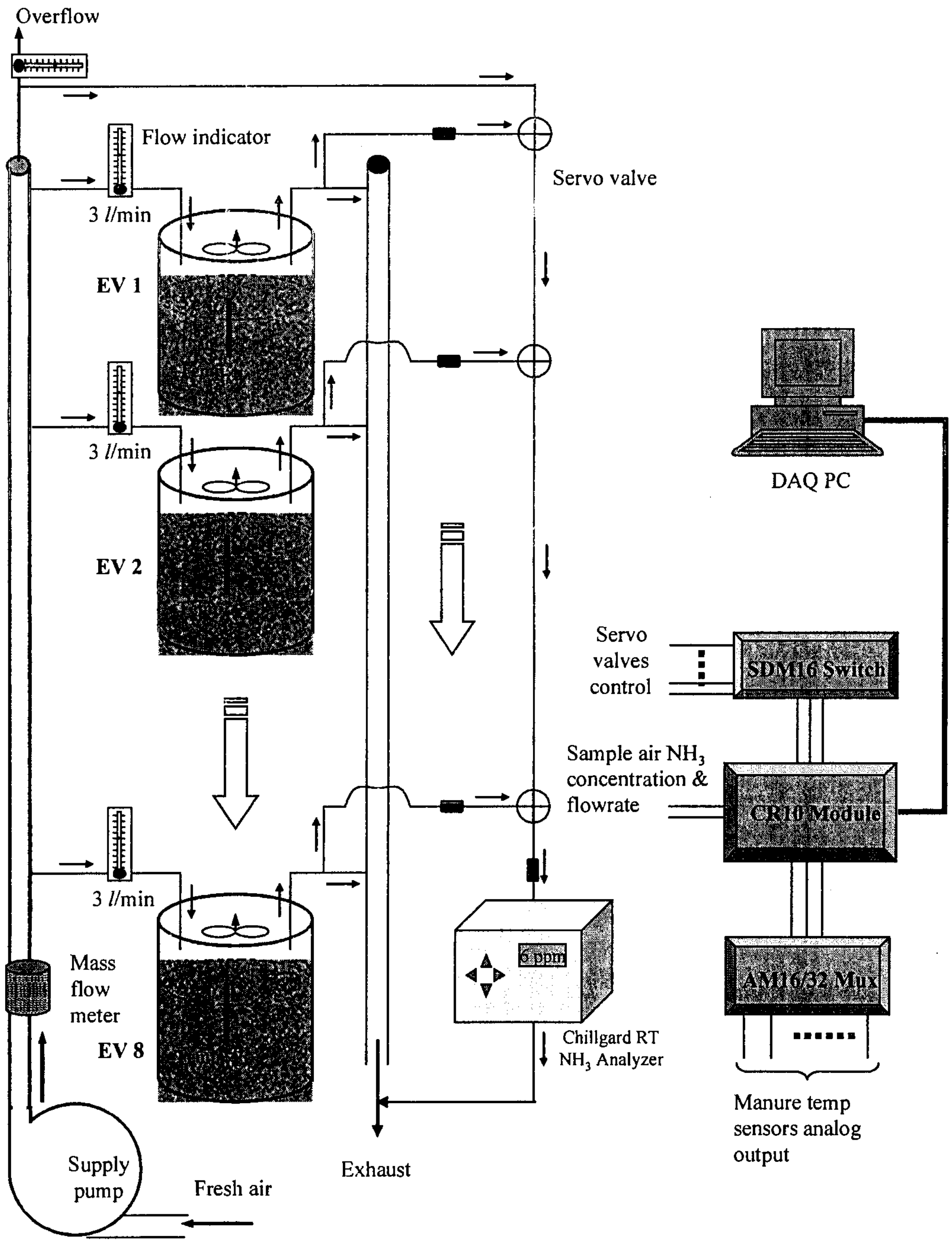


Figure 1. Schematic representation of the experimental setup for evaluating efficacy of treatment agents on ammonia emission reduction from laying hen manure (EV = emission vessel). (Courtesy of Xin, 2005)

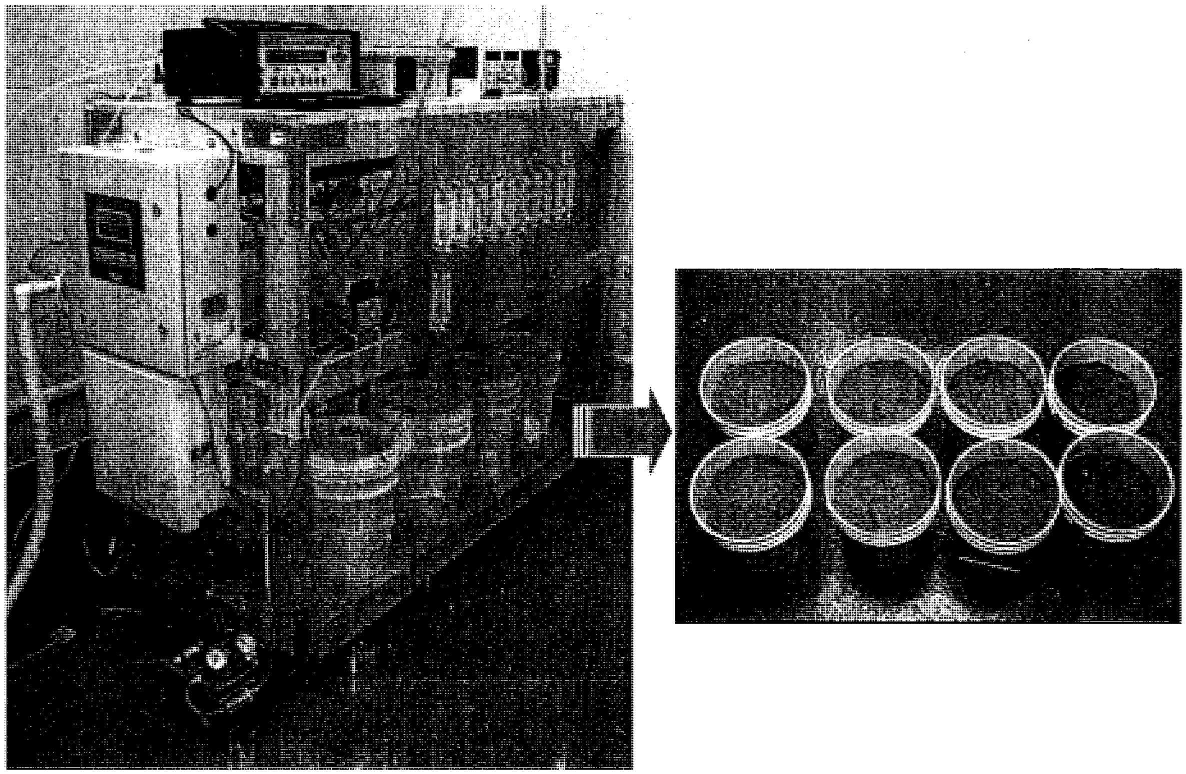


Figure 2. Photographs of the laboratory setup for evaluating efficacy of air emission mitigation strategies. Pictured to the right is topical application of zeolite on laying hen manure at various dosages.

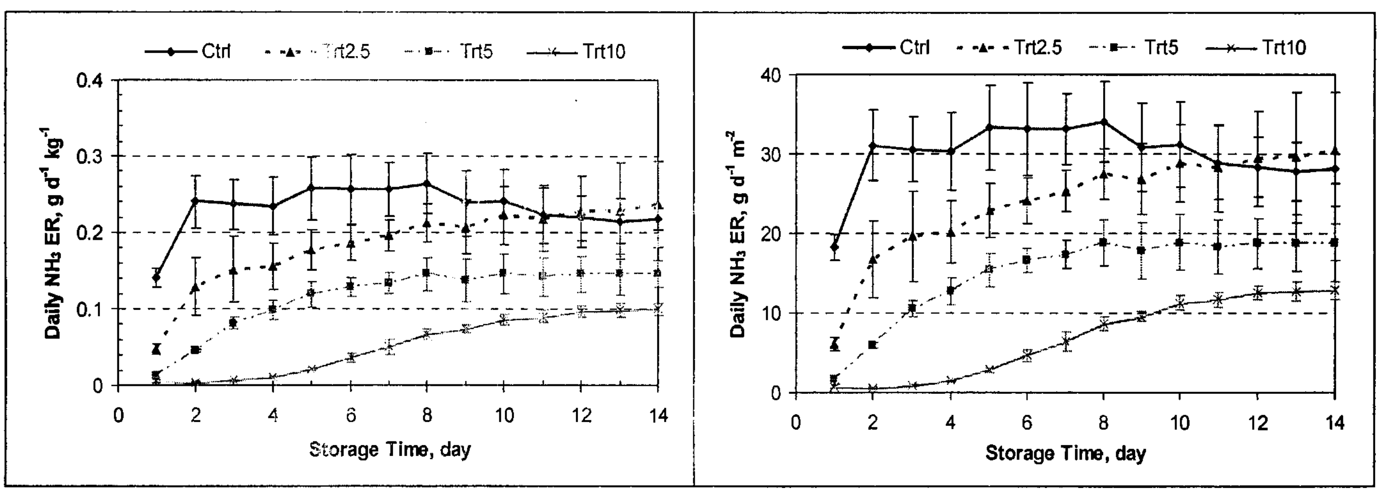


Figure 3. Daily ammonia emissions of ventilated laying hen manure storage with various rates of single surface application of zeolite (Ctrl: no zeolite; Trt2.5: 2.5% zeolite by weight; Trt5: zeolite 5% by weight; Trt10: 10% zeolite by weight).

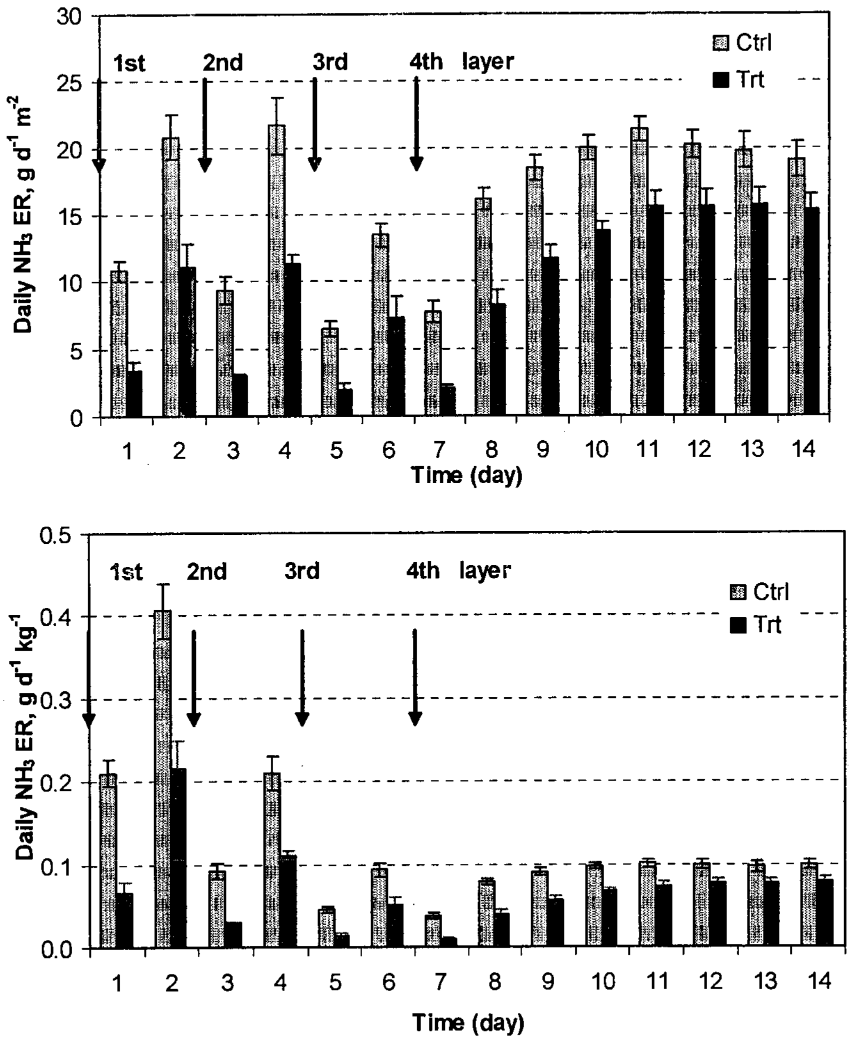
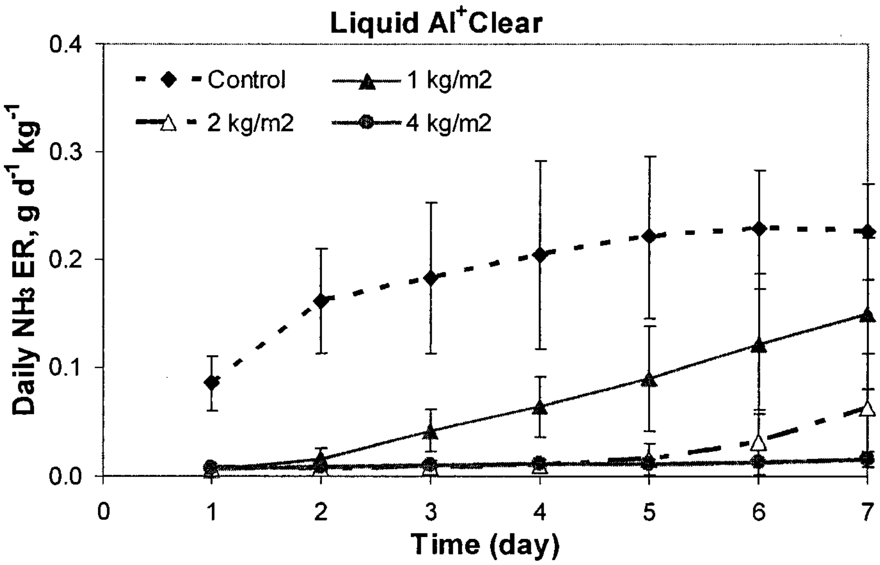


Figure 4. Daily ammonia emissions of ventilated hen manure storage. Fresh manure was added and zeolite topically applied on days 0, 2, 4, and 6 (Ctrl – no zeolite; Trt – 5% zeolite by weight).



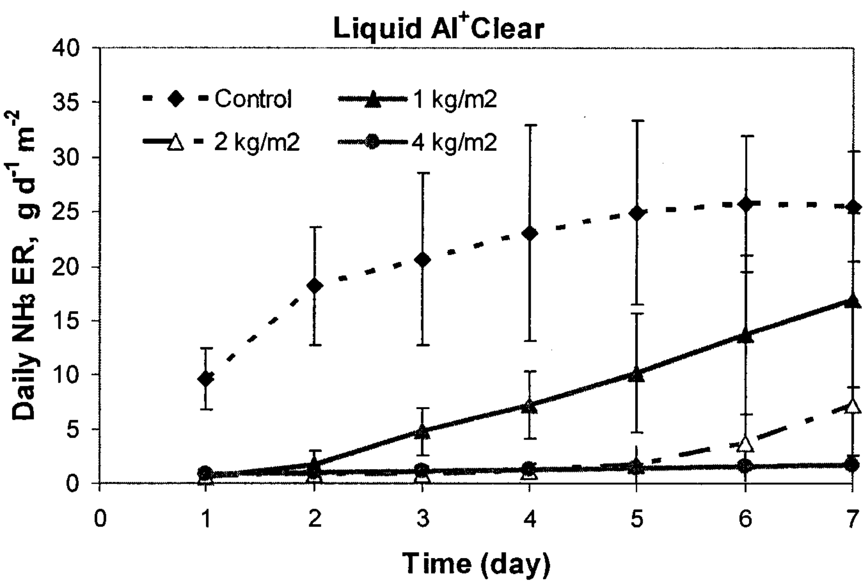
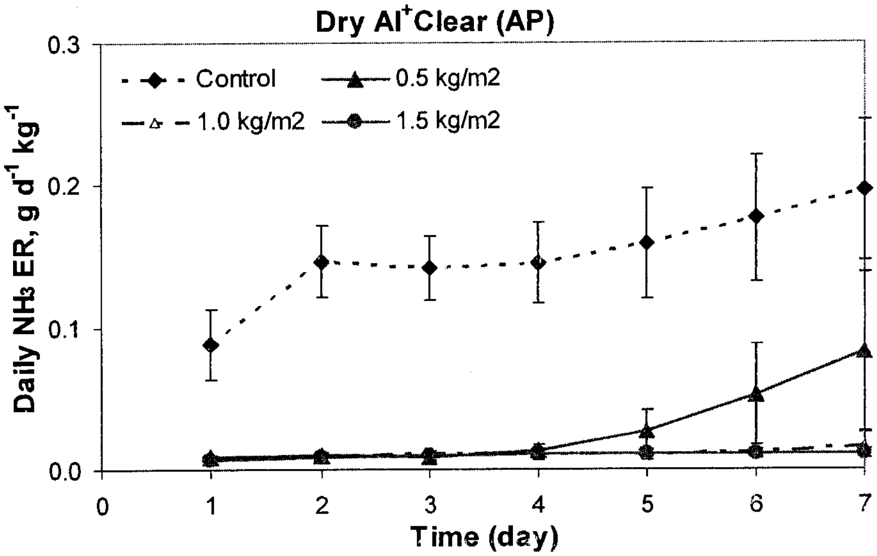


Figure 5. Daily ammonia emission rate (mean and standard error, n=6) of ventilated storage of laying hen manure with different rates of topical application of liquid Al+Clear.



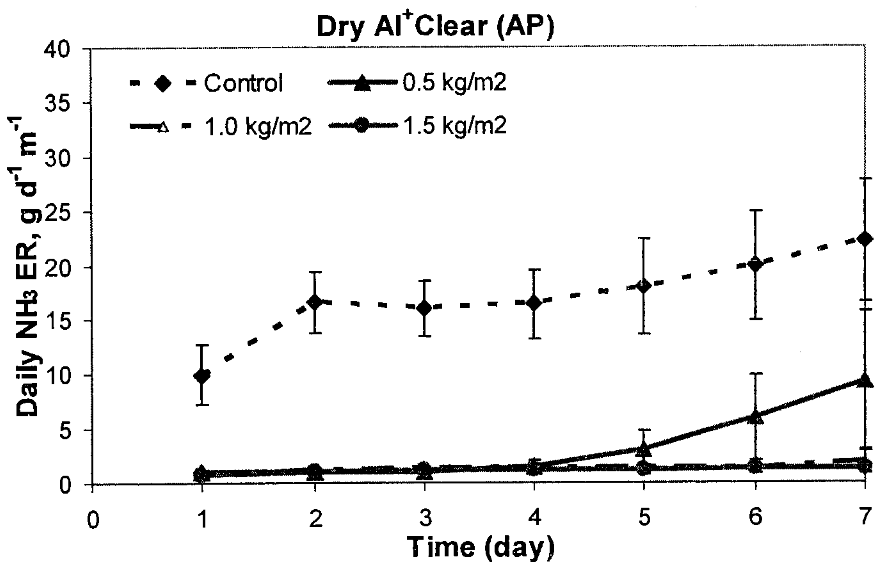
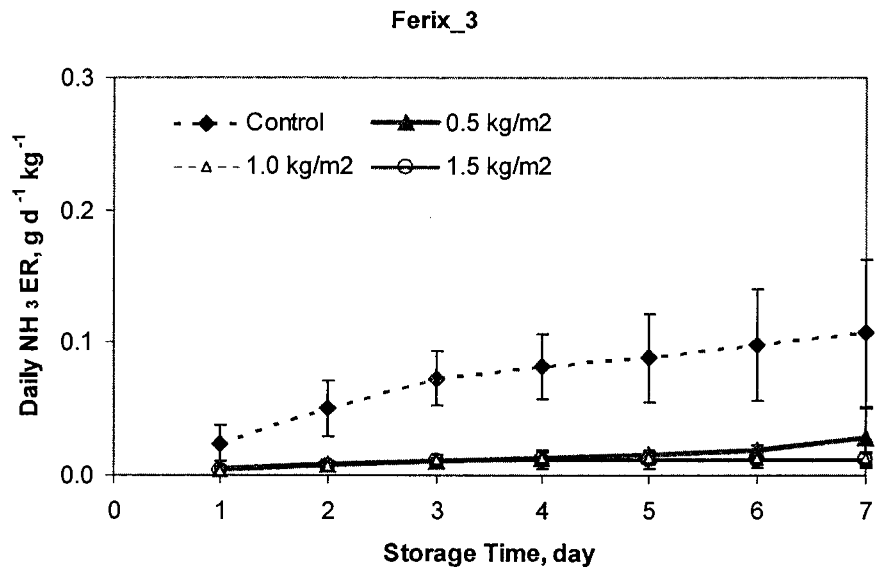


Figure 5 (continued). Daily ammonia emission rate (mean and standard error, n=6) of ventilated storage of laying hen manure with different rates of topical application of dry granular Al$^+$Clear



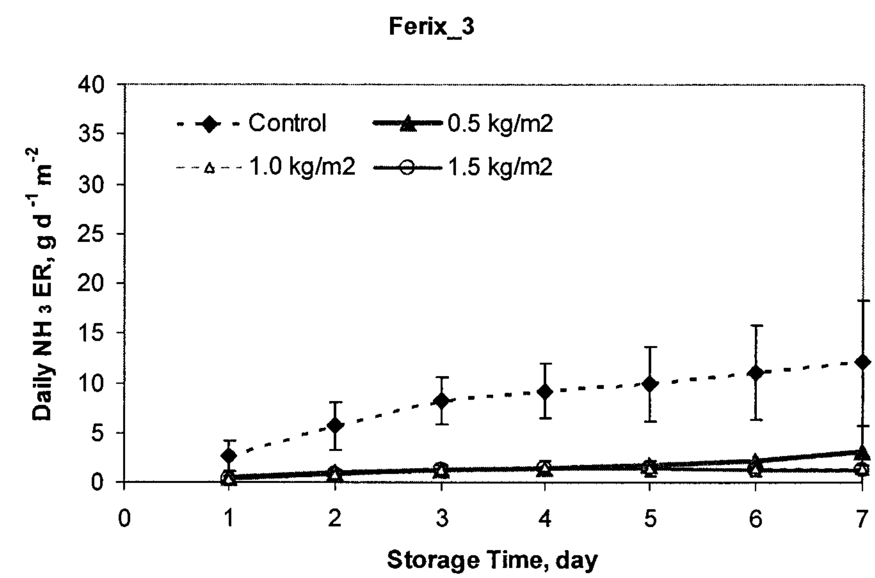


Figure 5 (continued). Daily ammonia emission rate (mean and standard error, n=4) of ventilated storage of laying hen manure with different rates of topical application of Ferix-3.

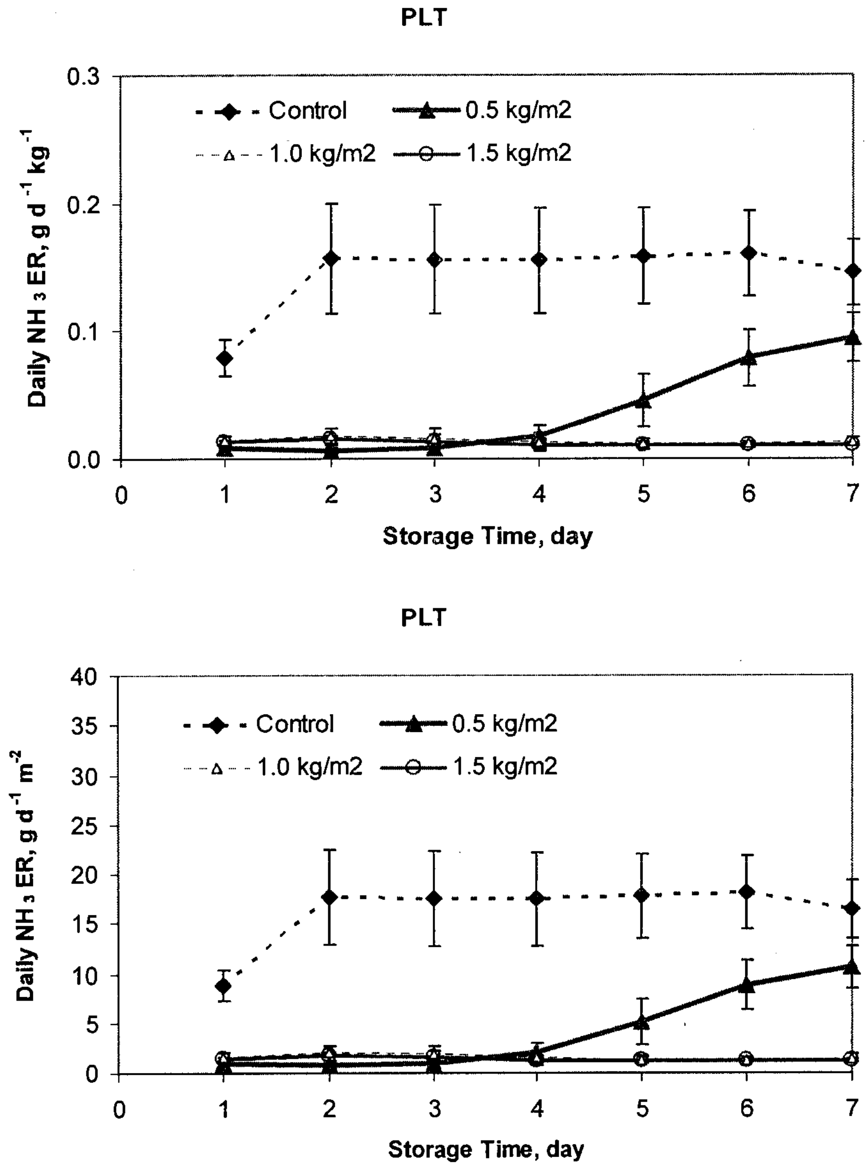


Figure 5 (continued). Daily ammonia emission rate (mean and standard error, n=4) of ventilated storage of laying hen manure with different rates of topical application of PLT.

A 24

EFFECTS OF POULTRY LITTER TREATMENT (PLT) AND ALUMINUM SULFATE (ALUM) ON AMMONIA AND BACTERIAL LEVELS IN POULTRY LITTER

K. S. Macklin, J. P. Blake, J. B Hess, and R. A. Norton

Department of Poultry Science, Auburn University, Auburn, AL 36849-5416

SUMMARY

Chemical litter treatments are commonly used to reduce ammonia and bacterial levels in poultry litter. They typically accomplish this by acidifying the litter. By acidifying the litter, the production of ammonia and growth of bacteria is inhibited. Two commercially available litter treatments that are commonly used are PLT and Alum. In order to test their efficacy, two experiments were performed on fresh pine shavings in which these litter treatments were added at 22.7, 45.5, and 68.2 kg per 92.9 m^2. Broiler chickens were raised on this litter under typical commercial conditions for seven weeks. The following measurements were taken weekly: ammonia, pH, percent moisture, and bacterial levels (total aerobic, total anaerobic, *C. perfringens*, and *Staphylococcus* in CFU/g). There was a decrease in pH and ammonia levels in all of the treated litter; however, there was no difference in bacterial levels or moisture content for any of the treatments.

INTRODUCTION

During the typical life span of commercial broilers, one metric ton of litter is produced per 1,000 birds. Over the course of a year this could lead to 120 metric tons of litter produced in one 20,000 bird poultry house. This built-up litter can result in high ammonia levels, which can adversely affect poultry and human health. Additionally, high ammonia levels make the birds more susceptible to respiratory diseases, like ILTV or airsacculitis. Methods to reduce ammonia levels and pathogenic microbes include changes in management practices and litter treatments. Though these methods work, they are not without problems. One example is litter treatments, which are typically effectual for three to four weeks before they lose effectiveness. The problem is that depending upon the target market, chickens are typically housed for 6+ weeks. The goal for this study was to determine the optimal application rate for prolonging the effectiveness of litter treatments in reducing both ammonia and bacteria. Two experiments were performed in which PLT and Alum was used at differing application rates.

MATERIALS AND METHODS

Trial 1

Housing. Clean pine shavings were placed to a depth of 8 cm in 16 environmental chambers (2.44 x 2.44 x 2.44 m). One-day old chicks were acquired from a commercial hatchery and 70 were randomly placed into each chamber.

Litter treatments. Poultry Litter Treatment (PLT) was applied according to manufacturer's instructions, 22.7 kg per 92.9 m^2. Two additional levels were also utilized 45.5 and 68.2 per 92.9 m^2 to see if the additional product would significantly affect the results. In addition to the three treated groups there was a non-treated control group. Each treatment group consisted of four randomly assigned chambers.

Ammonia measurements. The Drager CMS Analyzer equipped with the remote air sampling pump was used using the appropriate ammonia CMS chip (0.2-5ppm, 2-50ppm and 10-150ppm). The tube from the sampling pump was inserted into a (36 x 46 x 12 cm) container and then run for 60 seconds. If after 60 seconds there was no reading, additional time would be given (up to 300 seconds).

Litter collection. Litter was collected weekly, starting the day prior to chick placement and continued for seven weeks. Collection was performed in each pen by using the grab sampling technique (1). In brief, clean-new gloves are used to collect samples from three areas within each pen. This included litter from under the nipple drinkers, next to the feed troughs and the middle of the pen. The three collected samples were than thoroughly mixed together in a sterile stomacher bag and transported back to the lab for analysis.

Microbiology. Total aerobic, total anaerobic, *C. perfringens* and *Staphylococcus* levels were enumerated (CFU/g) for each pen. This was performed using plate count agar (PCA), reduced blood agar (RBA), tryptose sulfite cycloserine agar (TSC), and *Staphylococcus* medium 110 (m110) respectively. Dilutions were performed by adding 10 g of litter to 90 mL of sterile physiological saline (0.75% NaCl). This produced a 10^{-1} dilution. Further dilutions were performed by transferring 10 mL into another 90 mL sterile saline bottle; this was performed until dilutions ranging from 10^{-1} to 10^{-8} were made. The dilutions were then spiral plated in duplicate onto their respective media types and incubated under appropriate conditions. PCA and m110 were incubated aerobically at 37°C; while RBA and TSC were incubated at 37°C in an anaerobic chamber containing 5% CO_2, 5% H_2, and 90% N_2. After 18 hours colonies were quantified on a digital plate reader and average bacterial counts obtained.

Determination of pH. Litter samples were mixed 1:1 with distilled water and allowed to sit overnight at 4°C. The following day pH was measured in triplicate and recorded.

Percent moisture. After litter arrival in the lab, 10g of litter was weighed and placed in a drying oven that was set for 150°C and allowed to dry for 36 hours. After 36 hours the samples were reweighed and percent moisture was determined.

Statistical analysis. All of the data was analyzed using SPSS version 12.0 using GLM procedure. If there was a significant difference ($P \leq 0.05$), means would be analyzed using Tukey's Multiple Comparison Test. Before analysis all percentage data was arcsine transformed to normalize this data. Additionally, CFU/g counts were normalized for analysis by using log 10 transformations.

Trial 2

The same methods were used in trial 1, except aluminum sulfate (Alum) was used in place of PLT.

RESULTS AND DISCUSSION

The pH results for PLT are presented in Table 1. After two weeks the acidic effects of PLT applied at the rate of 22.7 kg have diminished so that its pH was the same as the untreated group. Both the 45.5 and 68.2 kg application rates kept the pH lower then untreated and 22.7 kg rate until week seven.

Ammonia levels were the same until week five, at which time all treated groups had significantly lower ammonia levels then the untreated group (Table 3). By week six, only the 68.2 kg group had significantly lower ammonia levels then the untreated group. By the seventh week there was no difference in ammonia levels between the four groups.

Bacteriologically there was no difference detected between the four groups. The only difference ($P \leq 0.05$) detected was with the 68.2 kg group on week seven. During that week this group had lower anaerobic bacterial numbers (11.8) then the untreated group (12.4). There was no difference between the four groups when litter moisture was measured.

Alum treated litter produced a variable pH among the treatments (Table 2). Generally though, the groups that contained the highest levels of Alum maintained a lower pH ($P<0.05$) over six weeks. Though the pH for Alum wasn't as low as that for PLT treated groups, they both had similar buffering capabilities. The three application rates (22.7, 45.5 and 68.2 kg) for both PLT and Alum lost their buffering capabilities during the same weeks (weeks two, four, and seven). Similar pH and buffering capacity results were observed by Line and Bailey (2) when they applied 3.63 kg per 9.3 m^2 (36.6kg/93m^2) with both sodium bisulfate (PLT) and aluminum sulfate (Alum).

Ammonia levels for Alum (Table 4) were higher then what was observed for PLT treated groups. Before week six the three treated groups had lower ammonia levels then the control; however by week six there was no difference in ammonia levels between the four groups.

Bacteriologically the only difference between the four groups was observed at week seven, with the 68.2 kg Alum rate having lower anaerobic bacterial numbers (9.7) then untreated litter (11.1) and the 45.5 kg treatment (11.4) with a $P<0.05$. Moisture levels were unaffected by the four groups for the duration of the trial. This lack of differences in moisture level when using Alum differs than what was reported recently (3). This difference could be due to our use of pine shavings, while in that trial they used clean rice bran and had an application rate of 1.15 kg /m^2 compared to our highest level of 0.73 kg/m^2.

From these results it was concluded that neither PLT nor Alum affect either bacterial numbers or litter moisture levels significantly in fresh pine shaving litter. Perhaps the observation in reduced anaerobic numbers on week seven with the highest application rate implies that long term usage of either of these products may reduce some bacterial populations. Additionally, the low initial ammonia levels are due to the use of clean litter. Subsequent research will be performed in which long term usage of these litter treatments will be.

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2. Line, J.E. and J.S. Bailey. Effect of on-farm litter acidification treatments on *Campylobacter* and *Salmonella* populations in commercial broiler houses in northeast Georgia. Poultry Science, 85: 1529-1534. 2006.

3. Do, J.C., I.H. Choi and K.H. Nahm. Effects of chemically amended litter on broiler performances, atmospheric ammonia concentration, and phosphorus solubility in litter. Poultry Science, 84: 679-686. 2005.

Table 1. The pH levels associated with PLT treated bedding. PLT was applied at three levels 22.7, 45.5 and 68.2 kg per 92.9 m^2 before chick placement and measurements were taken weekly. Letter differences signify statistically significant differences at $P \leq 0.05$.

PLT	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Untreated	6.35^a	6.30^a	6.52^a	6.82^a	6.67^a	7.95^a	8.47^a	8.75
T22.7	2.45^b	2.52^b	5.75^a	6.52^a	6.57^a	7.82^a	8.12^a	9.25
T45.5	2.32^b	2.42^b	4.47^b	5.40^b	6.40^a	7.27^b	7.47^b	8.72
T68.2	2.28^b	2.32^b	4.07^b	5.02^b	5.57^b	6.95^b	7.32^b	9.03

Table 2. The pH levels associated with Alum applied at three levels 22.7, 45.5 and 68.2 kg per 92.9 m^2 to fresh pine shavings. Letter differences signify statistically significant differences at $P \leq 0.05$.

Alum	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Untreated	6.78^a	6.35^a	6.88^a	6.98^a	8.58^a	9.00^a	9.67^a	$9.55^{a,b}$
T22.7	4.95^b	5.20^b	6.35^a	6.78^a	8.40^a	$8.35^{a,b}$	$9.50^{a,b}$	$9.52^{b,c}$
T45.5	4.38^c	4.58^c	5.48^b	5.55^b	8.43^a	$8.22^{a,b}$	$9.40^{b,c}$	9.60^a
T68.2	3.80^d	4.12^c	5.15^b	5.42^b	7.65^b	7.83^b	9.22^c	9.40^c

Table 3. The weekly ammonia levels in ppm associated with PLT treated litter. PLT was applied before chick placement at three levels 22.7, 45.5 and 68.2 kg per 92.9 m^2 to fresh pine shavings. Letter differences signify statistically significant differences at $P \leq 0.05$.

PLT	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Untreated	0	0	0	0	3.18	36.70^a	69.50^a	75.00
T22.7	0	0	0	0	0	23.45^b	$47.00^{a,b}$	64.00
T45.5	0	0	0	0	2.35	17.35^b	$38.90^{a,b}$	70.75
T68.2	0	0	0	0	0	13.80^b	26.07^b	85.67

Table 4. Ammonia levels, in ppm, from pine shaving litter that was initially treated with Alum. Alum was applied at three levels 22.7, 45.5 and 68.2 kg per 92.9 m^2 before chick placement onto fresh pine shavings. Letter differences signify statistically significant differences at $P \leq 0.05$.

Alum	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Untreated	0	0	0	2.83	22.95^a	77.25^a	74.00	123.25
T22.7	0	0	0	0.73	14.30^b	72.75^a	79.25	121.75
T45.5	0	0	0	0.60	$15.57^{a,b}$	34.17^b	66.75	135.00
T68.2	0	0	0	0.58	14.85^b	29.57^b	68.00	127.75

COMPARISON OF COMMERCIAL AND SPECIFIC PATHOGEN FREE EMBRYONATED CHICKEN EGGS TO TITER POULTRY VACCINES

Ruben Merino and Genoveva Flores

Departamento de Producción Animal: Aves, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, México DF, 04510

INTRODUCTION

Embryonated chicken eggs have been used for biological suspension titration for a long time; however, there is little bibliography about the comparison between both commercial and specific-pathogen-free (SPF) embryonated chicken eggs used to titer vaccines used routinely in poultry. The aim of this study was to compare the effect of maternal antibodies from the yolk sack of commercial embryonated chicken eggs on the titer of Newcastle disease and infectious bronchitis vaccines.

MATERIALS AND METHODS

Five live Newcastle disease and five live infectious bronchitis vaccines were tittered in duplicate in both, SPF and commercial 10-day old embryonated chicken eggs, according to standard procedures. In brief, all vaccines were diluted 10-fold from 10^{-1} to 10^{-9} (Newcastle disease) or from 10^{-1} to 10^{-6} (infectious bronchitis). Dilutions 10^{-5} to 10^{-9} of Newcastle disease and dilutions 10^{-2} to 10^{-6} of infectious bronchitis vaccines were inoculated into five embryonated eggs via the allantoic fluid, 0.2 mL/egg. After inoculation, all eggs were incubated at 37^{O}C for six days. Allantoic fluid from eggs inoculated with Newcastle disease vaccines were tested for hemagglutination with 2% chicken red blood cells; chicken embryos from eggs inoculated with infectious bronchitis vaccines were tested for typical gross lesions (dwarfing, embryo curled into a spherical form with feet deformed and compressed over the head and with the thickened amnion adhered to it, persistence of the mesonephros containing urates). Vaccine titers were calculated by using the Sperman-Karber methodology.

On day of allantoic fluid or chicken embryo evaluation, yolk sack samples from each egg were taken to perform an ELISA test in order to detect and quantify either Newcastle disease or infectious bronchitis specific antibodies. In brief, yolk sack samples were diluted 1:100 in sterile PBS and then tested by ProFlock NDV plus or ProFlock IBV ELISA test according to the manufacturer's directions (Synbiotics Co., San Diego CA, USA).

Vaccine titers were analyzed by comparison of means; ELISA antibody titers were compared by ANOVA.

RESULTS

Titer of five Newcastle vaccines and five infectious bronchitis vaccines are shown in table 1. There was no statistical difference (P>0.05) between titers of infectious bronchitis vaccines tittered in either commercial embryonated chicken eggs or SPF embryonated chicken eggs. The titer of one Newcastle disease vaccine was higher in SPF embryonated chicken eggs than in commercial embryonated chicken eggs. The mean IBV ELISA antibody titer was 7044 in commercial embryos and 61 (negative) in SPF chicken embryos. The mean NDV ELISA antibody titer was 8305 in commercial embryos and 1507 in SPF chicken embryos. ELISA titers from commercial eggs were higher (P< 0.01) than titers from SPF eggs.

DISCUSSION

Specific-pathogen-free embryonated chicken eggs cost around $1.00 each, while commercial chicken embryos are around $0.30. Results from this study show no difference in titers of infectious bronchitis vaccines when tested in SPF or commercial chicken embryonated eggs, regardless of the high antibody titer found in yolk sack of commercial chicken embryos. The same was seen in Newcastle disease vaccines, except in vaccine C, which titer in SPF embryos was 2 log10 higher than the titer from commercial chicken embryos.

On the other hand, yolk sack samples were suitable for ELISA antibody titration, using a single 1:100 dilution in PBS.

(The whole paper will be published in an indexed journal.)

A25

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1.

J Environ Qual. 2011 Sep-Oct;40(5):1395-404. doi: 10.2134/jeq2009.0383.

Ammonia emission factors from broiler litter in barns, in storage, and after land application.

Moore PA Jr[1], Miles D, Burns R, Pote D, Berg K, Choi IH.

Author information:
[1]Poultry Production and Product Unit, Plant Science 115, Univ. of Arkansas, Fayetterville, AR 72701, USA. phhilipm@uark.edu

Erratum in

- J Environ Qual. 2011 Nov-Dec;40(6):1998.

Abstract

We measured NH_3 emissions from litter in broiler houses, during storage, and after land application and conducted a mass balance of N in poultry houses. Four state-of-the-art tunnel-ventilated broiler houses in northwest Arkansas were equipped with NH_3 sensors, anemometers, and data loggers to continuously record NH_3 concentrations and ventilation for 1 yr. Gaseous fluxes of NH_3, N_2O, CH_4, and CO_2 from litter were measured. Nitrogen (N) inputs and outputs were quantified. Ammonia emissions during storage and after land application were measured. Ammonia emissions during the flock averaged approximately 15.2 kg per day-house (equivalent to 28.3 g NH_3 per bird marketed). Emissions between flocks equaled 9.09 g NH_3 per bird. Hence, in-house NH_3 emissions were 37.5 g NH_3 per bird, or 14.5 g kg(-1) bird marketed (50-d-old birds). The mass balance study showed N inputs for the year to the four houses totaled 71,340 kg N, with inputs from bedding, chicks, and feed equal to 303, 602, and 70,435 kg, respectively (equivalent to 0.60, 1.19, and 139.56 g N per bird). Nitrogen outputs totaled 70,396 kg N. Annual N output from birds marketed, NH_3 emissions, litter or cake, mortality, and NO_2 emissions was 39,485, 15,571, 14,464, 635, and 241 kg N, respectively (equivalent to 78.2,

30.8, 28.7, 1.3, and 0.5 g N per bird). The percent N recovery for the N mass balance study was 98.8%. Ammonia emissions from stacked litter during a 16-d storage period were 172 g Mg(-1) litter, which is equivalent to 0.18 g NH_3 per bird. Ammonia losses from poultry litter broadcast to pastures were 34 kg N ha (equivalent to 15% of total N applied or 7.91 g NH_3 per bird). When the litter was incorporated into the pasture using a new knifing technique, NH_3 losses were virtually zero. The total NH_3 emission factor for broilers measured in this study, which includes losses in-house, during storage, and after land application, was 45.6 g NH_3 per bird marketed.

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A26

Live performance of roasters raised in houses receiving different acidifier application rates[1]

E. O. Oviedo-Rondón,*[2] S. B. Shah,† J. L. Grimes,* P. W. Westerman,† and D. Campeau‡

**Prestage Department of Poultry Science, and †Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh 27695; and ‡North Carolina Cooperative Extension, Pittsboro 27312*

Primary Audience: Researchers, Integrators, Growers, Extension Agents

SUMMARY

The reutilization of litter is currently a common practice in broiler production due to several environmental and economic factors. The application of litter amendments in broiler houses is a popular practice that can reduce ammonia emissions from recycled litter by converting them to nonvolatile ammonium. Sodium bisulfate (SBS) is one of the acidifiers frequently used in broiler houses. Broilers raised to 9 wk may require higher acidifier application rates to prevent unhealthy NH_3 levels throughout the flock than broilers raised to smaller sizes. A study with 6 flocks of roasters was conducted under commercial conditions to evaluate 4 levels of SBS. In a farm with 8 houses, 4 treatments were evaluated. In the control treatment 0.49 kg/m^2 of SBS was applied to the brood chamber, whereas the low, medium, and high treatments received 0.49, 0.73, and 1.46 kg/m^2, respectively, in the whole house. Data were obtained as the average of 2 houses with approximately 21,000 broilers per house in each of the 6 flocks evaluated. Results indicated no significant differences due to treatments on final average BW, FCR, mortality, or the majority of condemnation parameters. The significant reductions in NH_3 levels observed in the whole flock across all 6 flocks receiving SBS treatments did not significantly improve broiler live performance or affect condemnations at the processing plant.

Key words: ammonia, roaster, litter amendment, sodium bisulfate

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DESCRIPTION OF PROBLEM

Ammonia is considered the most harmful gas in broiler chicken housing [1–4]. Ammonia is produced by the microbial degradation of the nitrogen excreted and waste feed accumulated in the litter, flock after flock. Over 50% of poultry manure N might be volatilized in the form of NH_3, which increases in-house concentrations. Commonly, levels of 10 to 100 ppm of NH_3 are observed in broiler houses [1, 3]. Many studies have demonstrated the negative effects of exposing broilers to NH_3 levels between 20 and 100 ppm for prolonged periods [1–5]. Ammonia has been reported to reduce broiler growth and damage the respiratory tract [6] and eye conjunctiva.

[1]The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service or the North Carolina Cooperative Extension Service of the products mentioned nor criticism of similar products not mentioned.

[2]Corresponding author: edgar_oviedo@ncsu.edu

Additionally, NH_3 impairs immune responses [7] and predisposes chickens to respiratory [8] and skin infections with the added risk of secondary infections that can result in airsacculatis, ascites, pododermatitis, hock burns, and breast blisters [2, 3]. Thus, reduction of NH_3 volatilization is very important to maintain broiler health and live performance, and minimize carcass condemnations.

In broiler production, many farms clean out litter annually, a few farms replace bedding after every flock, and the vast majority of farms go multiple years before a total cleanout [9]. The usage of litter amendments in the broiler industry has become a common practice to bind NH_3 as ammonium (NH_4^+), which allows reducing ventilation rates below that required for maintaining desirable RH during brooding and saving fuel. However, if the grower provides adequate ventilation rates for in-house humidity control and the litter has not been recycled many times, the effects of these acidifiers on fuel savings may not be observed. Currently, sulfate-based chemical acidifiers, such as sodium bisulfate (**SBS**; $NaHSO_4$), are most often applied before chick placement to bind NH_3 [9–11]. Lower in-house NH_3 concentrations improve broiler performance according to previously cited reports [2, 4, 5]. However, most research on the effect of NH_3 and studies conducted to evaluate SBS as a litter acidifier have been done during the first week of life or in broiler flocks raised up to 7 wk [9–12].

No reports are available on the effects of NH_3 concentrations and litter acidifier application levels on live performance and condemnations of roasters raised to 9 wk. Heavy broilers are usually raised to reach an average BW of 4 kg or higher with grow-outs of 8 to 12 wk [13]. These heavy broilers have different diet composition, FE, and longer grow-outs than broilers raised to a lower final BW. The average N excretion expected for 7- and 9-wk-old broilers is 1.97 and 2.61 g/d, respectively [14]. This increment in N input to the litter during the last 2 wk of grow-out can cause modifications in the results. The positive effect of acidifiers is expected to be bigger, but the application rates may need to be higher. Thus, the overall objective of this field study was to evaluate the effects of SBS [15] application rates in the whole house compared with a control treatment where SBS was applied only in the brood chamber.

MATERIALS AND METHODS

This research is part of a larger study conducted on a farm in North Carolina between 2007 and 2009 involving 6 flocks of heavy broilers. This report addresses the results related to broiler live performance and condemnations related to farm issues reported by the processing plant. Detailed information related to N mass balance study, NH_3 emissions, and inside house concentrations can be found in Shah et al. [16, 17].

Farm Description, Management, and Treatments

Eight identical broiler houses, measuring 12.5 × 152.4 m, aligned N-S, and built during 2005 and 2006 were used in this study. All the houses were tunnel-ventilated (11 belt-driven 1.22-m fans and three 0.91-m direct drive fans) and had evaporative cooling (cool cells and foggers). Each house had one curtain-sided sidewall (approximately 1.5 × 130 m), one insulated sidewall, and insulated end walls. The houses had drop ceilings with insulation. Each house was heated with 17 radiant brooders and had its own propane tank and meter. The fans, curtains, brooders, cool cells, and foggers controlled by an environmental controller programmed by the producer based on season, bird age, and bird comfort.

Day-of-hatch chicks, ranging in number from 20,000 to 21,300, were placed in each house (Table 1) and raised to an average of 4 kg and marketed at about 63 d. In each flock, chicks had the same genetics and came from the same hatchery with very uniform incubation conditions. Broiler flocks were randomized by breeder source across the houses. The downtime between flocks was 10 to 21 d. The integrator's guidelines specified desirable room temperatures of 34.4°C on d 1 gradually reduced to 16.7°C on d 63. These broilers were managed following the National Chicken Council's guidelines [18]. The chicks were brooded in the middle 40% of the house (brood chamber) for 12 to 14 d and then released into the expansion

Table 1. Flock placement dates and durations, birds placed per house, and treatments

Flock	Date placed	Duration (d)	Birds placed per house	Sodium bisulfate application rate (kg/m^2)			
				Control[1]	Low[2]	Medium[2]	High[2]
	6/22/07	66	20,000	0.37	0.37	0.37	0.37
1	3/4/08	64	20,700	0.49	0.49	0.73	1.46
2	5/22/08	66	20,100	0.49	0.49	0.73	1.46
3	8/12/08	62	21,300	0.49	0.49	0.73	1.46
4	11/17/08	58	21,300	0.49	0.49	0.73	1.46
5	2/10/09	58	21,300	0.49	0.49	0.73	1.46
6	4/28/09	63	20,700	0.49	0.49	0.73	1.46
	Average	63	20,756				

[1]Applied only to the brood chamber (40% of the house).
[2]Applied to the whole house.

brood area (60% of floor area) for another week before being released into the whole house. The birds were fed the same starter, grower, finisher, and withdrawal diets, independent of treatment.

After the birds were sold, the house was de-caked (i.e., the top 25 to 50 mm of wet, matted fecal cake material was removed). Litter was completely cleaned out every 2.5 to 3 yr, but not during the study. As described in Table 1, consistent with the integrator's standard litter treatment program, SBS as poultry litter treatment [15] was applied to the brood chamber in the control treatment and the whole house in the high, medium, and low treatments (Table 1). The acidifier was applied 1 d before bird placement. Each treatment was applied to a pair of adjacent broiler houses, but N output parameters and NH_3 concentrations were only measured for 1 house within each treatment [16, 17]. The average in-house ammonia concentrations observed by treatment by week were discussed in sufficient detail in a previous publication [17]. However, to facilitate interpretation of the data presented herein, the average ammonia concentrations (ppm) for the first 2 wk during brooding are presented in Table 2, and for the whole grow-out period within each flock in Table 3. The study began in June 2007 (Table 1), with the first flock being placed on litter that had supported one flock previously. All treatments received the same SBS application rate in flock 1 to evaluate if bird performance was affected by the specific house. No differences on performance or plant condemnations were observed in this first flock.

Data Collection

Data included BW, FCR, feed intake, final mortality rate, ADG, production efficiency factor (**PEF**), and condemnation parameters reported by the processing plant. The final live average BW per flock was obtained at arrival to the processing plant with the total weight of all broilers harvested from 2 houses under the same treatment divided by the total count obtained during hauling. Feed intake from each replicate was obtained by the difference of feed delivered for 2 houses with the feed left over

Table 2. Mean ammonia concentrations at bird height during the first 2 wk of brooding

Flock (ppm)	Control	Low	Medium	High	Mean across treatments
1	23.0	20.8	9.8	3.9	14.4
2	26.1	17.8	9.6	4.0	14.4
3	8.7	5.4	4.9	1.6	5.2
4	22.5	7.2	5.6	2.6	9.5
5	40.0	21.0	3.5	3.2	16.9
6	23.5	12.1	3.5	3.8	10.7
Mean across flocks	24.0[a]	14.0[b]	6.1[c]	3.2[c]	

[a–c]Mean values followed by the same letter are not significantly different at $\alpha = 0.05$ using Fisher's LSD (6.5 ppm).

Table 3. Mean ammonia concentrations at bird height averaged over the whole grow-out period within each flock

Flock (ppm)	Control	Low	Medium	High	Mean across treatments
1	37.0	34.1	26.7	19.9	29.4
2	14.0	14.9	10.9	9.2	12.2
3	10.3	9.1	10.4	5.4	8.8
4	44.8	30.2	34.0	27.7	34.2
5	46.2	33.6	22.9	16.6	29.8
6	16.5	12.9	9.5	10.0	12.2
Mean across flocks	28.1[a]	22.5[ab]	19.1[bc]	14.8[c]	

[a–c]Mean values followed by the same letter are not significantly different at $\alpha = 0.05$ using Fisher's LSD (6.0 ppm).

after each flock. The FCR was calculated with the previous data. Mortality rates were obtained with the daily records of mortality. The PEF was calculated according as PEF = [live BW (kg) × livability (%)]/[age at processing (d) × FCR (g/g)]. The condemnations reported by the processing plant for groups of 2 houses under the same treatment included percentage of airsacculitis, ascites, septicemia and toxemia, total field condemnations (including inflammatory processes, tumors, bruises, and synovitis), and total condemnations, which includes total field and plant condemnations (dead at arrival, plant rejects, and so on).

Data Analyses

Data were analyzed as a completely randomized design with 4 litter acidifier application rates and 6 replicate flocks per treatment. The mixed procedure of SAS version 9.3 [19] was used for all statistical analyses. Litter acidifier rates were considered as the fixed effect and season within the year as the random effect. The random effect accounts for the environmental factors observed during the study that affected broiler performance, ventilation rates, and in-house ammonia concentrations. Two flocks were evaluated in each season during the study. The effect of applying the lowest rate of SBS in the whole house was compared with the control treatment of application only in the brooding chamber by orthogonal contrast. All percentage data were transformed to Arcsin before analyses. The level of significance (α) used was 0.05, except where indicated.

RESULTS AND DISCUSSION

Results are presented in Tables 4 and 5. In the present field study, no significant differences among treatments were observed on mean BW, FCR, feed intake, mortality, PEF, or farm condemnations. Broilers raised in houses with an application of SBS at 0.49 kg/m^2 in the whole house (low) had similar performance and carcass traits to those raised in houses where SBS was applied only in the brooding chamber (control). One exception was observed on the incidence of ascites, which was reduced ($P = 0.06$) in the flocks raised in houses where SBS was applied to the whole house (0.004%) compared with control flocks where SBS was applied only in the brooding chamber (0.035%). However, this represents a very small number of broilers in each flock.

The levels of SBS applied in the present field trials did cause significant reductions on NH_3 concentrations (Tables 2 and 3) and emissions, as previously reported [16, 17]. It was expected that the NH_3 levels observed in the houses in the control treatment could cause negative effects on the performance of broilers raised to 9 wk of age. Unexpectedly, broiler performance and health, indirectly observed through mortality and condemnations, were not affected by the SBS levels evaluated. The effects of NH_3 depended on concentration and exposure time. In the field trials reported herein, the NH_3 concentrations in the houses utilizing the control treatment approached or exceeded the threshold of 25 ppm during cool season brooding (Table 2), whereas houses with medium and high SBS application (0.73 and 1.46 kg/m^2) had average NH_3 concentrations lower than 6 ppm during brooding and the entire duration of most of the warm season flocks [16]. The houses with a low SBS application rate (0.49 kg of SBS/m^2) in the whole house had an average NH_3 concentration of 14 ppm during brooding. These concentrations were the result of SBS application

Table 4. Roaster performance according to litter acidifier application rate

Item	BW[1]	Daily BWG[2]	Feed intake	FCR (g:g)	Mortality (%)	PEF[3]
Treatment (g, unless otherwise indicated)						
Control	3,942	65.02	8,378	2.123	2.99	293.9
Low	4,062	65.68	8,646	2.126	2.65	303.1
Medium	3,990	65.54	8,491	2.126	2.79	297.4
High	4,029	65.33	8,504	2.109	2.89	302.4
SEM	88	1.10	293	0.036	0.21	8.9
CV (%)	3.45	2.63	4.83	1.86	9.56	4.07
P-value						
Treatment	0.917	0.916	0.739	0.855	0.792	0.523
Brood vs. whole[4]	0.208	0.549	0.278	0.879	0.511	0.231

[1]Final average live weight obtained at arrival to the processing plant.

[2]BWG = average daily BW gain obtained by dividing final live weight by days in grow-out.

[3]PEF = production efficiency factor; [live BW (kg) × livability (%)]/[age at processing (d) × FCR (g/g)].

[4]Orthogonal contrast of sodium bisulfate application only in the brood chamber (control) versus application in the whole house (low, medium, high) at the same rate.

rates and ventilation rates used on this farm to comply with National Chicken Council's recommendations [18], temperature guidelines of the integrator company, and the producer's efforts to manage in-house RH. The NH_3 concentrations under these commercial conditions varied considerably but seldom exceeded 40 ppm; concentrations were even lower during ventilation cycles [16]. The ventilation rates and in-house temperatures among houses were similar [16]. Though the SBS application rate effect on NH_3 concentrations was more pronounced early in the flock, differences in NH_3 concentrations among the treatments decreased as the birds grew older [16]. The small differences in NH_3 concentrations among treatments (Tables 2 and 3) could be responsible for the lack of effect of treatments with higher SBS application rate on broiler performance and condemnations observed at the processing plant. Nevertheless, the house management followed in these field trials was very representative of the US broiler industry.

Our results are not consistent with the findings of other researchers who observed better BW gain, FCR, carcass traits, and lower breast blister, footpad, and air sac scores [10, 20] with the use of SBS or other litter acidifiers in broilers raised to a maximum of 50 d. Those studies [10, 20] were conducted in floor pens with

Table 5. Plant commendations of roasters according to litter acidifier application rate

Item	Airsacculatis	Ascites	Septicemia and toxemia	Total field condemnations[1]	Total condemnations[2]
Treatment (%)					
Control	0.021	0.036	0.21	0.66	1.16
Low	0.018	0.004	0.25	0.57	1.02
Medium	0.013	0.005	0.20	0.47	0.87
High	0.019	0.008	0.11	0.51	0.94
SEM	0.009	0.015	0.05	0.09	0.18
P-value					
Treatment	0.925	0.241	0.688	0.475	0.576
Brood vs. whole[3]	0.878	0.063	0.910	0.176	0.421

[1]Total field condemnations include airsacculitis, ascites, septicemia and toxemia, inflammatory processes, tumors, bruises, and synovitis.

[2]Total condemnations include total field and plant condemnations (dead at arrival, plant rejects, and so on).

[3]Orthogonal contrast of sodium bisulfate application only in the brood chamber (control) versus application in the whole house (low) at the same rate.

reused litter, the application rates of SBS were 0.24 and 0.45 kg/m^2, respectively, and always compared to a control without any litter amendment. Under those conditions, the authors reported NH_3 levels lower than 25 ppm during the whole study [10] or at least during the first 29 d [20], whereas the control, nontreated pens had NH_3 levels as high as 100 ppm for the first 3 wk and around 60 ppm until the end of the experiment. These differences in NH_3 concentrations obtained with gas tubes are much higher than observed with continuous NH_3 monitoring [16] in the field trials reported herein. According to those authors [10, 20], exposure to the air quality conditions in those studies was constant in pens and not cyclic, as was observed under commercial conditions in the present field trials [16].

Studies conducted in floor pens or environmental chambers that evaluated litter treatments such as SBS [21] and acidified char [22] have also reported significant effects of these acidifiers in reducing NH_3 air concentrations from 15 ppm to less than 7 ppm, but have not found significant effects on BW, feed intake, FCR, and mortality in broilers raised to 49 d of age. In one of these studies [21], the application of SBS caused numeric reductions on pododermatitis severity, but no other effects on broiler health or performance. In that study [21], the application rates of SBS tested were 0.22 and 0.44 kg/m^2 and the NH_3 levels in the control chambers reached a maximum of 30 ppm in the last 2 wk of grow-out, with no significant effect of SBS on NH_3 concentrations.

Although the results observed on broiler performance and carcass traits were not affected by treatments in the present field trials, it is important to take into consideration that there are specific guidelines of NH_3 levels for human safety and broiler welfare that are important to fulfill in commercial broiler production. The National Institute of Occupational Safety and has established a time-weighted human threshold limit value of 25 ppm for 8 to 10 h of exposure [23]. The Occupational Safety and Health Administration established an 8-h exposure level at 50 ppm. The short-term exposure limit (15 min) set by the American Conference of Governmental Industrial Hygienists is 35 ppm [24]. Finally, the National Chicken Council established a limit of 15 ppm for broiler welfare [18]. The present field trials were not able to detect significant improvements on broiler live performance and some parameters of health and carcass quality; however, the significant reductions on inside NH_3 concentrations (Tables 2 and 3) observed in these field trials [16, 17] can help to comply with human safety and animal welfare guidelines.

CONCLUSIONS AND APPLICATIONS

1. The application of SBS in the whole house at rates of 0.49, 0.73, and 1.46 kg/m^2 did not improve the live performance of broilers raised to 4 kg during growing cycles of 9 wk compared to a control treatment with application of 0.49 kg of SBS/m^2 only in the brooding chamber.
2. Significant reductions on NH_3 due to application of SBS as a litter acidifier did not cause significant reductions in farm condemnations and only ascites was reduced.
3. Higher SBS application rates lower ammonia levels in the roaster houses and may help to comply with guidelines for worker safety and broiler welfare.

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Effect of dietary adipic acid and corn dried distillers grains with solubles on laying hen performance and nitrogen loss from stored excreta with or without sodium bisulfate

C. Romero,*[1] M. E. Abdallh,† W. Powers,‡ R. Angel,§ and T. J. Applegate#[2]

*Departamento de Producción Animal, Universidad Politécnica de Madrid, 28040 Madrid, Spain; †Department of Poultry Production, University of Khartoum, Khartoum 13314, Sudan; ‡Department of Animal Science, Michigan State University, East Lansing, MI 48824; §Department of Animal & Avian Sciences, University of Maryland, College Park 20742; and #Department of Animal Science, Purdue University, West Lafayette, IN 47907

ABSTRACT Effects of dietary adipic acid (0 vs. 1%) and corn dried distillers grains with solubles (DDGS; 0 vs. 20%) were evaluated on hen performance and egg characteristics from 26 to 34 wk of age. Four isocaloric and isonitrogenous diets were randomly assigned to blocks of 6 consecutive cages (36 cages per diet; 2 hens per cage). On wk 2 and 7 of the experiment, excreta were collected by cage block, mixed, and equally split into 2 containers. Sodium bisulfate (SBS) was spread (8.8 kg/100 m^2) on the top surface of half of the containers. All containers were stored uncovered for 14 d at room temperature. Excreta pH, DM, and N content were measured on d 0, 7, and 14 of storage. Feed intake (112 g/d per hen), egg production (96.1%), and egg specific gravity (1.079 g/g) were not affected by diet. On excreta collection day, a synergy ($P = 0.014$) between dietary adipic acid and DDGS was detected, as the lowest excreta pH was obtained with the diet including both adipic acid and DDGS. On d 7 of storage, excreta pH was still reduced by dietary adipic acid ($P = 0.046$) and DDGS ($P < 0.001$), but a week later, only dietary DDGS decreased excreta pH (8.91 vs. 9.21; $P < 0.001$). Whereas dietary adipic acid had no influence on excreta N loss, excreta from hens fed 20% DDGS lost 19.7% more N ($P = 0.039$) during storage than hens not eating DDGS. Surface amendment of excreta with SBS increased excreta DM content, with the effect being even more marked on d 14 of storage (increase of 6.7 percentage units; $P < 0.001$), consistently decreased excreta pH during storage ($P < 0.001$) and reduced N loss by 26.1% for the 14 d of storage period.

Key words: adipic acid, dried distillers grains plus solubles, laying hen, nitrogen loss, sodium bisulfite

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INTRODUCTION

As by-products of the ethanol industry, dried distillers grains with solubles (**DDGS**) have long been available for animal feeding. However, in the last decades DDGS were mainly produced and sold locally. Today, because of the boost given to ethanol production by United States government policies, the amount of DDGS produced in the US ethanol plants has greatly increased since 1999, reaching 32.5 million metric tons in 2010 (RFA, 2011). Even if, at first, DDGS were mainly fed to ruminants and were limited to 5% in poultry diets due to their high fiber content (7% CF; Waldroup et al., 2007), recent studies (Lumpkins et al., 2005; Roberts et al., 2007a) have shown that the dietary inclusion level of DDGS could be increased up to 10 to 15% for laying hens during peak production. Nonetheless, Roberson et al. (2005) reported decreases in egg production and egg weight at certain ages when diets included DDGS at 15%. Additionally, a further increase of the dietary inclusion of DDGS up to 20% slightly reduced egg weight in 24- to 46-wk-old laying hens in the work of Masa'deh et al. (2011), whereas Wu-Haan et al. (2010) did not observe any effect of feeding 20% DDGS on egg weight or egg production in 21- to 26-wk-old hens. Hence, despite several publications on the use of DDGS in laying hens, the extent to which DDGS can be included in laying hen diets without having adverse effects on egg mass is still a matter of debate.

Currently, NH_3 emissions originating from livestock operations are a major concern because it has been documented that this gas can have negative effects on

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[1]Present address: Departamento de Física y Mecánica de la Ingeniería Agroforestal, Universidad Politécnica de Madrid, 28040 Madrid, Spain.
[2]Corresponding author: applegt@purdue.edu

the environment and on human and animal health (Deaton et al., 1984; De Boer et al., 2000; Omland, 2002). Therefore, it is interesting to note that Wu-Haan et al. (2010) decreased daily NH_3 emissions by feeding 20% DDGS diets to 21- to 26-wk-old laying hens.

In laying hen excreta, $[NH_3]/[NH_4^+]$ equilibrium depends on pH, among other factors. A reduction of the pH leads to the protonation of NH_3 to NH_4^+, which is less volatile (McCrory and Hobbs, 2001). Thus, NH_3 emissions could be partly mitigated by maintaining a low excreta pH. This could be achieved in laying hens by feeding acidogenic compounds, as reported by Romero et al. (2012). Adipic acid, which is a water-soluble dicarboxylic acid, has successfully been fed at a 1% dietary dose to reduce NH_3 emission from swine manure (van Kempen, 2001). However, to the authors' knowledge, the dietary effect of adipic acid on productive performance and excreta pH has not hitherto been evaluated in laying hens. Likewise, spread sodium bisulfate dissolves in the litter, releasing hydrogen ions that attach to NH_3 and form NH_4^+ (Chois and Moore, 2008). Thus, amending excreta with sodium bisulfate (e.g., Poultry Litter Treatment) acidifies poultry litter (Pope and Cherry, 2000) and could also decrease NH_3 volatilization from poultry excreta.

The aim of the present work was to test the synergistic effect of feeding 1% adipic acid and 20% corn DDGS on laying hen performance and elucidate whether an additional synergy exists between the dietary incorporation of these 2 ingredients and the application of sodium bisulfate as a litter amendment to reduce pH and control N loss in laying hen excreta.

MATERIALS AND METHODS

All the animal procedures were approved by the Purdue University Animal Care and Use Committee.

Experimental Design

The present study consisted of an experiment using 288 Hy-Line W36 hens, starting at 26 wk of age and lasting 8 wk [initial BW = 1,373 ± 81.8 (SD) g]. Hens were housed in wire cages in a completely enclosed fan-ventilated building. The experiment was designed with 4 dietary treatments that were fed to blocks of 6 consecutive cages. Hens were allocated randomly to 144 cages (24 blocks of 6 cages; 6 replicate blocks per diet; 2 hens per cage; 780 cm^2 of cage space per hen). An empty cage was kept between blocks to eliminate cross-feeding and allow more accurate excreta collection.

Diets

Based on a corn-soybean meal diet, 4 dietary treatments (Table 1) were arranged in a 2 × 2 factorial structure with 2 main effects: level of corn DDGS (0 vs. 20%) and supplementation with adipic acid (0 vs. 1%). Addition of adipic acid was done replacing 1% Celite (diatomaceous earth: an undigestible filler) in the diet. The 4 diets were formulated to be isonitrogenous (18.3% CP) and isocaloric (2,948 kcal of ME/kg). For formulation, the DDGS source used was from the same supplier as Wu-Haan et al. (2010). Presumed nutrient content from several prior analyses was 2,860 kcal/kg (ME_n),28.2% CP, 9.2% Lys, 5.3% Met, 10.9% Thr, 28.8% neutral detergent fiber, and 9.68% fat. Standardized ileal amino acid digestibility of this amino acid source in broilers has previously been determined to be 64.3% (S. A. Adedokun and T. J. Applegate, Purdue University, West Lafayette, IN; unpublished results). Feed was mixed at the experimental facilities of Purdue University (IN). Each experimental diet was randomly assigned to 6 blocks of 6 consecutive cages. Feed was offered daily in a mash form and water was provided ad libitum via nipples.

Bird and Egg Measures

Body weight change and feed intake were measured every 4 wk. All laid eggs were collected daily and number of eggs was recorded per cage (36 cages per diet; 2 hens per cage). Egg mass was calculated by multiplying daily egg production by egg weight divided by 100. Feed conversion was calculated by dividing feed intake by egg mass. Individual egg weight and specific gravity were determined for all cages with the eggs collected during the last 2 d of every 4-wk period. Egg specific gravity was determined through dividing the dry egg weight by the weight of deionized, distilled water displaced. All eggs weighed at the end of every 4-wk period were broken to separate yolk from egg white, and thereby determine the weight and proportion of yolk, albumen, and shell. Shell weight (including membranes) was determined after rinsing and drying at room temperature for 24 h. Moreover, on wk 8, yolks and egg whites from all 144 cages were retained for freeze-drying and determination of total solids.

Excreta Measures

On wk 2 and 7 of the experiment, excreta pans were placed under all cages for 2 consecutive d. The 2-d excreta collection from each block of 6 cages fed the same diet was pooled (6 pools per diet and collection) and mixed. A sample was retained from each mixed pool to determine excreta DM. Thereafter, each excreta pool was equally split into 2 buckets (26.4-cm diameter; 1.8 L; 12 buckets/diet). Sodium bisulfate (**SBS**) was spread (4.82 g/bucket according to manufacturer's use instructions: 8.8 kg/100 m^2) on the top surface of half of the buckets (6 buckets treated with sodium bisulfate/diet). Subsequently, pH was measured in all 48 buckets and an excreta sample was retained from each bucket to determine N content. Buckets were stored uncovered for 14 d at room temperature (22 ± 2°C). On d 7 and 14 of storage, pH, DM, and N contents were measured in every bucket. Nitrogen loss during the storage period was

Table 1. Composition (as-fed basis) of the experimental diets fed to 26- to 34-wk-old laying hens

Item	Diet			
	Control	Adipic acid	DDGS[1]	DDGS + adipic acid
Ingredient, % of diet				
Corn	54.4	54.4	41.7	41.7
Corn distillers dried grains with solubles	—	—	20.0	20.0
Soybean meal (48% CP)	29.6	29.6	20.3	20.3
Soy oil	2.60	2.60	4.60	4.60
Sodium chloride	0.40	0.40	0.33	0.33
DL-Methionine	0.19	0.19	0.18	0.18
L-Lysine HCl	0.00	0.00	0.15	0.15
Limestone	9.70	9.70	9.92	9.92
Dicalcium phosphate	1.76	1.76	1.47	1.47
Vitamin and mineral premix[2]	0.35	0.35	0.35	0.35
Diatomaceous earth[3]	1.00	—	1.00	—
Adipic acid[4]	—	1.00	—	1.00
Nutrient composition (formulated)				
ME_n, kcal/kg	2,948	2,948	2,948	2,948
CP, %	18.3	18.3	18.3	18.3
Lys, %	1.01	1.01	0.99	0.99
Met, %	0.48	0.48	0.48	0.48
TSAA, %	0.79	0.79	0.80	0.80
Thr, %	0.71	0.71	0.71	0.71
Ca, %	4.20	4.20	4.20	4.20
Total P, %	0.69	0.69	0.72	0.72
Nonphytate P, %	0.46	0.46	0.46	0.46
Nutrient composition (analyzed)				
CP, %	19.5	19.6	18.9	20.3
Neutral detergent fiber, %	7.89	8.43	12.89	12.70
Fat, %	4.96	5.34	8.28	8.39
Ca, %	5.01	4.64	4.92	4.79
Total P, %	0.74	0.68	0.72	0.71

[1]DDGS = dried distillers grains with solubles.

[2]Supplied per kilogram of diet: vitamin A, 12,320 IU; vitamin D_3, 4,620 IU; vitamin E, 15.4 IU; vitamin K, 3.08 mg; riboflavin, 6.16 mg; niacin, 46.2 mg; vitamin B_{12}, 23.1 µg; pantothenic acid, 15.4 mg; folic acid, 0.31 mg; choline, 401 mg; Fe, as $FeSO_4$, 50.4 mg; Zn, as ZnO, 71 mg; Mn, as MnO, 90 mg; Cu, as $CuSO_4$, 7 mg; I, as ethylenediamine dihydroiodide, 0.7 mg; and Se, as Na_2SeO_3, 0.25 mg.

[3]Celite Corp., Lompac, CA. The diatomaceous earth was included as a filler in the diets devoid of adipic acid.

[4]Alfa-Aesar, Ward Hill, MA.

calculated as the variation in the N content with respect to the concentration determined on excreta collection day. In all buckets, the electrode of the pH meter was introduced in 3 different points of the excreta sample. The 3 recorded measurements were then averaged (pH meter 300 Eutech Instruments/Oakton Instruments, Vernon Hills, IL; equipped with a flat-surface electrode for pH measurement on solids or semisolid substances, Orion 91–35, Boston MA). All homogeneous excreta samples collected were frozen, freeze-dried, and then ground (0.75-mm screen) before analyzing N content.

Chemical Analysis

Homogeneous samples of diets were retained and ground (0.75-mm screen) for determination of CP (6.25 × N), NDF, fat, Ca, and P contents. Diet and excreta DM were determined after drying at 105°C for 24 h. Dietary and excreta N content was analyzed using the Dumas N method (AOAC, 2006; method 990.03). Diets were also analyzed for NDF (VanSoest et al., 1991), fat (extraction by Soxtec HT6 System using anhydrous diethyl ether), Ca, and P (AOAC, 2006; method 985.01) contents.

Statistical Analysis

All data were analyzed as a factorial experiment using the PROC MIXED procedure of SAS (SAS Institute, 1990). Laying hen performance and egg characteristics data were analyzed as a completely randomized design with age of hens, supplementation with adipic acid, dietary inclusion of DDGS, and their interactions as fixed effects. In the analysis of the ending weight, the starting weight was included in the model as a linear covariate. Results obtained for excreta pH, DM, and N loss were also analyzed as a completely randomized design. In these analyses, the explanatory variables were the supplementation with adipic acid, the dietary inclusion of DDGS, the amendment with SBS, and their interactions. The effect of collection date on excreta measurements and its interactions with the aforementioned variables were also evaluated using the PROC MIXED procedure. A cage with 2 hens was the experimental unit for results on egg production and characteristics (36 replicates per diet). A block of 6 consecutive cages constituted the experimental unit for feed intake and conversion and excreta traits (6 replicates per diet). The significance level of the main effects was set at $P <$

Table 2. Effect of dietary adipic acid and corn dried distillers grains with solubles (DDGS) on egg production, egg weight, egg mass, and feed conversion in 26- to 34-wk-old laying hens

Item	Adipic, %	DDGS, %	Egg production,[1] %	Egg weight,[1,2] g	Egg mass,[1] g/d	Feed conversion,[3] g of feed/g of egg mass
Age, wk						
26 to 30	0	0	96.3	57.5	55.4	1.78
	0	20	96.6	57.7	55.7	1.76
	1	0	95.7	57.3	54.8	1.83
	1	20	96.2	57.9	55.7	1.75
30 to 34	0	0	95.7	58.2	55.8	2.31
	0	20	96.5	60.3	58.2	2.18
	1	0	95.4	58.4	55.7	2.22
	1	20	96.7	58.9	57.0	2.24
SEM			0.85	0.46	0.65	0.04
Source of variation, *P*-value						
Age			0.85	<0.001	0.009	<0.001
Adipic			0.66	0.32	0.30	0.95
DDGS			0.21	0.013	0.008	0.09
Age × adipic			0.70	0.35	0.71	0.63
Age × DDGS			0.61	0.19	0.18	0.87
Adipic × DDGS			0.79	0.40	0.78	0.43
Age × adipic × DDGS			0.92	0.12	0.35	0.13
Main effects means						
26 to 30			96.2	57.6	55.4	1.78
30 to 34			96.1	59.0	56.6	2.24
	0		96.3	58.4	56.3	2.01
	1		96.0	58.1	55.8	2.01
		0	95.8	57.9	55.4	2.04
		20	96.5	58.7	56.7	1.98

[1]Means represent 36 cages per diet at each age, 2 birds per cage.

[2]Means only represent eggs laid during the last 2 consecutive days of each 4-wk period.

[3]Means represent 6 blocks of 6 cages per diet at each age, 2 birds per cage.

0.05, whereas the interactions were considered significant at $P < 0.10$.

RESULTS AND DISCUSSION

Hen Performance

Laying hen BW change from 26 to 34 wk of age (average BW at 34 wk = 1,513 g/hen) as well as feed intake (112 g/d per hen, on average), egg production (96.1%), and egg specific gravity (1.079 g/g) were not affected by dietary inclusion of adipic acid or that of DDGS. Dietary supplementation with adipic acid did not affect egg weight or mass, but feeding 20% DDGS diets to hens increased egg weight (58.7 vs. 57.9 g; $P = 0.013$) and egg mass (56.7 vs. 55.4 g/d; $P = 0.008$) as compared with hens fed diets with no DDGS (Table 2). Albeit not significant ($P = 0.09$), there was a trend toward improved feed conversion (1.98 vs. 2.04 g of feed/g of egg mass) in hens fed 20% DDGS diets as compared with those fed the no DDGS diets.

Masa'deh et al. (2011) did not detect any effect of feeding 20% corn DDGS to 24- to 46-wk-old laying hens on feed intake, weight gain, or egg production. These authors found that egg weight tended (59.0 vs. 60.6 g; $P = 0.064$) to be reduced in hens fed 20% DDGS diets in comparison with hens fed diets with no DDGS. Roberson et al. (2005) also reported a linear decrease ($P = 0.03$) in egg weight of 63-wk-old laying hens as dietary corn DDGS concentration increased, but feeding DDGS had no effect on egg production or egg weight in 49-wk-old hens. In the studies of Wu-Haan et al. (2010) and Swiatkiewicz and Koreleski (2006), including up to 20% DDGS in laying hen diets did not have any influence on feed intake, laying rate, or daily mass of eggs from 21 to 26 and from 26 to 43 wk of age, respectively. Nonetheless, some other work can also be cited in agreement with the present one. As early as in 1973, it was already observed that dietary DDGS could improve egg weight when fed in a corn-based diet (Jensen, 1973). More recently, Pineda et al. (2008) reported that eggs of hens fed isocaloric diets including from 23 up to 69% corn DDGS were linearly heavier ($P < 0.01$), in parallel with the increase of dietary DDGS concentration which, nonetheless, was accompanied by an increase in dietary CP content (from 18.2 up to 21.9%).

Egg Quality

During the 30- to 34-wk period, the largest proportion of albumen and the lowest proportion of yolk were recorded in the eggs of hens fed the adipic acid-free diet containing 20% DDGS, whereas no differences were revealed among dietary treatments from 26 to 30 wk (Table 3). Eggshell percentage was respectively reduced by 1.8 ($P = 0.012$) and 3.1% ($P < 0.001$) with dietary adipic acid and DDGS. Apart from Roberson et al. (2005), who found that inclusion of DDGS in lay-

Table 3. Effect of dietary adipic acid and corn dried distillers grains with solubles (DDGS) on egg specific gravity, albumen, yolk, and shell proportions, and albumen plus yolk solids in 26- to 34-wk-old laying hens

Item	Adipic, %	DDGS, %	Specific gravity,[1] g/g	Albumen,[1] %	Yolk,[1] %	Shell,[1] %	Albumen + yolk solids,[2] g/egg
Age, wk							
26 to 30	0	0	1.079	64.0[c]	26.8[a]	9.21	—
	0	20	1.080	64.0[c]	26.8[a]	9.11	—
	1	0	1.082	64.3[bc]	26.6[a]	9.16	—
	1	20	1.080	64.5[bc]	26.7[a]	8.85	—
30 to 34	0	0	1.078	64.2[bc]	26.6[a]	9.14	23.8[c]
	0	20	1.077	65.4[a]	25.9[b]	8.74	24.8[a]
	1	0	1.079	64.7[b]	26.4[a]	8.92	24.2[bc]
	1	20	1.077	64.5[bc]	26.8[a]	8.62	24.3[ab]
SEM			0.00114	0.268	0.250	0.091	
Source of variation, P-value							
Age			0.001	0.002	0.040	<0.001	—
Adipic			0.19	0.40	0.99	0.012	0.97
DDGS			0.22	0.14	0.99	<0.001	0.005
Age × adipic			0.29	0.25	0.20	0.93	—
Age × DDGS			0.50	0.51	0.77	0.24	—
Adipic × DDGS			0.34	0.12	0.16	0.65	0.02
Age × adipic × DDGS			0.60	0.041	0.080	0.22	—
Main effects means							
26 to 30			1.080	64.2	26.7	9.08	—
30 to 34			1.077	64.8	26.4	8.86	—
	0		1.078	64.4	26.5	9.05	24.3
	1		1.079	64.6	26.5	8.89	24.3
		0	1.079	64.3	26.5	9.11	24.0
		20	1.078	64.6	26.5	8.83	24.6

[a–c]Means within a column with different superscripts differ significantly ($P < 0.05$).

[1]Means represent 36 cages per diet at each age, 2 birds per cage. Eggs were collected during the last 2 consecutive days of each 4-wk period.

[2]Means represent 36 cages per diet (2 birds per cage). This parameter was only determined for the last 2 d of wk 34.

ing hen diets was responsible for a decrease of specific gravity in 51-wk-old laying hens, no other work (Lumpkins et al., 2005; Swiatkiewicz and Koreleski, 2006; Masa'deh et al., 2011) observed any effect of feeding up to 20% corn DDGS on shell characteristics or specific gravity, which is thought to be a good indicator of shell quality. From 30 to 34 wk, no differences were observed for albumen plus yolk solids when diets of laying hens included adipic acid, but egg solids increased by 4.2% ($P < 0.001$) in hens not fed adipic acid when DDGS were incorporated in the diet.

As reported in Table 3, albumen proportion increased with age (64.8 vs. 64.2%; $P = 0.002$), whereas shell proportion was lower at 34 than at 30 wk of age (8.86 vs. 9.08%; $P < 0.001$). Likewise, specific gravity also decreased at 34 wk (1.077 vs. 1.080 g/g; $P = 0.001$). As noted in previous research (Etches, 1996; Romero et al., 2012), age of laying hens is well known to affect albumen and shell proportions in the way it was observed in this work.

Effect of Dietary Treatments on Excreta Moisture, pH, and Nitrogen Loss

No dietary effects were revealed on excreta DM content on collection day (Table 4). After 7 d of storage, no differences on the DM percentage were observed in the excreta from hens that had been fed 1% adipic acid (45.2%, on average), whereas the dietary inclusion of DDGS in the diet without adipic acid increased excreta DM content by 8.84% ($P < 0.001$). The effects of dietary inclusion of adipic acid and DDGS on excreta DM were lost by d 14 of storage.

On collection day, a synergy ($P = 0.014$) between dietary adipic acid and DDGS was detected on excreta pH (Table 5). Both the adipic acid-free diet with 20% DDGS and the diet with 1% adipic acid but no DDGS reduced excreta pH with respect to the control diet devoid of adipic acid and DDGS. However, excreta pH was reduced even further when both adipic acid and DDGS were included in the diet, reaching the lowest value (5.97) for hens fed the latter diet. Excreta pH below neutrality is typical from laying hens, but due to microbial activity, it rapidly increases, thus shifting the NH_3/NH_4 ratio and increasing the potential of NH_3 volatilization (Romero et al., 2012).

After 7 d of excreta storage, the interaction between dietary adipic acid and DDGS was still found to be significant ($P = 0.04$). Thus, no differences appeared between the 2 diets containing 20% DDGS (the excreta pH averaged 8.38), whereas in diets without DDGS the inclusion of 1% adipic acid decreased excreta pH 0.31 units ($P = 0.008$) with respect to the control diet (average excreta pH = 8.91), although the pH was still higher than in the excreta of hens fed DDGS (8.60 vs. 8.38; $P < 0.04$). After 14 d of storage, the effect of dietary adipic acid on excreta pH was lost, but the pH was still lower in the excreta originating from hens fed 20% DDGS (8.91 vs. 9.21; $P < 0.001$). However, in all treatments with pH being high would shift a loss of a

Table 4. Effect of dietary adipic acid and corn dried distillers grains with solubles (DDGS) and excreta amendment with sodium bisulfate (SBS) on DM content of excreta from 26- to 34-wk-old laying hens stored for 14 d at room temperature (22 ± 2°C)

			Excreta DM,[1] %		
			Days of storage		
Item	DDGS, %	SBS, %	0	7	14
Adipic, %					
0	0	No	45.2	46.3	41.1
0	0	Yes	—	46.5	47.9
0	20	No	47.5	48.9	43.4
0	20	Yes	—	52.1	51.7
1	0	No	42.5	44.3	40.7
1	0	Yes	—	45.9	46.6
1	20	No	43.6	44.4	40.2
1	20	Yes	—	46.2	46.2
SEM			2.31	1.18	2.03
Source of variation, *P*-value					
Adipic			0.16	<0.001	0.072
DDGS			0.46	0.011	0.37
SBS			—	0.046	<0.001
Adipic × DDGS			0.81	0.021	0.22
Adipic × SBS			—	0.99	0.58
DDGS × SBS			—	0.33	0.78
Adipic × DDGS × SBS			—	0.39	0.81
Main effects means					
0			46.3	48.4	46.1
1			43.1	45.2	43.4
	0		43.8	45.7	44.1
	20		45.6	47.9	45.4
		No	—	46.0	41.4
		Yes	—	47.7	48.1

[1]Means represent 12 excreta samples per diet and postexcretion amendment (6 excreta samples collected per diet at 2 separate time points; no significant effect of collection date). Excreta were collected over 48 h from 6 cages (2 hens/cage), mixed, and subdivided into postexcretion (SBS supplemented at 8.8 kg/100 m^2 or were unsupplemented).

Table 5. Effect of dietary adipic acid and corn dried distillers grains with solubles (DDGS), and excreta amendment with sodium bisulfate (SBS) on pH of excreta from 26- to 34-wk-old laying hens stored for 14 d at room temperature (22 ± 2°C)

			Excreta pH[1]		
			Days of storage		
Item	DDGS, %	SBS, %	0	7	14
Adipic, %					
0	0	No	6.38	9.03	9.27
0	0	Yes	6.38	8.78	9.19
0	20	No	6.09	8.59	9.01
0	20	Yes	6.09	8.14	8.82
1	0	No	6.10	8.85	9.30
1	0	Yes	6.05	8.35	9.08
1	20	No	5.98	8.72	8.99
1	20	Yes	5.96	8.06	8.82
SEM			0.053	0.11	0.046
Source of variation, *P*-value					
Adipic			<0.001	0.046	0.48
DDGS			<0.001	<0.001	<0.001
SBS			0.62	<0.001	<0.001
Adipic × DDGS			0.014	0.040	0.70
Adipic × SBS			0.70	0.15	0.39
DDGS × SBS			0.86	0.26	0.72
Adipic × DDGS × SBS			0.79	0.89	0.22
Main effects means					
0			6.24	8.64	9.07
1			6.02	8.50	9.05
	0		6.23	8.76	9.21
	20		6.03	8.38	8.91
		No	6.14	8.80	9.14
		Yes	6.12	8.34	8.98

[1]Means represent 12 excreta samples per diet and postexcretion amendment (6 excreta samples collected per diet at 2 separate time points; no significant effect of collection date). Excreta were collected over 48 h from 6 cages (2 hens/cage), mixed, and subdivided into postexcretion (SBS supplemented at 8.8 kg/100 m^2 or were unsupplemented).

Table 6. Effect of dietary adipic acid and corn dried distillers grains with solubles (DDGS), and excreta amendment with sodium bisulfate (SBS) on N loss from excreta of 26- to 34-wk-old laying hens stored for 14 d at room temperature (22 ± 2°C)

			Nitrogen loss,[1] %		
			Days of storage		
Item	DDGS, %	SBS, %	0–7	7–14	0–14
Adipic, %					
0	0	No	25.6	20.0	41.6
0	0	Yes	10.3	20.8	29.5
0	20	No	24.2	22.1	43.1
0	20	Yes	17.1	21.1	35.1
1	0	No	19.0	24.2	39.0
1	0	Yes	10.4	19.2	27.9
1	20	No	32.9	24.8	50.8
1	20	Yes	21.8	16.7	36.4
SEM			5.34	5.50	5.61
Source of variation, *P*-value					
Adipic			0.59	0.95	0.70
DDGS			0.018	0.96	0.039
SBS			0.001	0.30	<0.001
Adipic × DDGS			0.12	0.74	0.31
Adipic × SBS			0.84	0.32	0.68
DDGS × SBS			0.66	0.70	0.95
Adipic × DDGS × SBS			0.40	0.91	0.56
Main effects means					
0			19.3	21.0	37.3
1			21.0	21.2	38.6
	0		16.3	21.0	34.5
	20		24.0	21.2	41.3
		No	25.4	22.8	43.6
		Yes	14.9	19.4	32.2

[1]Means represent 12 excreta samples per diet and postexcretion amendment (6 excreta samples collected per diet at 2 separate time points; no significant effect of collection date). Excreta were collected over 48 h from 6 cages (2 hens/cage), mixed, and subdivided into postexcretion (SBS supplemented at 8.8 kg/100 m^2 or were unsupplemented). N loss refers to the amount of N present in the excreta samples on d 0.

proton from NH_4 to NH_3 and thus volatilization of N as NH_3. Although dietary supplementation with adipic acid had no influence on excreta N loss during storage, excreta from hens fed 20% DDGS lost 47.2% more N ($P = 0.018$) during the first 7 d of storage than hens not eating DDGS (Table 6) and for the whole length of the storage period; feeding 20% DDGS to the hens increased N loss by 19.7% ($P = 0.039$). The increment in excreta pH observed in the current work after 7 d of storage is fully consistent with values measured in stored excreta in previous studies (Jiménez-Moreno et al., 2009; Romero et al., 2012).

In the present study, dietary supplementation with 1% adipic acid increased moisture content in stored excreta, reduced excreta pH on collection day and on d 7 of storage, but lost its effect on d 14 and did not control N loss. Jiménez-Moreno et al. (2009) also reported that feeding 1% adipic acid to broilers reduced pH in 7-d stored excreta, whereas no differences were detected after 14 d of storage. Contrary to this work, van Kempen (2001) managed to decrease ($P < 0.05$) NH_3 emission by 25% in pigs fed a diet supplemented with 1% adipic acid. In the latter study (van Kempen, 2001), adipic acid had a strong effect on reducing urinary pH, but this effect disappeared in manure pH because of the buffering capacity that feces have on urine. This could explain why in the current work the adipic acid effect on excreta pH was lost during storage. Excreta pH was sharply decreased, even after 7 d of storage, in laying hens fed a diet containing 5.76% $CaSO_4$ (Romero et al., 2012). Even though adipic acid is a stronger acid than $CaSO_4$, the dietary supplementation rate used in the present work may have been too low to maintain the pH lowering effect during storage. Based on the foregoing, it could be thought that the low dietary inclusion of adipic acid and the buffer effect of the undigested feedstuff accounted for a mitigated reduction of excreta pH that was not great enough to control N loss in the current study.

The dietary inclusion of 20% DDGS resulted in a reduction of the excreta pH greater and more time-consistent than that caused by adipic acid. In agreement with this result, Pineda et al. (2008) reported a linear decrease ($P < 0.01$) of laying hen excreta pH with increasing dietary concentrations of corn DDGS. In fact, a 0.13 pH-unit reduction was achieved with a 23% dietary inclusion of DDGS in the mentioned work. Usually, manure pH and NH_3 emission have been directly related (Canh et al., 1998). However, in this work, the N loss from excreta of hens fed 20% DDGS diets was unexpectedly higher than that of hens eating no DDGS. This result contradicts the findings of Roberts et al. (2007b) and Wu-Haan et al. (2010). Roberts et al. (2007b) reduced ($P < 0.01$) NH_3 emissions per hen by 38.5% with feeding diets including 10% corn DDGS, and in the study of Wu-Haan et al. (2010), daily NH_3 emissions decreased by 24% ($P < 0.05$) when 21- to 26-wk-old laying hens were fed diets containing 20%

corn DDGS. In this particular study, manure remained relatively wet (44.8% DM) after 14 d of storage, and thus may have influenced excreta microbial activity differently, and thus N loss, versus that observed by Roberts et al. (2007b) and Wu-Haan et al. (2010). Thus for future studies, moisture content of the manure during storage should be a managed or experimental variable.

Nevertheless, numerous studies (Batal and Dale, 2006; Waldroup et al., 2007) have reported low digestibility coefficients for Lys, Cys, and Thr in DDGS, which results very frequently in an increased N excretion in poultry and swine fed diets containing high levels of DDGS (Adeola and Ileleji, 2009; Jarret et al., 2011). In the current work, feeding 20% DDGS may have greatly increased the excreta N content, resulting thereafter in greater losses of N. Future studies, therefore, should consider analyses of form of N, either as undigested feed protein or uric acid and the influence on NH_3 volatilization during excreta storage, particularly when lower digestible ingredients are fed.

Effect of Excreta Amendment with Sodium Bisulfate on Excreta Moisture, pH, and Nitrogen Loss

The effect of postexcretion amendment with SBS on excreta DM content was maintained for 14 d of storage, as at both 7 and 14 d of storage, excreta amended with SBS presented higher DM percentage (47.7 vs. 46.0%; $P = 0.046$ and 48.1 vs. 41.4%; $P < 0.001$ on d 7 and 14 of storage, respectively). On d 7 of storage, the surface amendment with SBS resulted in a 0.46-unit reduction of excreta pH ($P < 0.001$; Table 5) and in a 41.3% ($P = 0.001$) decrease of N loss from the 7-d stored excreta. These effects could also be observed for the whole length of the storage period, as pH was still lower in treated excreta samples on d 14 of storage (8.98 vs. 9.14; $P < 0.001$), and N loss was globally reduced by 26.1% ($P < 0.001$) with the amendment of excreta.

Among the different strategies tested (adipic acid, DDGS, and SBS) in the current work to control N loss from laying hen excreta, the surface amendment of excreta with sodium bisulfate appeared as the only one that was effective. Thus, spreading SBS on the top surface of excreta increased its DM content, with the effect being even more marked on d 14 of storage (increase of 6.7 percentage units; $P < 0.001$), consistently decreased excreta pH during storage and led to an 11.4 percentage point reduction of N loss for the whole length of the storage period. The amount of NH_3 that volatilizes from animal manure is greatly conditional upon manure pH, as lower pH values shift the $[NH_3]/[NH_4^+]$ equilibrium (pKa = 9.3) toward NH_4^+, which is more soluble and less volatile than NH_3. Moreover, as reviewed by Mobley and Hausinger (1989), optimum pH for the activity of microbial uricases is alkaline, being in some cases above 8.0. In the trials conducted by Pope and Cherry (2000) in broiler houses, reduced NH_3 release from SBS-treated litter was associated with decreased litter pH, but beyond the controlling effect that acidity is assumed to have on NH_3 emissions, these authors ascribe the ability of SBS to effectively reduce atmospheric NH_3 levels in the farms to chemical interaction of sodium bisulfate with uric acid and to decreased counts of bacteria generating NH_3 from excreted uric acid. As it has been observed in the present work for pH and N loss from stored excreta, Pope and Cherry (2000) noted that the decreasing effect of SBS on litter pH and NH_3 concentration at floor level remained 2 wk after litter treatment. More recent research (Xin et al., 2006; Chois and Moore, 2008) has also reported sharp decreases (from 74 up to 92%) in NH_3 volatilization from SBS-enriched litter in comparison with control groups. In the present work, amending excreta with SBS reduced N loss by 26.1%. This difference in SBS effectiveness with respect to the aforementioned studies is certainly due to differences in the application rate of the product. Thus, in this work, SBS was applied at the rate suggested by the manufacturer's use instructions (8.8 kg/100 m^2), whereas Pope and Cherry (2000) and Xin et al. (2006) applied it at 24 kg/100 m^2 and 50 to 150 kg/m^2, respectively. In fact, Moore et al. (1996) attributed the lack of differences in N losses between SBS-treated and control litter to the low rate at which they applied the SBS (2 g of SBS/100 g of litter).

In conclusion, feeding 20% DDGS diets to 26- to 34-wk-old laying hens increased daily egg mass, resulted in a reduced pH in excreta stored up to 14 d at room temperature, and unexpectedly increased N loss from excreta. Dietary supplementation with adipic acid had a weaker and less time-consistent decreasing effect on excreta pH than dietary DDGS and did not affect N loss during storage. Surface amendment of excreta with sodium bisulfate increased excreta DM content, with the effect being even more marked on d 14 of storage, consistently decreased excreta pH during storage, and reduced N loss by 26.1% for the whole length of the storage period.

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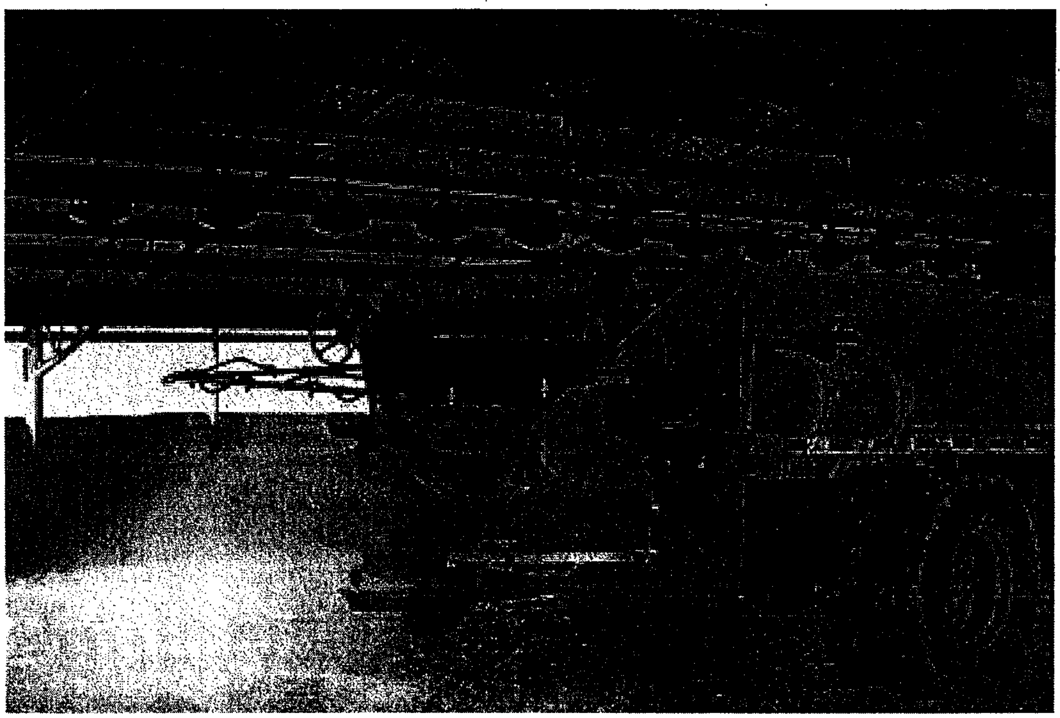
ORGANIC PRODUCTS
Labels

Poultry Litter Amendments



(Photo courtesy of C. Kim, General Chemical Corp.)

Figure 1. Al+Clear (alum) being applied inside a poultry house using a spinner spreader. Sprinkling water helps reduce dust levels during application and activates the amendment.

High ammonia levels in poultry houses can result in poor bird performance and health and a loss of profits to the grower and integrator. When broilers and turkeys are raised on litter, amendments (Figure 1) can be used to reduce ammonia levels in the houses and improve productivity.

Broiler and turkey litter typically consists of wood shavings, rice hulls, or peanut hulls. Uric acid and organic nitrogen (N) in the bird excreta and spilled feed are converted to ammonium (NH_4^+) by the microbes in the litter. Ammonium, a plant-available N form, can bind to litter and also dissolve in water. Depending on the moisture content, temperature, and acidity of the litter, a portion of the ammonium will be converted into ammonia (NH_3). Ammonia production is favored by high temperature and high pH (i.e., alkaline conditions).

Ammonia is a pungent gas that irritates the eyes and respiratory system and can reduce resistance to infection in poultry. At high-enough concentrations, ammonia will reduce feed efficiency and growth while increasing mortality and carcass condemnations. The result is economic loss to the grower and integrator. Carlile (1984) recommended limiting ammonia concentration in poultry houses to 25 parts per million (ppm) or less. However, Blake and Hess (2001) reported that continuous exposure to ammonia concentrations as low as 10 ppm can damage a bird's respiratory system and increase the risk of infectious disease.

Due to the high price of wood shavings and the increasing scarcity of land available for litter application, complete poultry house cleanouts may be done only once every two years or longer. Only the crust or cake (top portion of the litter) may be removed after each flock. The increased duration between complete cleanouts results in a greater buildup of litter and ammonia. Because chicks are more susceptible to the negative effects of ammonia, placing broods in houses with high levels of

Worley et al. (2000) compared gas usage, bird performance, darkling beetle populations, and litter composition with alum applied at 100 and 200 pounds per thousand square feet to northern Georgia broiler houses between flocks. Ventilation rates were increased when ammonia concentrations exceeded 25 ppm. While ammonium was higher and soluble P was lower in the litter with the higher application rate, gas usage, bird performance, feed conversion, and mortality were unaffected by application rate. The higher alum application rate reduced darkling beetle populations, compared with the lower application rate. Worley et al. concluded that 100 pounds per thousand square feet of alum provided adequate ammonia management.

In a study of 194 broiler houses in Delaware, Maryland, and Virginia, half of which received alum (average of 287 pounds per thousand square feet per application), the alum treatment increased total N by 5.4 pounds per ton, ammonium by 4.4 pounds per ton, and sulfur by 23.2 pounds per ton above control litter concentrations (Sims and Luka-McCafferty, 2002). Alum reduced soluble fractions of P by 67 percent, arsenic by 63 percent, copper by 37 percent, and zinc by 48 percent, compared with untreated litter. Thus, alum increased the litter's fertilizer value and reduced the potential of P and heavy metal pollution. Soluble P and metal concentrations in the litter changed very little in the range of aluminum to P ratios of 0.2 to 1.0, while to obtain higher ammonium in the litter, a ratio greater than 0.6 was required. Sims and Luka-McCafferty suggested that further studies would be required to determine the most effective and economic alum application rate to achieve different production and environmental objectives.

Poultry Guard

McWard and Taylor (2000) evaluated the impact of Poultry Guard on ammonia levels and broiler performance in Colorado over 48 days. When applied at 112 pounds per thousand square feet to litter, Poultry Guard-treated pens had ammonia concentrations of about 12 to 20 ppm, compared with 60 to 85 ppm in the untreated pens during the first 28 days. For the remainder of the study, the treated pens had ammonia concentrations of 40 ppm, at least 20 ppm lower than the untreated pens. The litter amendment increased broiler body weight by 5 percent, improved carcass quality, and reduced breast blisters, foot-pad dermatitis, and air-sac lesions. McWard and Taylor attributed improved bird performance to reduced ammonia levels in the house. They also found Poultry Guard offered the potential to reduce darkling beetle populations.

In another study, Poultry Guard, with 40 percent sulfuric acid, applied at 25, 50, 100, and 150 pounds per thousand square feet reduced salmonella levels in the litter by 74 percent, 83 percent, 98 percent, and nearly 100 percent, respectively, compared to no amendment (Watkins et al., 2002).

Poultry Litter Treatment (PLT)

Pope and Cherry (2000) compared the impact of using PLT on ammonia levels and bacterial loads in broiler houses in Texas. PLT was applied at 50 pounds per thousand square feet in the half-house brooding area one day prior to placement, at 50 pounds per thousand square feet to the off chamber (non-brooded area) just before migration, and then at 50 pounds per thousand square feet to the whole house one week before processing. During weeks 0, 1, and 2, the PLT-treated houses had ammonia concentrations of 6, 18, and 11 ppm, compared with 62, 28, and 20 ppm, respectively, in the untreated houses. No ammonia data were presented for the later weeks. Due to litter acidification, bacterial loads in the litter were greatly reduced prior to stocking. Under commercial conditions, Pope and Cherry said that PLT may reduce bird pathogen levels entering the processing plant. Line (2002) also reported that PLT (and alum) reduced Campylobacter infections in broiler chicks.

Terzich et al. (1998a, 1998b) evaluated the effect of PLT on ammonia levels, body weight, respiratory-tract lesions, and death due to ascites in broilers grown on used litter. PLT applied at

Adsorbers

Naturally occurring materials like clinoptilolite (a type of zeolite, a natural clay mineral) and peat tend to adsorb ammonia (i.e., bind on the surface instead of absorb). However, the performance of clinoptilolite has been mixed. Nakaue et al. (1981) reported modest reductions in ammonia levels in the poultry house, while Amon et al. (1997) reported large increases in ammonia levels when clinoptilolite was applied to litter. Researchers in Finland used peat as litter material in poultry houses and reported lower ammonia levels. However, in North Carolina, using peat as litter in place of the cheaper and more abundant wood shavings may not be economically attractive.

Inhibitors

Inhibitors slow the conversion of uric acid and urea to ammonia by inhibiting enzymes and microorganisms. Phenyl phosphorodiamidate inhibits urease activity, reducing conversion of urea into ammonia (McCrory and Hobbs, 2001). However, McCrory and Hobbs report that inhibitors are currently too expensive and too easily broken down to be practical or economical to growers.

Microbial and enzymatic treatments

Such treatments may consist of beneficial microbes and enzymes that create the right environment in the litter to convert uric acid and urea rapidly into ammonia. The manufacturers of these products say that such treatments allow microbes to work in suboptimal conditions in the litter or improve the conditions in the litter to enhance performance of the microbes or the enzymes. Venting the produced ammonia during layout will result in lower ammonia levels when the chicks are placed in the house later. One microbial product, USM-98, marketed by UAP Southwest [(903) 855-0481] of Pittsburg, Texas, was evaluated in North Carolina by UAP Southwest, which reported that the product reduced ammonia levels, improved bird weight, and reduced mortality and crust loads. However, since the above statements come from studies not published in scientific journals, they were not reviewed by impartial scientists. Further, venting ammonia into the environment degrades air quality.

Summary

High ammonia levels in the poultry house can reduce bird performance and health, reducing profits to the grower and integrator. Using litter amendments after each flock is removed can reduce these ammonia levels, and it may also decrease energy use by reducing ventilation needs during the winter.

Acidifiers, the most widely used type of amendment, lessen ammonia levels by converting ammonia to ammonium. Reducing ammonia losses will also improve the fertilizer value of the litter. Odor complaints from neighbors may be reduced. Pathogen and pest levels may decrease, too.

A grower or applicator should follow the instructions provided by the manufacturer or supplier on how and when to apply the amendment to make sure that the material is fully activated and effective. Different amendments may require different application or activation methods. Personal protective equipment should be worn while applying amendments—at a minimum, protective gloves, long pants, a long-sleeved shirt, goggles, and a mask (to guard against "dust" from granular material). The grower/applicator should obtain a Material Safety Data Sheet (MSDS) from the supplier to be aware of the hazards associated with use of the material. The MSDS also will be useful to emergency responders in case of an accident.

Table 1. Summary of Commercially Available Acidifier-Type Poultry Litter Amendments

Amendments	Al+Clear	Poultry Guard	Poultry Litter Treatment (PLT)
Manufacturer	General Chemical Corp. genchemcorp.com 1-800-631-8050	Oil Dri Corp. poultryguard.com 1-800-643-3064	Jones Hamilton Co. jones-hamilton.com 1-800-379-2243
Common name; chemical formula	Alum; aluminum sulfate [$Al_2(SO_4)_3 \cdot 14H_2O$]	Acidified clay; 36% sulfuric acid (H_2SO_4) soaked in a type of clay	PLT; 93% sodium bisulfate ($NaHSO_4$)
Type of product	Solid (powder+granules) or liquid	Granules	Granules
Controls ammonia[1]	Yes	Yes	Yes
Potential to neutralize mass of ammonia per 100 lb product[2]	17.0 (solid) 8.6 (liquid)[3]	12.5	13.3
Improves bird health & performance[1]	Yes	Yes	Yes
Saves energy[1]	Yes	Not evaluated but likely	Yes (company research)
Reduces darkling beetles[1]	Yes	Yes	Yes
Reduces pathogens[1]	Yes	Yes	Yes
Reduces loss of P & soluble metals in runoff[1]	Yes[4]	Not evaluated	Not evaluated
Manufacturer recommended application rate after each growout (lb/1,000 sq ft)	50-75 75 (litter with more than 5 flocks, short layouts or extremely dry litter)	50 75-100 (litter older than 1 yr, deep litter, shorter layouts)	50-75 75-100 (litter with more than 5 flocks or layouts less than 10 days)
Application timing before placing chicks[5]	0-7 days depending on litter conditions	0-3 days	1-24 hours
Application method[6]	Surface-apply on dry litter; mix into top ½ in. and re-level in wet litter	Surface-apply	Surface-apply
OSHA Communication Standard for safety	Hazardous[7]	Corrosive	Mild irritant[8]
2004/05 price (per ton)[9]	$86[10] $355[11] $473[12]	$438-500	$373 (bulk) $398 (50 lb bag)

[1] Based on published, scientific research.
[2] All dry acids require sufficient moisture for activation; with inadequate moisture, ammonia removal will be reduced.
[3] 8.7 gallons of liquid equal to 100 lb.
[4] Heavier application rates (for instance, 275-300 lb/1,000 sq ft) required for substantial (about 70-75%) reduction in P losses in runoff (based on published literature).
[5] Between growouts on litter on which at least one flock has been raised.
[6] Drop spreader preferred for solids to get uniform application.
[7] Hazardous only if quantity greater than 8,700 lb per Material Safety Data Sheet (MSDS).
[8] Generally regarded as safe (GRAS) as a food additive by FDA.
[9] Provided for general guidance by manufacturer/supplier; price based on location, volume, and purchase source.
[10] For liquid delivered to Raleigh, NC.
[11] For Al+Clear by the truckload, FOB Wilmington, DE.
[12] 50 lb. bag, retail.

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Ancillary effects of different acidifier application rates in roaster houses[1]

S. B. Shah,*[2] P. W. Westerman,* J. L. Grimes,† E. O. Oviedo-Rondón,† and D. Campeau‡

**Department of Biological and Agricultural Engineering, and †Prestage Department of Poultry Science, North Carolina State University, Raleigh 27695; and ‡North Carolina Cooperative Extension, Pittsboro 27312*

Primary Audience: Flock Supervisors, Production Managers, Researchers, Extension Agents

SUMMARY

High ammonia levels in broiler houses can reduce bird performance. Broiler producers commonly use acidifiers to reduce ammonia build-up. In addition to improving broiler performance, acidifiers can also provide other ancillary benefits such as reducing propane and electricity use and increasing cake (caked litter) N content. In this 2-yr study involving 9 flocks, 4 levels of an acidifier (sodium bisulfate) were applied to commercial roaster houses in eastern North Carolina. The control treatment had a sodium bisulfate application rate of up to 0.1 lb/ft^2 to the brood chamber, whereas the high, medium, and low treatments had application rates of up to 0.3, 0.15, and 0.1 lb/ft^2, respectively, to the whole house. No treatment effect was observed on propane or electricity use. However, compared with published studies involving smaller broilers, roasters required lesser amounts of propane and electricity. Linear regressions of propane and electricity use as a function of ambient temperature may help with decision making in roaster production. Brooding accounted for 88% of propane consumption. Reduced pH in the high treatment compared with the other treatments led to significantly higher ammonium concentration in the cake.

Key words: propane, electricity, ammonia, nitrogen, fertilizer value, sodium bisulfate

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DESCRIPTION OF PROBLEM

Broiler producers commonly use acidifying litter amendments, such as aluminum sulfate [**ALS**; $Al_2(SO_4)_3.14H_2O$] and sodium bisulfate (**SBS**; $NaHSO_4$) to reduce ammonia (**NH_3**) buildup in broiler houses [1]. Acidifiers reduce NH_3 buildup in the litter by speeding up its conversion into the nonvolatile ammonium (**NH_4**) ion and by inhibiting the bacteria that are involved in NH_3 formation. By reducing in-house NH_3 concentrations, acidifiers can improve broiler performance [2, 3]. Acidifiers may also provide other ancillary benefits, such as reduced propane and electricity use [3] and increased fertilizer value of the litter due to greater NH_4 concentration [4]. Reduced energy use in acidifier-treated houses is due to lower winter ven-

[1]The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service or the North Carolina Cooperative Extension Service of the products mentioned nor criticism of similar products not mentioned.
[2]Corresponding author: sanjay_shah@ncsu.edu

tilation needs during brooding because of lower NH_3 levels than untreated houses [3].

However, the ancillary effects of acidifier use have not been evaluated in roaster houses. Roasters are broilers that are removed at 8 to 12 wk of age [5] and weigh ≥4 kg. Energy savings and litter N conservation in 42-d broilers studied by Moore et al. [3] and Worley et al. [4] may not apply to roasters because of their longer grow-out periods and higher protein diets. Hence, the overall objective of this research was to evaluate the ancillary effects of 4 SBS application rates in commercial roaster houses over 9 roaster flocks covering 2 yr. The specific objectives were to evaluate SBS application rate effects on (1) propane use, (2) electricity use, and (3) cake (caked litter) total N and total ammoniacal-N (**TAN**; determined by NH_3-N + NH_4-N) concentrations. Following the broiler integrator's litter treatment program, SBS [6] was used in this study; 100 lb of SBS can neutralize 16 lb of NH_3. Acidifier application rate effects on NH_3 emissions, inside NH_3 concentrations, and bird performance will be presented elsewhere.

MATERIALS AND METHODS

This research is one aspect of a larger study conducted on a roaster farm near Tar Heel, in southeastern North Carolina from 2007 to 2009. Materials and methods used in the main study are discussed in greater detail in Shah et al. [7]. Abridged and relevant portions of the Materials and Methods are presented here.

Farm Description and Management

Eight identical broiler houses were used in this study measuring 41× 500 ft, aligned north-south, and built between 2005 and 2006. All the houses were tunnel-ventilated and had evaporative cooling (cool cells and foggers), except for one sidewall that was curtain-sided (approximately 5 × 425 ft) with a thermal resistance or insulation (**R**) value of 1 $h \cdot ft^2 \cdot °F$ per British thermal unit (**BTU**). The end walls and one sidewall of each house were insulated (R = 11 $h \cdot ft^2 \cdot °F/BTU$). The houses had drop ceilings with an R value of about 21 $h \cdot ft^2 \cdot °F/BTU$. Each house had 11 belt-driven 48-in. fans (1-horsepower motor) and three 36-in direct-drive fans (1/2-horsepower motor). Minimum ventilation was provided by the three 36-in. fans and one 48-in. fan, which were timer-controlled. Ten 48-in. fans that were controlled by a thermostat provided mild and hot weather ventilation. Fresh air for cold or mild weather ventilation was brought in through intermittent sidewall inlets, whereas fresh air for hot weather ventilation was brought in through the cool cell pads. Each house was heated with 17 radiant brooders and had its own propane tank and meter. The fans, curtains, brooders, cool cells, and foggers were controlled by an environmental controller that was programmed by the producer based on season, bird age, and bird comfort.

Straight-run day-of-hatch chicks, ranging from 20,000 in summer to 21,300 in winter, were placed in each house, raised to about 9 lb each, and marketed at about 63 d; downtime between flocks was 10 to 21 d. The integrator's guidelines specified desirable room temperatures (**DRT**) based on age [8]; the DRT was the same for all the houses. Obviously, cooling to maintain DRT was limited by the efficiencies of the evaporative cooling systems. The chicks were center-brooded in the middle 40% of the house (brood chamber) for 12 to 14 d and then released into the expansion brood area (70% of floor area) for another week before being released into the whole house. The brood chamber was separated from the rest of the house with plastic curtains on both sides. The birds were fed starter, grower, finisher, and withdrawal diets. After the birds were sold, the house was decaked, that is, the wet, matted fecal cake material (top 1–2 in.) was removed. Litter was completely cleaned out every 2.5 to 3 yr but not during the study.

Treatment and Experimental Designs

There were 4 SBS application rates or treatments (Table 1). Each treatment was applied to a pair of adjacent broiler houses, but electricity and propane usage were measured and litter and cake analyses performed in only one of the 2 houses. Though SBS was applied (Table 1) to the whole house in the high, medium, and low treatments, it was only applied in the brood chamber in the control treatment, consistent with the integrator's standard litter treatment program. Though the integrator guidelines required no SBS use in the midsummer flock, in this study all flocks received SBS 1 d before bird

Table 1. Flock placement dates and durations, modified heating degree days (mHDD) and cooling degree days (mCDD), and sodium bisulfate (SBS) application rate by treatment and flock

Flock no.	Date placed	Duration (d)	mHDD[1] (°F)	mCDD[2] (°F)	SBS application rate (lb/ft²)[3] High[4]	Medium[4]	Low[4]	Control[5]
1	6/22/07	66	187	496	0.075	0.075	0.075	0.075
2	9/14/07	65	700	10	0.195[6]	0.150	0.075	0.075
3	12/7/07	66	1,773	7	0.260[7]	0.150	0.075	0.075
4	3/4/08	64	1,078	51	0.300	0.150	0.100	0.100
5	5/22/08	66	243	387	0.300	0.150	0.100	0.100
6	8/12/08	62	258	73	0.300	0.150	0.100	0.100
7	11/17/08	58	1,636	0	0.300	0.150	0.100	0.100
8	2/10/09	58	1,410	5	0.300	0.150	0.100	0.100
9	4/28/09	63	400	313	0.300	0.150	0.100	0.100
	Average	63	854	149				

[1]Equation (1).
[2]Equation (2).
[3]Conversion: 1 lb/ft² = 4.88 kg/m².
[4]Applied to the whole house.
[5]Applied only to the brood chamber.
[6]A total of 0.150 lb/ft² to the center two-thirds of house with the remaining one-sixth at each end receiving 0.300 lb/ft².
[7]A total of 0.200 lb/ft² to the center brood area with the rest of the house receiving 0.300 lb/ft².

placement. The study began in June 2007 (Table 1), with the first flock being placed on litter that had supported one flock earlier.

In the first flock (Table 1), when all the treatments received the same SBS application rate, bird performances in all 4 houses were very similar [7]; hence, we assumed the bird performance and measurables (e.g., fecal N content) were affected only by the treatment. In the high treatment, based on the NH_3 challenge as confirmed by visual observations of the litter and gas tube NH_3 readings, SBS application rate was gradually increased with each successive flock to reach the target application rate in the fourth flock (Table 1). Lower acidifier application rates in the brood chamber versus the rest of the house in the high treatment in flocks 2 and 3 (Table 1) were done to allow for observation of SBS at rates that were much higher than had been used commercially. No adverse effects were observed. Beginning with the fourth flock, SBS application rates in the low and control treatments were increased to match the increased NH_3 levels resulting from built-up litter.

Measurements and Calculations

Degree Day Calculations. Energy use not only varies with weather conditions but also on heating or cooling demand. Residential and livestock housing insulation levels are based on winter or heating degree days that use a reference temperature of 65°F for the heating season [9]. However, in broiler houses, propane and electricity use are better correlated with the DRT. Accordingly, for every flock, the modified heating degree days (**mHDD**; °F) and modified cooling degree days (**mCDD**; °F) were calculated as shown below.

$$\text{mHDD} = \sum_{n=1}^{n=N} (\text{DRT} - T_{av}), \text{ if DRT} > T_{av}. \quad (1)$$

$$\text{mCDD} = \sum_{n=1}^{n=N} (T_{av} - \text{DRT}), \text{ if DRT} < T_{av}. \quad (2)$$

In equations (1) and (2), n is the number of days of the flock with $n = 1$ being the first day and $n = N$ being the last day. The term T_{av} (°F) is the average daily temperature during the study, obtained by averaging 24 hourly values measured at 6.56-ft height at the State Climate Office of North Carolina weather station in Elizabethtown, North Carolina, the weather station closest to the farm. For other applications, T_{av} in equations (1) and (2) may be substituted with 30-yr average daily temperatures; the 30-yr average daily temperatures are obtained by averaging the maximum and minimum daily temperatures during the period of record for that Julian day. As is clear from Table 1, a flock may have both mHDD and mCDD depending on its placement date and also because young birds need more heating whereas older birds need more cooling.

Energy Use Measurements. Cumulative propane consumption was read weekly on the individual propane meters; these gas volume readings were then converted to liquid volumes using the formula supplied by the propane supplier. Cumulative electricity consumption (kilowatt hours; **kWh**) was measured weekly with electric submeters [10] installed in each of the 4 houses. Propane and electricity use among all the treatments for all the flocks as well as their mean values, expressed per animal unit (**AU**; 1 AU = 500 kg or 1,102 lb of live weight as harvested), are compared graphically. Propane use (gal/AU) was compared among the treatments using ANOVA for flocks 4 through 8 when the high treatment received the same SBS application rate (Table 1); flock 9 was excluded (discussed later). Electricity use (kWh/AU) was compared among the treatments using ANOVA for flocks 4 through 9. If the null hypothesis (SBS application rate did not affect energy use) was rejected, Fisher's LSD was used to compare treatment means. The software package, SAS version 9.3 [11], was used for all statistical analyses. The level of significance (α) of 0.05 was used throughout the study.

Cake Sampling and Analyses. After the birds were removed from each flock, the top 1 to 2 in. of the cake was removed with a decruster. Each house yielded between 8 and 14 loads of cake. Each load of cake was weighed on portable wheel scales (for N balance) and then unloaded in a covered shed. Twelve to twenty scoops (100–200 g each) of cake was randomly collected from each load, mixed thoroughly, and, through subsampling, about 250 g was set aside in a plastic bucket. Cake collected from all the loads, about 2 to 3 kg, was mixed thoroughly and, through subsampling, one 250-g sample for each house was placed in a sealed plastic bag. This sample was transported on ice to the Environmental Analysis Laboratory in Raleigh for analysis; samples were frozen if not analyzed immediately. The cake samples were analyzed for total Kjeldahl N (**TKN**) [12], TAN [13], pH (1 part cake to 5 parts deionized, distilled water) [14], and total solids [15]. Total Kjeldahl N (or total N, as nitrate-N concentrations are very low in cake), TAN, and pH among the treatments were compared using ANOVA for flocks 4 through 9. Means for all the flocks are also presented. If the null hypothesis was rejected, Fisher's LSD was used to compare treatment means. For the last flock, the 2 to 3 kg of mass of cake collected from all the loads in a house was sampled in triplicate and analyzed for TKN, TAN, and pH; total solids was measured in 1 sample only.

RESULTS AND DISCUSSION

Propane Use

As expected, propane use was much higher during winter (Figure 1); averaged for all treatments, propane use during the winter (seventh) flock was 9.5 times higher than the preceding summer (sixth) flock. Because propane use in the low treatment in flock 9 was inexplicably high (Figure 1) during brooding (27 April–14 May, 2009), all treatments in flock 9 were excluded from the statistical analyses and the low treatment in flock 9 was excluded in calculating the mean for all flocks (Figure 1). Averaged over flocks 4 through 8 (Figure 1), though propane use was at least 0.28 gal/AU lower in the control treatment than the other treatments (Figure 1), the treatments were not significantly different ($P = 0.94$). Lack of significance was due to high within-treatment variability introduced by seasonal temperature variations (highly variable mHDD values; Table 1). A propane use pattern similar to the average for flocks 4 through 8 (Figure 1) was observed for the mean values for all flocks (Figure 1), though the mean values were lower because they included 2 additional summer flocks (Table 1).

In Arkansas, ALS use (0.2 lb/bird) reduced propane use by 11% versus control [3]. In Georgia, there was a 31% reduction in propane use in 2 winter flocks with 0.2 lb/ft^2 of ALS [4]. In the current study, even the high treatment did not reduce propane use versus the control treatment

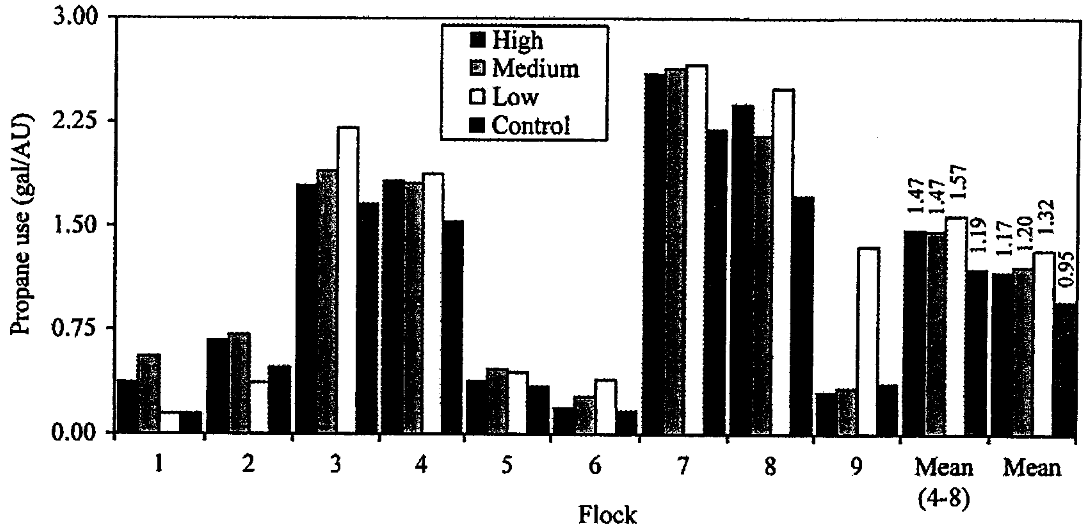

Figure 1. Comparison of propane use among the treatments (described in Table 1). Mean (4–8) is the average propane use for flocks 4 to 8, and Mean is the average of all flocks. For flocks 4 through 8, the treatments were not significantly different ($P = 0.94$). Flock 9 was omitted in calculating Mean (4–8), and the low treatment for flock 9 was omitted in calculating Mean.

in the winter flocks (Figure 1), even though high treatment reduced inside NH_3 concentration by 86% versus the control treatment during brooding [16]. Lack of treatment effect on propane use may be due to differences in minimum ventilation rates versus those studies [3, 4]. In the current study, the producer based the minimum ventilation rate on RH conditions in the barn. When the minimum ventilation rate is based on RH, it is generally adequate for maintaining proper air quality [9], and so the treatments did not affect propane use. However, the practice of reducing the minimum ventilation rate to conserve propane is common. In houses where producers reduce minimum ventilation rates below what are required to maintain desirable RH, fan run times may need to be increased to reduce NH_3 levels. Therefore, houses with acidifier treatments requiring a smaller increase in fan time would consume less propane than those without acidifier. For example, Worley et al. [4] reported that the minimum ventilation timer was adjusted to maintain NH_3 levels below 25 ppm. Also, if the control treatment had not received any SBS, as was the case in the other studies [3, 4], a higher minimum ventilation rate might have been required, which would result in greater propane use versus other treatments.

In northwest Arkansas, propane use in tunnel-ventilated, curtain-sided and solid sidewall houses were 10 and 8.6 gal/AU, respectively, with birds weighing 3.8 to 8.2 lb each [17]. With radiant brooders in old curtain-sided houses on ALS treatment, propane use was about 11.5 gal/AU (3.8 lb/bird and 20,000 birds/house) [3]. In northern Georgia, for the 2 winter flocks (4 lb/bird and 18,000 birds/house) propane use was 10 gal/AU with radiant brooders in curtain-sided houses [4]. Averaged for all the treatments and all 9 flocks (except flock 9 of the low treatment) over 2 yr, in the current study, propane use was 1.2 ± 0.2 gal/AU. Even considering the 2 flocks (7 and 8) with the highest propane use (Figure 1), winter propane use was only 2.4 ± 0.2 gal/AU in the current study. The much higher propane and electricity use (discussed later) in the above studies [3, 4] versus this study may be due to differences in house characteristics (type, tightness, and insulation levels), weather conditions, as well as bird size, with larger birds requiring less energy [17]. Propane use may also be higher if the birds are brooded at the fan end of the house and the unused fans are not covered to prevent heat loss versus center brooding, as used in the current study. The type of heater also greatly influences energy use; the radiant

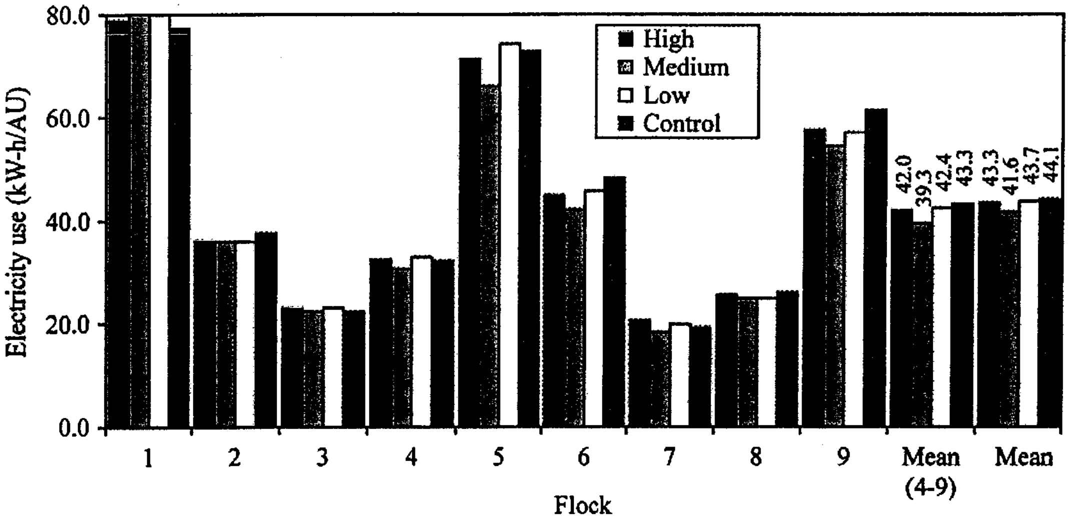

Figure 2. Comparison of electricity use among the treatments (described in Table 1). Mean (4–9) is the average electricity use for flocks 4 to 9, and Mean is the average of all flocks. For flocks 4 through 9, the treatments were not significantly different ($P = 0.99$).

brooder is more effective in heating the chicks and requires less propane versus the furnaces and pancake brooder [18]. In the study by Liang et al. [17], in addition to radiant brooders, the houses also had forced-air furnaces that may have increased propane use.

Propane use during brooding (house warming for chick placement plus the first 14 d) was unaffected by treatment and averaged 88% of the total propane consumption, ranging from a low of 78% for the third (coldest) flock (Table 1) to a high of 99% for the first (hottest) flock (Table 1) in southeastern North Carolina. Therefore, energy conservation measures during brooding, such as increasing insulation in the brood chamber (including insulated curtains) and optimizing the minimum ventilation rate, should be considered.

Electricity Use

As expected, electricity use (Figure 2) was higher in the warmer-season flocks due to greater fan run times; electricity consumption was 3.8 times higher in flock 1 (highest mCDD; Table 1) than flock 7 (highest mHDD; Table 1). Averaged over flocks 4 through 9, electricity use (kWh/AU) was unaffected by the treatment (Figure 2; $P = 0.99$). Averaged for flocks 4 through 9, the high, medium, low, and control treatment had total ventilation volumes of 4.97, 5.03, 5.15, and 5.25 billion ft^3/flock, respectively [16]. Hence, the ventilation volumes were generally consistent with electricity use in the 4 houses. Reduction in electricity use by 13% due to ALS use in the Moore et al. [3] study might be due to minimum ventilation rates in their control treatment being inadequate for maintaining acceptable NH_3 levels, requiring greater fan run times than the ALS-treated houses.

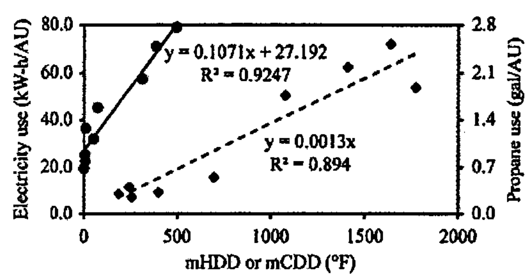

Figure 3. Correlation between energy use and modified degree days. Each data point is the average of electricity (•) or propane (♦) use for all treatments. Modified heating degree days (mHDD) is calculated by Eq. (1), whereas modified cooling degree days (mCDD) is calculated by Eq. (2). Electricity use versus mCDD is indicated by solid trend line, whereas propane use versus mHDD is indicated by dashed trend line. The abnormally high propane use in the low treatment in flock 9 was excluded.

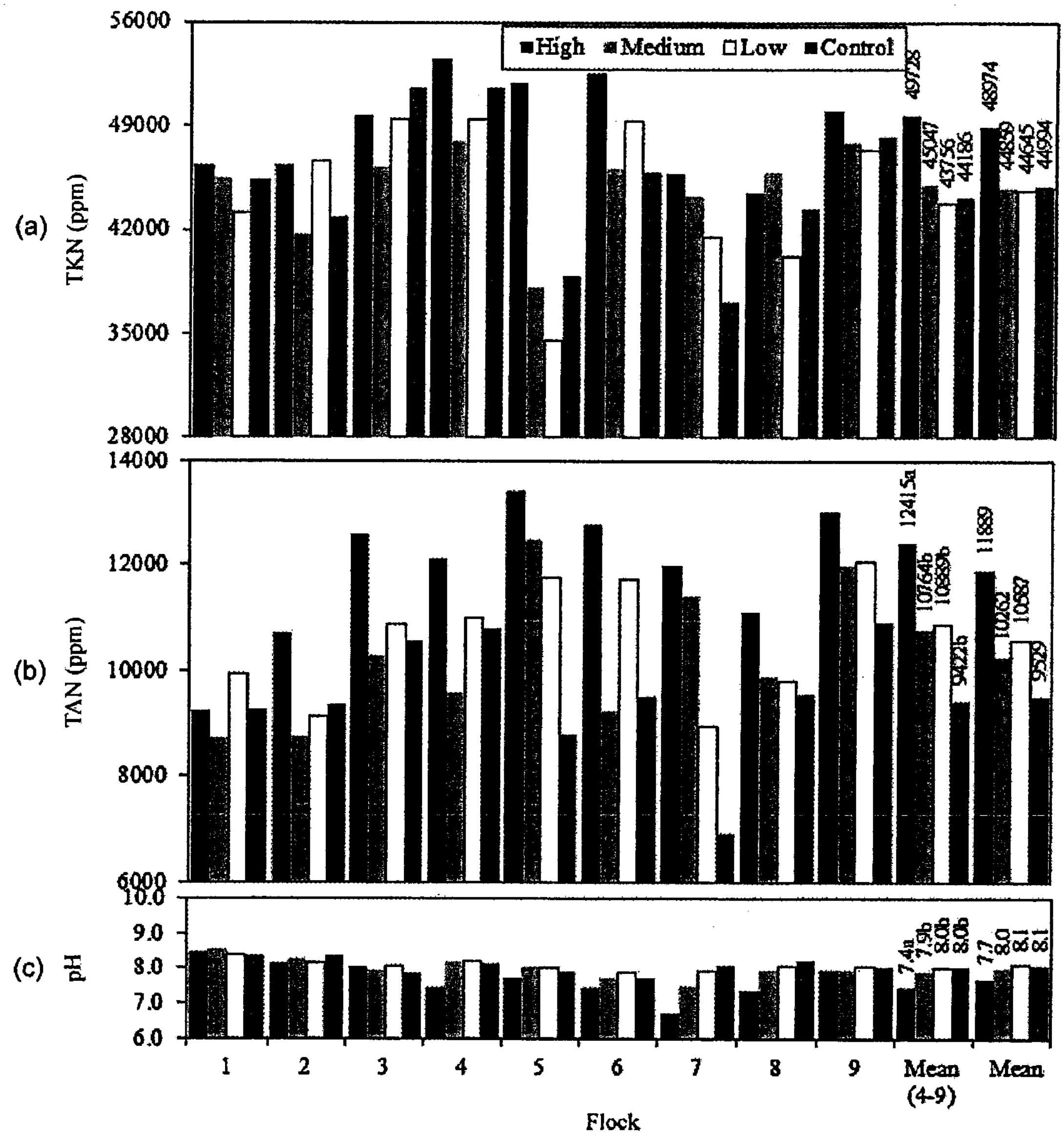

Figure 4. Comparison of N specie concentrations (dry basis) and pH in the cake among the treatments (described in Table 1). Treatments were only compared statistically for flocks 4 through 9 and were significantly different for total ammoniacal nitrogen (TAN; b; $P < 0.01$) and pH (c; $P < 0.01$) but not total Kjeldahl nitrogen (TKN; a; $P = 0.16$). Mean (4–9) values for the treatments followed by the same letter are not significantly different at α = 0.05 using Fisher's LSD; LSD for total ammonical nitrogen and pH were 1,512 ppm and 0.3, respectively.

Mean (Figure 2), electricity use among the treatments were very similar, with an average of 42.5 ± 1.1 kWh/AU. By contrast, broilers <4 lb required 105.8 kWh/AU [3]; their higher electricity use could be due to the houses being old and curtain-sided with sidewall ventilation. Sidewall ventilation requires more fans and, hence, more electrical energy than tunnel-ventilated houses [19]. With 6.2 to 8.2-lb broilers, electricity use in tunnel-ventilated solid sidewall houses in northwest Arkansas [17] was 20% higher than this study.

Degree Day Effect on Energy Use in Roaster Production

Averaged for all treatments, electricity and propane use increased linearly with mCDD and mHDD, respectively (Figure 3). Such relationships are useful for predicting energy use under different ambient temperature conditions in similar houses with comparable husbandry and management practices. However, there is need to collect additional data.

Concentrations of N Species and pH in the Roaster Cake

Averaged for all treatments, the CV values for TKN and TAN were 4.3% (ranging from 2.8–5.2%) and 2.3% (ranging from 0.6–6.4%), respectively. With such low CV values, we suggest the sampling and compositing techniques yielded representative samples in all 9 flocks. No treatment effect ($P = 0.16$) was observed on TKN concentrations in the cake for flocks 4 through 9 (Figure 4) despite >4,000 ppm (wt/wt) or µg/g greater TKN concentration in the high treatment versus the other treatments, probably because of high within-treatment variability. Both Moore et al. [3] and Worley et al. [4] also found no difference in total N concentrations between ALS-treated versus control litters.

Cake TAN concentrations (average of flocks 4–9; Figure 4) were significantly ($P < 0.01$) higher in the high treatment than the other treatments, which were not different from one another (Figure 4). Because roasters are fed a higher protein diet and produce more waste, even with the higher SBS application rates in the medium and low treatments, TAN retention in the cake was not significantly higher than the control treatment (Figure 4). Worley et al. [4] also reported higher TAN in ALS-treated versus untreated litter. Greater TAN concentration in the cake in the high treatment was due to significantly reduced pH (average of flocks 4–9; (Figure 4), which facilitated NH_3 conversion to NH_4 versus the other treatments. However, the medium, low, and control cake samples were not significantly different in pH levels from one another (Figure 4). More than 2 mo after 0.3 lb/ft^2 of SBS application, cake pH was 0.5 units lower than the other lower SBS application rates.

CONCLUSIONS AND APPLICATIONS

1. The higher rates of SBS application did not reduce propane or electricity use compared with lower SBS application rate.
2. Propane use during brooding (first 14 d plus house preheating) accounted for 88% of the total propane use in eastern North Carolina. Therefore, energy conservation measures during brooding will be very effective in reducing propane use.
3. Propane and electricity use per AU for roaster (8.8 lb each) production were much lower than reported for smaller broilers.
4. Linear relationships of mCDD with electricity use and mHDD with propane use may be useful in predicting energy use in roaster production.
5. Whereas TKN concentration was unaffected by the SBS application rate, TAN concentrations were significantly higher in the high treatment flocks due to significantly lower pH values.

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A-30

Nitrogen mass balance in commercial roaster houses receiving different acidifier application rates[1]

S. B. Shah,*[2] J. L. Grimes,† E. O. Oviedo-Rondón,† P. W. Westerman,* and D. Campeau‡

**Department of Biological and Agricultural Engineering and †Prestage Department of Poultry Science, North Carolina State University, Raleigh 27695; and ‡North Carolina Cooperative Extension, Pittsboro 27312*

Primary Audience: Researchers, Integrators, Extension Agents

SUMMARY

Broiler production has the potential to cause water and air pollution. Acidifiers such as sodium bisulfate (SBS) can reduce ammonia (NH_3) emissions from broiler houses; NH_3 is an important air pollutant that also affects bird health. Due to their longer grow-outs, roasters may require higher acidifier application rates to prevent unhealthy NH_3 levels during the flock than ordinary broilers. Changes in NH_3 emission with acidifier use may affect the partitioning of the input nitrogen (N) among the different N output pathways. Accounting for these output pathways through N mass balance provides a complete picture of N as it cycles through the roaster house. In a 2-yr study involving 9 flocks of roasters, 4 levels of SBS were applied to the litter in commercial roaster houses. Whereas the control treatment received up to 0.49 kg/m^2 to the brood chamber, the high, medium, and low treatments received up to 1.46, 0.73, and 0.49 kg/m^2, respectively, to the whole house. Ammonia-N emission decreased and N removed in cake and litter increased with SBS application rate. Nitrogen output components were averaged over the 4 treatments and expressed as percent of total N input or per unit mass of live weight (LW). Ammonia-N emission during grow-out, bird N exported, and cake and litter N removed accounted for 17.3% or 11.2 g/kg of LW, 38.9% or 25.1 g/kg of LW, and 22.4% or 14.4 g/kg of LW, respectively. We accounted for 79.1% of the total N inputs, with NH_3-N losses during layout probably constituting the bulk of the unaccounted N. In addition to uncertainties in measurements of inputs and outputs, other factors that limited the ability to close the N mass balance were exclusion of feathers during cake and litter sampling, soil N leaching, and nitrous oxide emissions.

Key words: ammonia emission, cake, litter, feed, tissue, sodium bisulfate

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DESCRIPTION OF PROBLEM

Due to economics of scale, concentrated animal production provides a reasonably-priced source of protein that is uniform in quality. However, the resulting concentration of animal waste increases the potential for pollution. Concentration of animal production, mainly poultry

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[2]Corresponding author: sanjay_shah@ncsu.edu

and swine, in the coastal plain of North Carolina led to the estimated annual production of animal waste containing 124,000 Mg of nitrogen (N) and 29,000 Mg of phosphorus (P), respectively [1]. Leaching and runoff of animal waste constituents may result in the contamination of soil, groundwater, and surface water. Similarly, volatilization of gaseous waste constituents, particularly ammonia (NH_3), can degrade air quality. Ammonia emission from concentrated livestock operations is regarded to be of major importance because of atmospheric deposition and haze [2]. An estimated 71% of the NH_3 emission in the United States comes from livestock production [3], with broiler houses emitting between 0.24 and 0.32 million Mg of NH_3 per year [4].

Acidifiers, such as sodium bisulfate (SBS; $NaHSO_4$), reduce NH_3 concentrations by inhibiting NH_3 formation in the litter [5] and also reduce NH_3 emissions [6] from broiler houses. In broiler houses, 100 kg of SBS can neutralize 16 kg of NH_3, but when moisture is not limiting it can neutralize up to 22.4 kg of NH_3. Reduced inside NH_3 concentrations may improve bird performance [7]. Changes in NH_3 emission with acidifier application rate may then affect the partitioning of the input N among the different N output pathways (e.g., N in carcass, litter, and so on). Accounting for the various N input and output pathways using mass balance will provide a complete picture of N as it cycles through the broiler house. Specifically, the mass balance approach tells us where our effort should be focused to reduce N losses and where better accounting of N inputs are needed.

Recently, Moore et al. [8] performed an N balance using 5 flocks of broilers (2.58 kg each) in broiler houses in Arkansas that also included measurement of NH_3 and nitrous oxide (N_2O) losses. Coufal et al. [9] also did an N balance during an 18-flock study in pens in Texas with an average broiler mass of 2.24 kg assuming unaccounted N to be gaseous N loss, primarily as NH_3. There are no mass balance studies on roasters, a group of birds that are increasing in popularity due to the growing demand for white (breast) meat. Roasters are large broilers (usually $\geq$4 kg each) that have grow-outs of 8 to 12 wk [10]. Because ordinary broilers and roasters have different diets and FE, mass balances developed for broilers may not apply to roasters. Further, there are no studies on how different acidifier levels affect partitioning of N inputs among the different N output pathways.

Hence, the overall objective of this study was to perform N mass balance in southeastern North Carolina commercial roaster houses as affected by SBS [11] application rates. Specific objectives were to (1) quantify all N input terms, (2) quantify and evaluate the effect of SBS application rate on N output terms, and (3) perform N mass balance.

MATERIALS AND METHODS

This research was part of a larger study conducted on a roaster farm near Tar Heel, in southeastern North Carolina during 2007 to 2009 involving 9 flocks. Only relevant portions of the materials and methods are presented here; additional description can be found in Shah et al. [5, 6, 12].

Farm Description, Management, and Treatments

In this study, there were 8 identical broiler houses, measuring 12.5 × 152.4 m, aligned north-south, and built between 2005 and 2006. All the houses were tunnel-ventilated (11 belt-driven 1.22-m fans, three 0.91-m direct-drive fans) and had evaporative cooling (cool cells and foggers). Except for one sidewall that was curtain-sided (approximately 1.5 × 130 m), the end walls and one sidewall of each house were insulated. The houses had drop ceilings. Each house was heated with 17 radiant brooders and had its own propane tank and meter. The fans, curtains, brooders, cool cells, and foggers were controlled by an environmental controller that was programmed by the producer based on season, bird age, and bird comfort.

Twenty thousand to 21,300 day-of-hatch chicks were placed in each house (Table 1) and raised to about 4 kg each and marketed at about 63 d; downtime between flocks was 10 to 21 d. The integrator's guidelines specified desirable room temperatures of 34.4°C on d 1 was gradually reduced to 16.7°C on d 63 [12]. The roasters were managed by the producer following the National Chicken Council's guidelines [13]. The chicks were brooded in the middle 40% of the

Table 1. Flock placement dates and durations, birds placed per house, and treatments

Flock no.	Date placed	Duration (d)	Birds placed per house (n)	SBS application rate[1] (kg/m^2)			
				High[2]	Medium[2]	Low[2]	Control[3]
1	6/22/07	66	20,000	0.37	0.37	0.37	0.37
2	9/14/07	65	20,700	0.95[4]	0.73	0.37	0.37
3	12/7/07	66	20,700	1.27[5]	0.73	0.37	0.37
4	3/4/08	64	20,700	1.46	0.73	0.49	0.49
5	5/22/08	66	20,100	1.46	0.73	0.49	0.49
6	8/12/08	62	21,300	1.46	0.73	0.49	0.49
7	11/17/08	58	21,300	1.46	0.73	0.49	0.49
8	2/10/09	58	21,300	1.46	0.73	0.49	0.49
9	4/28/09	63	20,700	1.46	0.73	0.49	0.49
	Average	63	20,756				

[1]Conversion: 1 kg/m^2 = 0.205 lb/ft^2; SBS = sodium bisulfate.

[2]Applied to whole house.

[3]Applied only to brood chamber.

[4]A total of 0.73 kg/m^2 to the center two-thirds of house with the remaining one-sixth at each end receiving 1.46 kg/m^2.

[5]A total of 0.98 kg/m^2 to the center brood area with rest of the house receiving 1.46 kg/m^2.

house (brood chamber) for 12 to 14 d and then released into the expansion brood area (70% of floor area) for another week before being released into the whole house. The birds were fed starter, grower, finisher, and withdrawal diets. After the birds were sold, the house was decaked, that is, the wet, matted fecal cake material (top 25 to 50 mm) was removed. Litter was completely cleaned out every 2.5 to 3 years but not during the study.

As described in Table 1, SBS was applied to the brood chamber in the control treatment and the whole house in the high, medium, and low treatments. The acidifier was applied 1 d before bird placement. Each treatment was applied to a pair of adjacent broiler houses, but N output parameters were only measured for one house. The study began in June 2007 (Table 1), with the first flock being placed on litter that had supported one previous flock.

All the treatments received the same SBS application rate in flock 1 (Table 1) to see if bird performance was affected by the specific house. As bird performances in all 4 houses were very similar [14], N outputs were assumed to be affected only by the treatment. In the high treatment, the SBS application rate was gradually increased with each successive flock, reaching the target application rate in the fourth flock (Table 1). Beginning with the fourth flock, SBS application rates in the low and control treatments were increased to match the increased NH_3 levels resulting from built-up litter.

N Mass Balance Measurements and Calculations

The following equation was used for preparing N mass balance:

$$(N_{ch} + N_f) - (N_g + N_b + N_m + N_{ck}) = \Delta N_{ac}, \quad (1)$$

where the components (kg) are N_{ch} is N in the chicks; N_f is N in the feed; N_g is gaseous N emitted; N_b is N exported in the mature birds; N_m is N lost in mortalities; N_{ck} is N removed in the cake; and ΔN_{ac} is N accumulating in the litter over the study period. Equation (1) does not include N leaching losses from the litter into the soil because it was not measured in the study. If all inputs and outputs are fully accounted for, ΔN_{ac} would be zero. The methods used to quantify each component are discussed below.

Chick N Added. For flocks 2 through 9, at the time of bird placement 2 chicks were selected at random and killed humanely by cervical dislocation by the producer or the integrator representative. The chick carcasses were placed in a sealed plastic bag and transported back to the laboratory on ice and preserved in a freezer before processing. The 2 whole chick carcasses from each house were collectively weighed, ground, and homogenized in a laboratory grinder; thereafter, a sample was weighed and then freeze-dried to constant mass to determine total solids (TS). The dried tissue sample was ground and analyzed for total Kjeldahl N (TKN) [15]. As the TKN concentrations in the 4 treatments were not significantly different (ANOVA P = 0.42) for the 8 flocks, the mean (n = 4) TKN concentration, adjusted to wet basis (wb), was multiplied by the mass of the total number of chicks placed in each house to calculate N in the chicks. As flock 1 TKN concentrations were not measured, values of the second flock were used.

Feed N Consumed. Feed samples were obtained every week from the feed hopper inside each house and stored in a freezer in separate sealed plastic bags. For each flock and house, one sample of each type of feed (e.g., starter) was prepared by compositing and thoroughly mixing equal amounts of weekly samples. If not immediately analyzed for TKN [15], the sample was frozen. So for each flock and house, there were 4 feed samples, namely, starter, grower, finisher, and withdrawal. As the birds in all the houses were the same age and received the same type of feed, the TKN concentration required for the N mass balance for a particular type of feed for a flock was obtained by averaging the TKN concentrations of the feed samples from all 4 houses.

The mass of each type of feed consumed in each house was obtained from the feed tickets and later corroborated from the load-out tickets; any feed left over at the end was returned and a credit applied to the withdrawal feed for that house. Feed N mass for a particular type of feed was obtained by multiplying the average (n = 4) TKN concentration (wb) by the mass of feed consumed. Total feed N input (N_f; equation 1) was calculated by summing up the masses of N in the 4 different types of feed.

Gaseous N Emitted. Gaseous N emissions should include both NH_3 and N_2O. However, because broiler N_2O emissions are negligible [16], only NH_3-N emissions were measured continuously [6]. We undertook limited N_2O emissions monitoring from one fan in the control treatment using the photoacoustic sensor [17] for 40 d (2 periods, flocks 8 and 9). Ammonia emissions were not measured during layout because the workers dropped the curtains and left the doors open to ventilate the house.

The methodology for NH_3-N emission measurement is described in detail in Shah et al. [6]. Briefly, NH_3-N concentration was measured using 250-mL boric acid (2% vol/vol) scrubbers at the outlet of each fan, and the scrubber operated only when the fan ran. The scrubbers were replaced at 3 to 4-d intervals and analyzed for ammonium-N concentration (mg/L) using colorimetry [18] and further adjusted for blank scrubber concentration. Based on the scrubber and airflow rate (m^3/min) through the scrubber, NH_3-N concentration of air through a particular fan was calculated and adjusted for ambient NH_3-N concentration also measured with one scrubber in each house. Based on the total fan run time for the period and the average fan speed (rpm) measured with Hall Effect sensor [6], the fan curve (flow rate vs. fan speed) developed for those fans was used to calculate the total volume (m^3) of air moved by each fan. Ammonia-N emission (kg) from a fan over the 3 to 4-d period was calculated by multiplying the adjusted NH_3-N concentration (mg/m^3 of air) through the scrubber with the volume of air (m^3) moved. Finally, total gaseous N emitted (equation 1) for each flock and house was calculated by summing up the emission from each fan over the entire flock.

Bird N Exported. During load-out, 2 roasters (male and female) were randomly selected from each house and killed humanely by cervical dislocation by the producer or integrator representative. The handling, processing, and chemical analyses of the grown birds were very similar to the chicks, except that these birds were ground (while still frozen) and homogenized in an industrial grinder. The pulverized mass of 2 birds from each house was run through the grinder multiple times until the tissues appeared homogenized. Because there was no treatment effect on TKN concentration (ANOVA; P = 0.85), the average TKN concentration (n = 4) was applied to all the treatments for each flock.

The bird live weight (LW) marketed from each pair of houses receiving the same SBS treatment was provided by the integrator. As one trailer usually had birds from both houses during each load-out, project personnel counted the number of birds from each house in that trailer to calculate LW per house. In flocks 1 (medium, low, control) and 5 (control), when data collected by the project personnel were misplaced, the total LW for the pair of houses receiving the same treatment was divided by 2 to obtain LW for the house of interest. Mass of N exported in the birds (N_b; equation 1) was calculated for each flock and house by multiplying the average TKN concentration in the bird tissues by the LW.

Mortality N Lost. Mortalities removed daily were aggregated weekly to obtain number of dead birds per house. The Gompertz growth curve [19] was fitted by flock and treatment using feed conversion and final weight to obtain estimated weights by age. Hence, the mass of mortalities was estimated for each flock and treatment using the age and number of mortalities. The mortality TKN concentration was assumed to be the average of the chick and roaster TKN concentration. Mass of the mortality times the mortality TKN concentration yielded nitrogen lost in mortalities (N_m; equation 1).

Cake N Removed. When the birds were removed after each flock, the top 25 to 50-mm of the cake was removed with a decruster. Each house yielded between 8 and 14 loads of cake. Each load of cake was weighed on portable wheel scales and then unloaded in a covered shed. The detailed method of cake sampling and analyses for TKN [15] and TS [20] is described in Shah et al. [12]. As broiler cake and litter contain very little nitrate (NO_3) [21, 22], the cake samples were not analyzed for NO_3. Total N (or TKN) concentrations among the treatments were compared using ANOVA for flocks 4 through 9. If there was treatment effect, Fisher's LSD was used to compare treatment means. Means for all the flocks are also presented.

Litter N Accumulated. As the study began on litter that had supported one flock previously and the houses were not cleaned out at the end of study, the masses of N in the litter at the beginning and end of the study were also estimated. The trench method [23] was used to determine masses of litter and sample for TKN [15]. A rectangular steel template (0.15 × 0.15 × 1.2 m, height by width by length) that was open at the top and bottom was driven into the litter down to the soil and the depth of the litter measured; thereafter, the litter inside the template was collected in a large plastic tub and weighed. Litter from a 6.1 × 0.15-m trench extending from one sidewall to the middle of the house was collected by moving the template 5 times.

Six such trenches were made in each house, 2 each in the brood chamber (40% area), expansion brood section excluding the brood chamber (30% area, referred to as the expansion section), and off-chamber (30% area). In each of the 3 sections, 1 trench was started from the eastern sidewall and the other from the western sidewall; hence, 2 tubs of litter were collected from each section. After thoroughly mixing the litter in each tub, equal amounts of litter (~1 kg) were taken from each tub and the 2 amounts were then thoroughly mixed and a sample of about 250 g was collected for chemical analysis. Thus, 3 litter samples from each house were analyzed for TKN and TS in the beginning. At the end of the study, a total of 9 samples (3 from each area) were analyzed for TKN and 3 composited samples (from 2 trenches in each area) were analyzed for TS. The average CV value of TKN concentrations based on a total of 12 mean (4 houses × 3 sections per house) values was 6.0% (0.7–16.2%), suggesting that the method likely yielded representative samples. Total litter N mass was calculated for each section based on the TKN concentration, litter mass per unit area, and total area. Total N in the 3 sections was summed to obtain initial or final N mass in each house.

Data Analyses

Nitrogen inputs (kg) were compared among the treatments for each input pathway (except N in the chicks) using ANOVA for all flocks and assuming that N inputs were unaffected by the treatments. If there was a treatment effect, Fisher's LSD was used to compare treatment means. If there was no treatment effect, all the treatments for a flock were assumed to be replicates and the effect of flock on N input component was analyzed using ANOVA, and if necessary, using Fisher's LSD. For the N output components (except N lost in mortalities), the same process used for N inputs was used except that only flocks 4 through 9 were used for analysis because flocks 1 through 3 had lower SBS application rates for all treatments (Table 1). The software package SAS Version 9.3 [24] was used for all statistical analyses with α of 0.05, except where indicated.

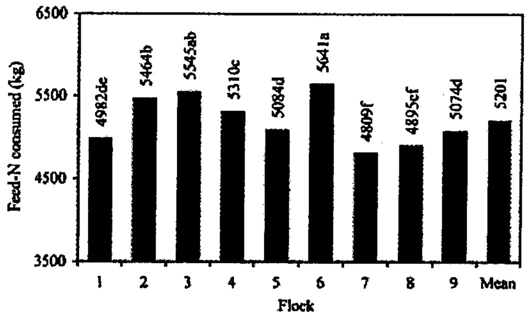

Figure 1. Average house feed N consumption across treatments (see Table 1). Average house feed N consumption varied significantly with flock ($P < 0.01$). Average house feed N consumption values for the flocks followed by the same letter (a–f) are not significantly different at $\alpha = 0.05$ using Fisher's LSD (135 kg).

RESULTS AND DISCUSSION

First, N concentrations in the mass balance components are discussed and compared with literature values where relevant. Also, the effects of treatment or flock on the mass of N input or output pathways are discussed. Finally, the N mass balance is presented and discussed.

N Inputs

Chick N Added. Average ± SD (throughout the article) TKN concentration in the chick tissue (n = 32) was 2.30 ± 0.21% wb and 9.15 ± 1.29% on dry basis (**db**). Summed over the study and averaged over the 4 treatments, N in the chicks was 189 ± 0 kg, the smallest input component of the N mass balance.

Feed N Consumed. To safeguard the integrator's diet formulation, TKN concentrations in the feed are not presented. Averaged for all feed types, TKN concentrations in this study were slightly higher than Moore et al. [8] (2.58-kg birds) but in the range of concentrations reported by Patterson et al. [25] for both 2- and 2.7-kg birds.

There was no treatment effect ($P = 0.96$), though N in the feed varied (Figure 1) significantly ($P < 0.01$) with flock. Generally, feed N consumption decreased in summer, probably due to decreased appetite, and increased in winter (flock 3, Table 1), though the grow-out period also contributed to these differences (Table 1). The highest feed N consumption was in flock 6 (Figure 1) placed on 12 August 2008; milder conditions as the birds grew older probably improved their appetites. However, the lowest feed consumption was in the seventh flock (Figure 1) placed in winter, which may be partly attributed to a shorter grow-out of 58 versus 63 d on average for the study (Table 1).

N Outputs

Gaseous N Emitted. Ammonia-N emission data for flock 1 are incomplete, with 10 d of missing data for the high and medium treatments, 28 d for the low treatment, and 4 d for the control treatment due to delay in the installation of the sampling equipment. For flocks 4 through 9, NH_3-N emission from the high treatment was significantly lower ($P < 0.01$) than the low and control treatments but not the medium treatment, whereas the medium, low, and control treatments did not significantly differ from one another (Figure 2). For flocks 4 through 9, emissions were lower during winter, as expected, particularly from the high treatment (Figure 2).

Bird N Exported. Average (n = 36) TKN concentration in the bird tissue was 2.51 ± 0.25% wb (6.95 ± 1.27% db), much lower than the TKN concentration of 3.03% wb for 2.58-kg birds [8] or 8.27% db for 2.24-kg birds [9]. Decreased tissue TKN concentration with increasing bird weight [26] may explain the lower TKN value in this study. Higher feed conversions in 0 to 9-wk-old broilers (2.12) versus 0 to 6-wk-old broilers (1.80) [27] also indicates that, compared with smaller birds, larger birds assimilate less and excrete more N.

The weight of birds harvested was unaffected by treatment ($P = 0.87$), though there was a very significant flock effect ($P < 0.01$; Figure 3). Flock-wise, bird weight correlated well with feed N consumption (Figure 1), and the colder weather flocks (2 and 3) as well as flock 6, which was removed in the fall, performed better than the other flocks (Figure 3). Lower production in flocks 7 and 8 were due to their shorter grow-outs (58 vs. average of 63 d).

Bird N was unaffected by treatment ($P = 0.99$). When averaged for all treatments, N exported in mature birds was significantly affected by flock ($P < 0.01$; Figure 4). The lowest values for N exported in the bird were for flocks 7 and 8 (Figure 4), which had the shortest grow-out

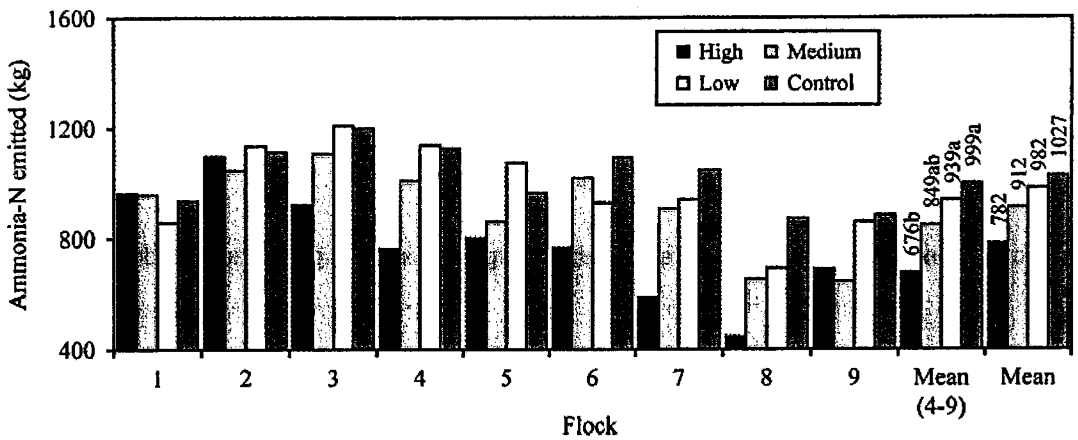

Figure 2. Ammonia-N emission per house from the treatments (see Table 1). Mean (4–9) is the average for flocks 4 to 9, and Mean is the average of all flocks. For flocks 4 through 9, the treatments were significantly different ($P < 0.01$); flocks 1 through 3 were not analyzed statistically due to differences in sodium bisulfate application rates. Ammonia-N emission values for the treatments followed by the same letter (a,b) are not significantly different at $\alpha = 0.05$ using Fisher's LSD (174 kg).

times (58 d), whereas the higher N exported in mature bird values were generally observed in flocks that had longer grow-out times (Figure 4).

Mortality N Lost. As mentioned previously, mortality TKN concentration was obtained as the average of the chick and full-grown bird TKN concentrations.

Cake N Removed. Details of cake TKN and ammonium-N concentrations and pH are presented in Shah et al. [12]. Briefly, TKN concentrations (2.83 ± 0.28% wb; n = 36) were not significantly affected by treatment ($P = 0.16$); the TS was 61.7 ± 3.0% (n = 36). Moore et al. [8] reported slightly lower total N (2.42%) for 2.58-kg birds for both cake and litter.

Treatment effect on cake N mass removed was significant at $P = 0.06$; significantly higher N removed from the cake was observed from the high treatment (LSD = 239 kg) than the other treatments, which did not differ from one another (Figure 5). There was considerable variability in the amount of cake taken among flocks and treatments because of differences in both manure deposition as well as cake removal by the decruster; thus, N removed from the cake varied considerably (Figure 5). Averaged over the treatments, the greatest amount of N removed from the cake (~1,010 kg/house) was after flock

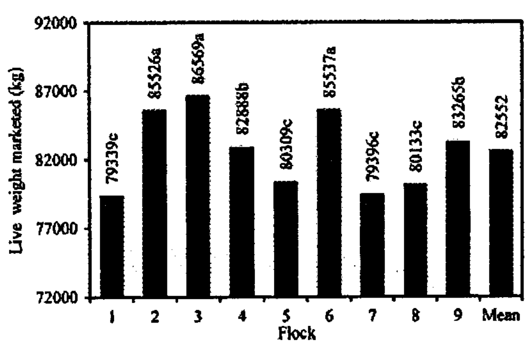

Figure 3. Average house bird live weight marketed across treatments (see Table 1). Bird live weight marketed varied significantly with flock ($P < 0.01$), and values followed by the same letter (a–c) are not significantly different at $\alpha = 0.05$ using Fisher's LSD (1,910 kg).

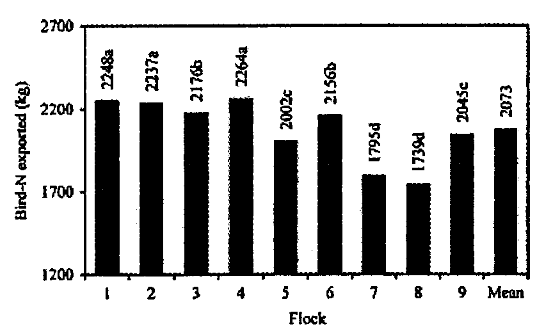

Figure 4. Average house bird N exported across treatments (see Table 1). Average house bird N varied significantly with flock ($P < 0.01$), and values followed by the same letter (a–d) are not significantly different at $\alpha = 0.05$ using Fisher's LSD (48 kg).

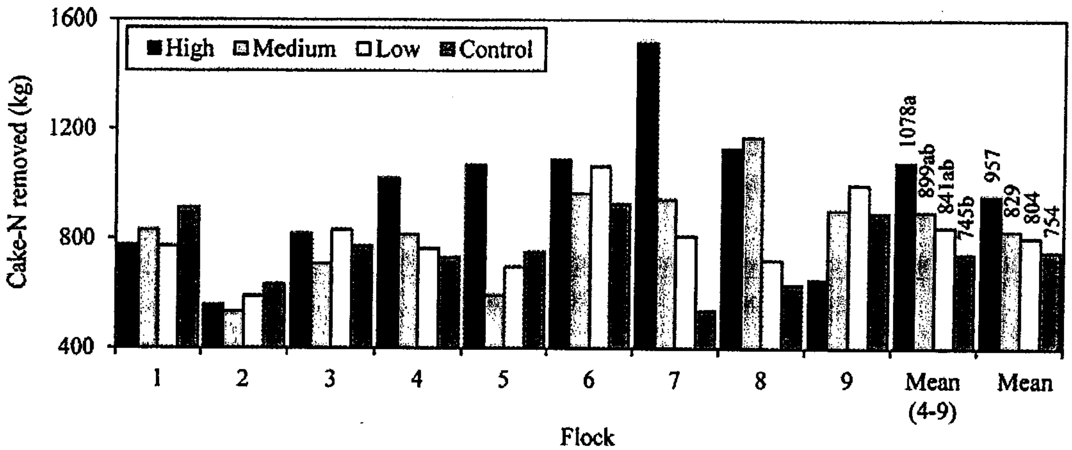

Figure 5. Cake N output per house from the treatments (see Table 1). Mean (4–9) is the average for flocks 4 to 9, and Mean is the average of all flocks. For flocks 4 through 9, the treatments were significantly different at $P = 0.06$; flocks 1 through 3 were not analyzed statistically due to differences in sodium bisulfate application rates. Cake N output per house values for the treatments followed by the same letter (a,b) are not significantly different at $\alpha = 0.06$ using Fisher's LSD (239 kg).

6 in the fall of 2008, when fertilizer-N prices were very high and the roaster producer had contracted to sell his cake to a neighboring row-crop producer.

N Accumulation in the Litter

Compared with cake, litter TKN concentrations at the beginning and end of the study were lower and drier (Table 2). Lower TKN in the litter was unexpected because, generally, North Carolina broiler cake samples have lower TKN [22]. As expected, TKN concentrations were highest in the brood chamber and lowest in the off-chamber (Table 2), both in the beginning and end. This was because the birds occupied the brood chamber for the longest period and the off-chamber for the shortest period. Higher TKN concentration in the brood chamber at the end versus beginning may be due to longer period of N accumulation, but it was the opposite in the other sections (Table 2).

Averaged over the 4 treatments, estimated litter N mass at the end was nearly 3 times higher than at the start. Weighted average (by region) TKN concentration at the beginning was slightly higher than at end (Table 2), but a much larger mass of N was retained in the litter at the end (Figure 6) because of the greater mass. In addition to the lower TS at the end (Table 2), greater bulk density of the litter due to more compaction resulting from greater traffic

Table 2. Total Kjeldahl N (TKN) and total solids (TS) in the litter in different sections of the roaster houses at the beginning (June 2007) and end (July 2009) of the study

Section	Stage	TKN[1] (%, wet basis)	TS[2] (%)
Brood (40%)[3]	Beginning	2.09 ± 0.14[4]	78.7 ± 1.2[4]
	End	2.71 ± 0.35	67.2 ± 3.6
Expansion (30%)	Beginning	1.79 ± 0.35	84.7 ± 2.4
	End	1.40 ± 0.17	78.3 ± 2.3
Off-chamber (30%)	Beginning	1.43 ± 0.22	86.0 ± 2.8
	End	1.27 ± 0.45	76.6 ± 11.4

[1]At the beginning, each value is the average of 4 treatments (houses) with 1 sample per treatment; at the end, each value is the average of 12 values with 3 samples per treatment.

[2]At both stages, each value is the average of 4 treatments with 1 sample per treatment.

[3]Percent area of house occupied by section.

[4]Mean ± SD.

Table 3. Nitrogen mass balance for 9 flocks of roasters, as affected by sodium bisulfate application rate

Mass balance component	Treatment				
	High	Medium	Low	Control	Mean
N inputs (kg)					
Beginning litter N	1,183	973	928	1,015	1,025
Chick N added	189	190	189	189	189
Feed N consumed	46,793	46,461	47,196	46,772	46,806
Total N input	48,166	47,625	48,313	47,977	48,020
N outputs (% total N input)					
NH_3 N emitted	14.6	17.2	18.3	19.3	17.3
Bird N exported	38.5	39.0	39.0	38.9	38.9
Mortality N lost	0.5	0.5	0.5	0.5	0.5
Cake N removed	17.9	15.7	15.0	14.1	15.7
End litter N	5.8	7.5	6.1	7.3	6.7
Unaccounted N	22.7	20.0	21.2	19.8	20.9
N outputs (g/kg of live weight marketed)					
NH_3 N emitted	9.5	11.1	11.8	12.4	11.2
Bird N exported	25.1	25.1	25.1	25.1	25.1
Mortality N lost	0.3	0.3	0.3	0.3	0.3
Cake N removed	11.7	10.1	9.7	9.1	10.1
End litter N	3.8	4.9	3.9	4.7	4.3
Unaccounted N	14.8	12.9	13.7	12.8	13.5

(both birds and during catching) may have also contributed.

N Mass Balance

The N mass balance components for the 9-flock, 2-yr study are presented in Table 3. To better account for input and output terms, beginning and end litter N are listed as N input and output, respectively. Feed N accounted for 97.5% of the total N input (Table 3). Chick N addition and N lost to mortalities were negligible components of the N mass balance inputs and outputs, respectively (Table 3), and will not be discussed further.

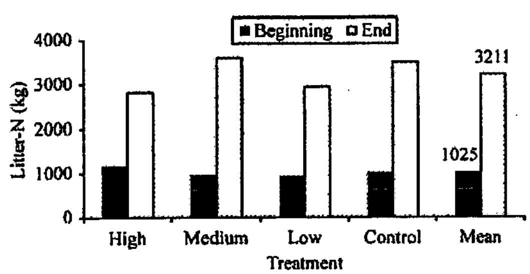

Figure 6. Litter N remaining at the beginning and end of the study in the different treatments (see Table 1 for description).

Unlike other mass balance studies that began on new litter [8, 9], this study started on built-up litter; thus, a sizeable component of the total N input included N in the litter. Therefore, comparing the N outputs as percent total N input of this study with other studies may not be appropriate. As expected, NH_3-N emitted was inversely correlated with SBS application rate with substantially lower N emission in the high treatment (Table 3). Because NH_3 emission monitoring began late in the first flock, some data (about <100 kg/house or 1% of the total NH_3-N emitted) were lost. Whereas Coufal et al. [9] did not measure direct NH_3 loss, their average gaseous N loss of 11.1 g/kg of LW was comparable to the mean in the current study (Table 3). Despite raising smaller birds (2.58 kg), Moore et al. [8] reported higher NH_3-N emission of 14.5 g/kg of LW from the barn in the current study, probably because they did not use acidifiers.

Coufal et al. [9] and Moore et al. [8] reported that bird N accounted for 29.1 and 30.3 g/kg of LW, respectively, which were higher than the current study (Table 3) probably due to lower TKN concentrations in the larger birds [26]. This also explains higher N loss in cake and litter in the current study (Table 3) versus Coufal et al. [9] and Moore et al. [8], with losses of 11.7 and 11.1 g/kg of LW, respectively. Higher N output in the cake and litter in the current study versus those [8, 9] studies was due to greater manure production by and higher feed conversion [27] in the larger birds. Higher N in litter and cake in the high and medium treatments (Table 3), due to reduced NH_3-N emission, can increase their fertilizer value versus the other treatments.

Averaged over the treatments, we could not account for 20.9% of the total N input or 13.5 g of N/kg of LW. Coufal et al. [9] assumed that all N that was not recovered in the birds, cake, or litter was lost through volatilization, whereas Moore et al. [8] accounted for 98.8% of the total N input. Some of this missing N could be due to uncertainty in the measurement of properties of constituents and their masses; for example, the CV for feed TKN analysis was 5%. However, there are 4 other N loss pathways that were not considered in this study: NH_3-N emission during layout, loss of other gaseous N species (primarily N_2O), exclusion of feathers during cake and litter sampling, and N leaching.

Moore et al. [8] estimated that, compared with NH_3-N emission during the flock, 32% of the NH_3-N was emitted during layout. Given the similarity in NH_3-N emission between the current study and Moore et al. [8] during the flock, it could be assumed in our study too, a similar fraction was lost during the layout. Hence, averaged over all the treatments, NH_3-N emission during the flock and layout may have accounted for 22.8% of the total N input, accounting for >25% of the unaccounted N in the N mass balance.

Emissions of NH_3-N and N_2O-N from the same fan in the control treatment over the 40-d period were 85.0 and 6.3 kg, respectively. Higher N_2O-N emission as percent ofNH_3-N emission in the current study (7.4%) versus Moore et al. [8] (1.3%) may be because in the current study monitoring was only done at the end of 2 warm-season flocks. Warmer temperatures and higher litter moisture content due to evaporative cooling may have increased N_2O emissions in the current study versus Moore et al. [8]. Because cake and litter have very low NO_3 concentrations (not measured), very little of this N_2O may have been produced through denitrification, with the majority likely being produced by NH_3-oxidizing chemoautotrophic microorganisms [28]. Even if N_2O-N emission were assumed to be 7.4% of NH_3-N emissions during grow-out and lay-out, we could account for 86.3% of the total N input. Monitoring N_2O emissions from roaster houses may improve mass balance closure.

The exclusion of feathers when sampling cake and litter for N analysis may have also resulted in slight underestimation of the N mass in the cake and litter, as the N content of the feather can be >15% of its mass [29]. This underestimation may be greater in roasters than ordinary broilers due to additional juvenile molts. Some of the unaccounted N likely leached into the soil below the litter in the roaster house, which was not measured in the current study. Lomax et al. [30] observed total N concentrations >2,000 mg/kg (db) in the top 1.5 m of soil beneath Delaware broiler houses. Given the average moisture content (wb) of the cake of ~39%, soluble N species could have leached from the cake into the litter and then into the sandy soil below. Hence, any future N balance study in broiler houses with soil floors should also monitor N leaching into the soil.

CONCLUSIONS AND APPLICATIONS

This is the first study to monitor N inputs and outputs from 9 flocks of roasters receiving 4 different acidifier applications. Important findings are listed below.

1. Averaged over the 4 treatments, during grow-out, roaster NH_3-N emission accounted for 17.3% of the total N input, or 11.2 g/kg of LW, with a low of 14.6% (9.5 g/kg of LW) in the high treatment and a high of 19.3% (12.4 g/kg-LW) in the control treatment.
2. Averaged over the 4 treatments, ~39% of the total N input (25.1 g/kg of LW) was exported in the roasters, which was substantially lower than ordinary broilers.
3. Averaged over the 4 treatments, >22% of the total N input (14.4 g/kg of LW) was in the roaster cake and litter, slightly higher than ordinary broilers.
4. Averaged over the 4 treatments, we accounted for 79.1% of the total N inputs.
5. Extrapolating findings from published research on NH_3-N emissions during

layout and limited N_2O-N emission monitoring, we accounted for up to 86% of the total N input.

6. In addition to uncertainty in the measurement of inputs and outputs, 4 factors likely accounted for most of the remainder of the input N: NH_3-N emissions during layout, N_2O emissions, N in the feathers, and soil N leaching. These factors should be considered in future mass balance studies.

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Effect of Dry Neeem Leaves (DNL) in the Reduction of Ammonia Level of Poultry Litter Compared to Biochemicals Amendment

Shishir S. R., Murshed H. M., Dey B., Al-Mamun M.

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Original Article

Effect of Dry Neem Leaves (DNL) in the Reduction of Ammonia Level of Poultry Litter Compared to Biochemicals Amendment

*[1]Shishir S. R., [2]Murshed H. M., [1]Dey B., [3]Al-Mamun M.

[1]Faculty of Animal Husbandry, Agricultural University, Bangladesh.
[2]Department of Poultry Science, Agricultural University, Bangladesh.
[3]Department of Animal Nutrition, Agricultural University, Bangladesh.

Abstract

An experiment was carried out on broiler litter by using dry neem leaves (DNL) and biochemical product to know their effect on the reduction of ammonia (NH3) level. Cobb 500 day old chicks were reared under semi environmental controlled house for 28 days where last 7 days was the experimental period. Body weight (BW), mortality rate, feed conversion ratio (FCR) was recorded from treatments. NH3 level of litter was measured by LaMotte Ammonia air test kit. DNL and biochemical product was spread in the litter at 32g, 50g and 100g per 16 sq ft respectively. The NH3 level before application and after 1 day and 2 days was measured and resu shown, after using Biochemical product, NH3 level was reduced by 64%, where DNL at 50 g per 16 sq ft has a great effect on the reduction of NH3 (90%) also on bad odor of the poultry litter but not affecting BW, FCR, mortality rate. Application of 100g in 16 sq ft was simultaneously reduced the level of NH3 (93%), but with negative effect on the BW (final BW 1250.00±12.34). It may be concluded that DNL at an amount of 50 gm /16sq ft may be considered as standard to reduce the NH3 level of litter also bad smell. It may be cost effective where Biochemical products are unavailable and ignored by the farmers.

Keywords: Neem leaves, broiler, ammonia, litter.

*Corresponding author: Department of Animal Nutrition, Agricultural University, Bangladesh.
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Introduction

There is a saying "As the litter goes, so goes the flock!" This saying has a lot of truth as it relates to managing litter and the subsequent effect it has on air quality. For the most part, litter management has often more to do with managing the systems that influence litter quality rather than managing the litter. Litter conditions are often a reflection of how well one has done in managing litter. So, the litter management is very important in case of poultry because bad litter can create a lot of problems. Improper litter management leads to NH3 gas accumulation in the poultry shed. NH3 is a toxic, color, odorous and corrosive gas which pollutes the air. In addition, it creates few diseases such as conjunctivitis, immune suppression, lung congestation, impaired kidney function leading to problems like nephritis & urolithiasis and also included to resistanceto infection with Newcastle Disease virus (Anderson et al. 1966).

Asia, especially South Asia is rich in plants of significant medicinal value. These plants have been reported to contain useful pharmacological potent chemical substance for use in poultry as feed or in litter. Neem leaves may exert its beneficial effects when it is use as a bacteria inhibiting material on the litter of poultry without affecting the BW gain, FCR, mortality, body growth etc. At present poultry producers are trying to reduce the NH3 level of the poultry litter by different means. This has involved a number of approaches including litter treatments for poultry (John P. Blake & Joseph B. Hess. 2001), use of litter amendments (such as acidifiers, alkaline material, absorbers, inhibiters and microbial and enzymatic treatments, frequent change of litter etc. which are not economically feasible in poultry farming.

Neem (Azadirachta indica) a large evergreen fast growing perennial tree, is native to Bangladesh and inhabitant of South Asian countries. Among the all plant parts the processed leaves play the most significant role inlivestock health (Sharma and Reddy. 2002). Neem leaves have some medicinal properties like antibacterial, antifungal, antimalarial, antiviral, anti cancer, etc. (Agarwal. 2002; Subapriya and Naigin. 2005). To author's knowledge a number of research has been done with poultry litter, but the use of DNL on poultry litter may be the first. Therefore, an attempt was under taken in this study to investigate the effect of DNL in reducing of NH3 level on poultry litter. The present work was, therefore, undertaken with the following objectives:

1. To determine the effect of DNL in the reduction of NH3 level of the litter.
2. To compare DNL and biochemical product in the reduction of NH3 level in poultry litter.
3. To observe the effect of DNL on productive performance (BW gain, FCR and mortality) of poultry birds.

Medicinal Properties of Neem (Azadirachta Indica) Leaves in General

Neem leaves have a wide spectrum of uses. The development of traditional medicinal system may be highly beneficial for the farmers and also for overall improvement of the poultry industry; in Bangladesh because neem leaves may exert its beneficial effects effectively on performance of birds at a minimum expense. During the past two decades the biological activity of neem extracts has been investigated intensively, and six international neem conferences have been held (Schmutterer et al. 1981; Schumutterer and Ascher. 1984, 1987).

The necessity for ancient medicinal practice has been recognized by WHO for meeting the primary health needs for the people of the developing countries like Bangladesh. This is especially true for poultry in a region where modern system of veterinary medicine and poultry health care have been made little in road into the rural areas. The very common uses of neem are in Ayurvada, Unani and Homeopathic systems of medicine.

Use of Neem as a Antibacterial Ingredient on Poultry Litter(Broiler)

For thousands of years the beneficial properties of Neem (Azadirachta indica A. Juss) have been recognized in the Indian tradition. Each part of the neem tree has some medicinal property. Biswas et al. (2002) have recently reviewed the biological activities some of the neem compounds, pharmacological actions of the neem extracts, clinical study and plausible medicinal applications of neem along with their safety evaluation D.P

Agarwal. (2002) found that Oil from the leaves, seed and bark possesses a wide spectrum of antibacterial action against Gram-negative and Gram-positive microorganisms, including M. tuberculosis and streptomycin resistant strains. In vitro, it inhibits Vibrio cholerae Klebsiella pneumoniae, M. tuberculosis and M. pyogenes. Antimicrobial effects of neem extract have been demonstrated against Streptococcus mutans and S. faecalis. Bhowmik et al. (2010) Neem leaves possess excellent medicinal properties. In addition to it usefulness in Pest management and Disease control they can also be fed to livestock when mixed with other fodder. Neem leaves are used in some parts of Indian as fertilizer in rice fields, especially in the south Indian states. In some countries, Neem leaves are used as mulch in tobacco and tomato fields. They can be very effectively used to kill weeds by spreading them over plant roots to retain moisture. Neem leaves can also be used to protect stored woolen and silk clothes from insects.

Different Experiment on Litter Treatment

Moore et al. (2008) added aluminum sulfate (alum) to poultry litter in the poultry house to precipitate soluble phosphorus. Alum additions to poultry litter reduce poultry house NH3 concentrations and emissions. Alum additions also result in decreased phosphorus runoff, improving water quality. There are three types of alum that can be used in poultry houses; dry, liquid and high acid liquid alum (this paper focuses on dry alum). Typically alum is not applied to fresh bedding material, but added to use bedding prior to each subsequent flock. NH3 levels in poultry houses receiving alum have been shown to be reduced by over 75% for the first two weeks of the flock, 50% the third week, and 20-30% thereafter.

Miles et al. (2008) conducted research on Instrumentation for Evaluating Differences in NH3 Volatilization from Broiler Litter and Cake. They found Litter moisture for the original bulk sample was 23.1%, which decreased to 13.6% after the experiment. Similarly, the pH dropped between the pre- and post-experiment measurements. The pH originally averaged 8.67 but was 8.22 at the end of the experiment. When reporting mean cumulative NH3 released from the homogeneous litter samples, the data followed a log trend and also revealed a relative standard deviation between 6.3 and 2.6%, decreasing with time. Daily NH3 losses increased through day 3 of the study and then decreased, which may be attributed to the sample drying within the chamber. The standard deviation of the litter NH3 released at each measurement day ranged from 0.6 to 0.4 mg of N.

John and Joseph. (2001) showed the uses of sodium bisulfate in poultry litter treatment (PLT) reduced NH3 level, pH level, fuel usage, bacterial population and improve the performance. PLT eliminates NH3 by converting litter ammonium to ammonium sulfate and lowers litter pH to acidify litter. PLT was the first nonhazardous and nontoxic litter treatment used in an overall total litter management program.

Kim and Patterson (2003) found in their research on Effect of Minerals on Activity of Microbial Uricase to Reduce NH3 Volatilization in Poultry Manure, that Uricase alone resulted in a time-dependent decrease in uric acid levels. The effect of ZnSO4 on the microbial Uricase activity is presented in their research paper. The Uricase+ ZnSO4 and the Uricase pre-incubated with ZnSO4 treatment inhibited 91 and 98% of the microbial Uricase activity ($P<0.05$), respectively. The Uricase treatments with CuSO4 showed a similar trend as in the ZnSO4 treatments. The Uricase + CuSO4 and the Uricase pre-incubated with CuSO4 blocked the activity of the microbial Uricase (approximately 90% inhibition) ($P<0.05$). However, the immediate Uricase treatments with MgSO4 and MnCl2 (Uricase+ MgSO4 or MnCl2) did not inhibit the activity of microbial Uricase. When the Uricase was pre-incubated with MgSO4 orMnCl2 for 15min before the Uricase assay, the decomposition of uric acid was reduced to 80 and 66%, respectively, compared to the Uricase treatment ($P <0.05$). Therefore, the Uricase assays demonstrated that ZnSO4 and CuSO4 strongly inhibited Uricase activity, whereas MgSO4 and MnCl2 had comparatively less impact on the enzyme. JC et al. (2005) had conducted a research named" Effects of chemically amended litter on broiler performances, atmospheric NH3 concentration, and phosphorus solubility in litter" where they showed that, the effects of 6 different litter amendments on broiler performance, level of atmospheric NH3 concentration, and soluble reactive phosphorus

(SRP) in litter was determined. Through 3 experiments conducted on 2 different commercial farms, one chemical amendment was added to the litter and then was compared with a control. Broiler performance was not affected by any of the amendments except the ferrous sulfate amendment for which mortality was 25.5%. Application of aluminum chloride ($AlCl_3 \times 6H_2O$) to the litter lowered atmospheric NH_3 concentrations at 42 d by 97.2%, whereas ferrous sulfate ($FeSO_4 \times 7H_2O$) lowered it by 90.77%. NH_3 concentrations were reduced by 86.18, 78.66, 75.52, and 69.00% by aluminum sulfate [alum or $Al_2(SO_4)_3 \times 14H_2O$)], alum + $CaCO_3$, aluminum chloride + $CaCO_3$, and potassium permanganate ($KMnO_4$), respectively, when compared with each control at 42 d. Each amendment except $KMnO_4$ significantly reduced soluble reactive phosphorus contents. Alum and aluminum chloride were the effective compounds evaluated on the commercial farms with respect to reducing NH_3 contents, phosphorus solubility and mortality.

Miles et al. (2004) in their research on Atmospheric NH_3 is Detrimental to the Performance of Modern Commercial Broilers, found that Comparisons of male broiler BW are given in Table for near 0 (control), 25, 50, and 75 ppm aerial NH_3 concentrations. Broilers in the control atmosphere had a mean weight of 1,421 g at 4 wk of age. Compared with the control group at 4 wk, the treatment with 25 ppm demonstrated a 2% BW deficit, which was not statistically supported. The 50 and 75 ppm NH_3 treatments at 4 wk were comparable, in that each resulted in 17 and 21% respective reductions in BW when compared with controls. The control treatment BW mean at 7 wk was 3,211 g. At 7 wk, the 25 ppm treatment did not differ significantly from the control group, whereas the 50 and 75 ppm levels were depressed by 6 and 9%, respectively, compared with the 0 ppm treatment. Thus, there was a rebound in BW after NH_3 treatment was discontinued at 4 wk of age. Reece et al. (1981) noted a similar recovery in BW once NH_3 was removed so that at 7 wk male broilers had a final BW of 2,012 g. Both the current work and that of Reece et al. (1981) agree with earlier work (Charles and Payne 1966a) re-porting reduced growth rate for broilers as well as delayed maturity in pullets after exposure to atmospheric NH_3. In other research, Charles and Payne (1966b) did not observe a rebound in BW where laying hens were subjected to a prolonged exposure (10 wk). Further, they noted that voluntary food intake of the hens was reduced in high ammonia contain atmospheres (approximately 100 ppm). For pullets exposed to 200 ppm NH_3, feed intake, growth rate, and egg production were less and mortality was greater compared with control (0 ppm) birds (Deaton et al. 1984). The severity of damage to the bird is apparently greater when birds are subjected to exposures that are prolonged and involve high concentrations of NH_3.

John E. Currey (1981) invented a deodorizing process of poultry litter and described that the litter is a mixture comprised of from about 80 to about 95 percent by weight ferrous sulfate heptahydrate; from about 0.1 to about 3.5 percent by weight iron oxide and may contain from about 0.2 to about 1.5 percent calcium carbonate. The particles have from about 0.1 to about 0.5 percent by weight free sulfuric acid distributed on their surfaces. The particles range in size from about 0.02 to about 0.2 inches in diameter. The NH_3 produced by zymosis of bird droppings is effectively reduced and maintained at levels less than 50 ppm and usually less than 30 ppm.

Research Gap and the Recent Study

It appears from various reports that genetic selection is not a suitable tool for reduction of NH_3 from the litter of poultry. It would be possible by making low production line which will require intensive study and high cost involvement. The administrations of drugs which have been successfully in reducing the level of NH_3 have a dubious acceptability with regard to human consumption. All the evidence suggested that it is possible to manipulate the level of NH_3. Various dietary components or additives have used towards this goal. Some of the ingredients have negative effects on production characteristics. It will be wise to reduce NH_3 from the poultry litter by using locally available resources which have no adverse effect on production characteristics and human health. Neem is such an ingredient which has not only bactericidal effect but also has some medicinal properties in Ayurvedic system of medicine are well recognized in Bangladesh, India, and Pakistan. Among the all plant parts the processed leaves play the most significant role in livestock health (Sharma and Reddy. 2002). Different parts of neem had already been used in chicken but to author's knowledge DNL has been never tested in broiler litter to see the bactericidal effect on reduction of NH3 from the litter Thus, it would be interesting to see whether DNL has any bactericidal effect on reduction of NH3 from the litter of poultry.

Materials and Methods

Statement of Research Work

The present study was carried out at Shahjalal Animal Nutrition Field Laboratory, Bangladesh Agriculture University (BAU), and Mymensingh to nvestigate the effects of neem ground dry leaves (Azadirachta indica) in the reduction of NH3 level poultry litter. The experimental trial was conducted from September 06 to November 02, 2011. NH3 level of litter was measured by LaMotte (NH3 IN AIR TEST KIT) in Animal Nutrition Laboratory, BAU, Mymensingh.

Experimental Design

The experiment was conducted using three dietary treatment group containing Chemical product (T1), DNL (T2) and control group (T3). There were three replications under each dietary treatment group and each replication consists of ten birds. So the total experimental unit were nine and total number of birds were Ninety.

Collection, Processing, and Storage of Dry Ground Neem Leaf

The fresh green leaves were harvested from neem trees grown at BAU campus, Mymensingh The green leaves were cleaned and then sun-dried on a polyethylene sheet. The leaves were made free of stems and ground properly by grinding machine. The ground neem leaf were stored in a polyethylene bag and preserved in the feed storage room until used for experimentation. Proper care was taken in the feed storage room to avoid spoilage of dry ground neem leaves.

Experimental Birds

Ninety, healthy Day Old Chicks of Cobb 500 were reared in floor litter. Chickens were almo[st] uniform with regard to BW. Ten birds were accommodating in each space containing 16 square feet. Ten birds were kept in a separate pen and considered as an experimental unit.

Experimental Diet

Chickens were supplied to commercially manufacture ready mate feed from Nourish Poultry Feed maintaining starter for 12 days and grower ration up to marketing (28 days).

Routine Management

The experimental birds in all the treatment groups were exposed to similar care and management in all treatment groups throughout the experimental period. Feeding of birds was done with in a group. Feed and water offered three times, once in the morning at 7 am, in the afternoon at 2.30 pm and in the evening at 8.00 pm. The birds were supplied feed according to their age and water as ad-libitum basis. Feed supplied, feed retained etc were recorded daily and BW was recorded on weekly basis. A continuous 23 hours lightin[g] program was maintained during brooding perio[d] and during growing period lighting was needed in night and in the dark period of the day. The experimental was conducted in semi-open house with exhaust fan system. As the experiment was conducted in summer season, sometime multivitamin and electrolyte were supplied to birds in drinking water to combat stress due to high environmental temperature (27°C to 33°C). Adequate hygienic condition and sanitation were maintained during the experimental period. The entrance point and the floor of the house were kept clean and swept with phenyl mixed water daily and foot dip and sprayed with vircon solution were facilitated in the entrance of the house. The inside wall was also kept clean and sprayed with phenyl solution. Proper bio-security measures were taken during the experimental period. Equipment was made clean and disinfected. Entrance of personnel was restricted except researcher, supervisor, co-supervisor who visited farm by taking special cares. Before entrance, hands were washed with liquid soap and shoes were changed, feet were dipped i[n] footbath. Special cloth dress was used inside th[e] housing during working hours with the birds.

Adequate precautions were taken in case of vaccination. The experimental areas were kept free of rats, cats, dogs and wild flying birds. Calculations were made for change in the BW gain, mortality, feed conversion ratio and NH3 level on the litter.

Data Collection and Record Keeping

Body weight: The day old BW was recorded (initial BW) and then measured BW weekly up to marketing at fourth week of age (final BW). BW gain was calculated by subtracting the initial BW from final BW.

Feed consumption: The amount of feed consumed by the experimental birds under different replication was calculated from the amount of supplied feed at each week and the amounts retained at the end of week.

Feed conversion ratio: The feed conversion ratio was calculated by dividing the total feed consumed during the total period of rearing and the total BW gain.

Measurement of NH_3: The measurement of NH3 gas was done by using the La Motte NH3 in Air Test kit, the content and analytical procedures are given

NH_3 in air test kit
Code 7735
Quantity contents code

2 x 120 mL	*NH_3 Nitrogen Absorbing Solution *7737-J
30 mL	NH_3 Nitrogen Reagent #1 4797WT-G
30 mL	* NH_3 Nitrogen Reagent #2 *4798WT-G

2 Test Tubes, 5 mL, glass, w/caps 0230
1 Ammonia In Air Comparator 7736

Use of the Octet Comparator

The Octet Comparator contains eight permanent color standards. A test sample is inserted into the openings in the top of the comparator. The sample can then be compared to four color standards at once, and the value read off the comparator. For optimum color comparison, the comparator should be positioned between the operator and a light source, so that the light enters through the special light-diffusing screen in the back of the comparator. Avoid viewing the comparator against direct sunlight or an irregularly lighted background.

Working Procedure

1. Pour 10 ml of *NH3 Nitrogen Absorbing Solution (7737) into impinging apparatus. Connect impinging apparatus to intake of air sampling pump.

NOTE: Make sure the long tube is immersed in the absorbing solution.

2. Set flow meter to sample at a rate of 1.0 L pm for 10 minutes or until a measurable amount of NH3 is absorbed.
3. At the end of the sampling period, add contents of impinge to the 5 mL line of test tube (0230).
4. Add 2 drops of NH3 Nitrogen Reagent #1 (4797WT). Cap and mix.
5. Add 8 drops of * NH3 Nitrogen Reagent #2 (4798WT). Cap and mix. Solution will turn yellow to brown color if NH3 is present.
6. Place test tube into NH3 in Air Comparator (7736). Match sample color to index of color standards. Note the index number which gives the proper color match. Record results as ppm NH3 Nitrogen.

NOTE: To convert NH3 nitrogen to NH3, multiply chart Value by 1.2. Record as ppm NH3.

NH_3 in air calibration chart**

Time comparator index number

	1	2	3	4	5	6	7	8
5	3.43	6.86	10.30	13.73	17.16	0.59	4.02	7.46
10	1.72	3.43	5.15	6.86	8.58	0.30	2.01	3.73
15	1.15	2.28	3.43	4.58	5.71	6.86	8.02	9.14
20	0.86	1.72	2.58	3.43	4.30	5.15	6.01	6.86

**Values in ppm

Results and Discussion

NH_3 Level

- Investigation has shown that maximum reduction of NH3 level(93%) in the poultry litter was found hen applied100gm of DNL spread in the saw dust litter; i. e 32.95ppm NH3 gas level reduced into 2.06ppm where as Moore found a result reduction about 75% by using alum (Moore et al, 2008).
- Second highest result (90%) was observed when applied 50gm of DNL spread in the saw dust litter; i. e 32.95ppm NH3 gas level reduced into 3.94ppm
- There was also observed as the increasing amount of DNL spread over the litter, higher reduction rate of NH3

Table1: Result after application of DNL and Biochemical Product.

	Amount (gm/16sq ft)	Ammonia level (Before) ppm	After ppm
	0	20.59	20.59
Saw dust	0	18.53	18.53
	0	19.56	19.56
Sawdust +	32	24.71	12.36
Biochemical	50	28.80	10.29
product	100	26.77	6.17
	32	28.82	4.12
Saw dust+ DNL	**50**	**32.95**	**3.94**
	100	**32.95**	**2.06**

Productive Performance

Body Weight

Analyze of BW data shown that application of DNL at an amount 50 gm spreaded on the litter do not have any negative effect on BW but may be have some positive effect; i.e in controlled treatment the avg final BW of three replication was1490 gm, when applied DNL an amount 50 gm the final BW was 1500.00±60.92gm, which was better than the controlled.

When applied biochemical product and DNL an amount 50 gm, there is no significant difference between them

Investigation also prove that increasing in the amount of DNL create negative effect in feed consumption as well as BW; i.e at 100 gm DNL application, the BW of that birds were on an avg 1250.00±12.3gm

Feed Conversion Ratio

Analyze of feed conversion ratio shown that application of DNL at an amount 50 gm spreaded on the litter do not have any negative effect on feed conversion ratio but may be have some positive effect; i.e in controlled treatment the feed conversion ratio of three replication was1.46, when applied DNL an amount 50 gm, feed conversion ratio was 1.44, which was better than the controlled.

When applied biochemical product and DNL an amount 50 gm, there is no significant difference between them; i.e the feed conversion ratio in case of biochemical product was 1.43 and in case of DNL it was 1.44.

Higher application level of DNL create negative effect in feed conversion ratio; i.e at tl level of 100 gm DNL, the feed conversion ratio was 1.67.

Mortality Rate

There was no significant effect of DNL and biochemical product found in my experiment. Two birds were dead due to heat stress. But very high level of application of DNL may be cause serious problem to the poultry.

Conclusion

The effect of DNL in the reduction of NH3 level of the litter showed a dramatic result when used in the amount of 50g in 16 sq ft without effecting production performance • Comparison of dry DNL and biochemical product in the reduction of NH3 level in poultry litter proved that DNL is more effective based on cost and utilization. Observation of the effect of DNL on productive performance (BW gain, feed conversion ratio and mortality) of poultry birds showed negative when use in optimum level (50g) DNL can be used in a minimum effective amount (50gm) on the reduction of NH3 level of poultry litter due to availability of DNL, its antibacterial, antifungal properties which help the birds for better production performance and protect them from different diseases. Biochemical product is also a good product, but DNL may be more useful because of some reasons such as-availability of the DNL in comparison to biochemical product, there may be some chemical side effect of biochemical product, cost effectively etc.

Higher dose of DNL application may be uneconomic and harmful to birds and lower dose cannot remove the level of NH3 as expected, so 50 gm of NH3 may be preferred for application per 16 sq ft for reducing the level of NH3 gas in the litter of poultry Further research should be carried out to investigate the better effect of DNL application on poultry litter.

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Mortality was related to the timing of infection by the agents, one oncogenic and the other protective. This theory was reported at the 1968 WPDC meeting. Starting in 1970 Kimber farms provided inoculation of fresh turkey blood to chicks going to farms chronically affected with Marek's disease. This followed reports from the USDA regional poultry laboratory at East Lansing that a protective virus was present in turkey blood.

The Kimber laboratory was equipped and staffed for tissue culture production of viruses as a result of the RIF test used in lymphoid leukosis studies. Within 5 months of the 1970 report by Crittenden and Witter of the protective effect of turkey herpes virus, the Kimber laboratory was producing a field-tested effective HVT vaccine. Initially it was given only to Kimber chicks before ownership of the chicks was transferred to purchasers. When demand required wider distribution, a state vaccine license was obtained in 1971.

THE EFFECTS OF SODIUM BISULFATE ON POULTRY HOUSE AMMONIA, LITTER pH, LITTER PATHOGENS AND INSECTS, AND BIRD PERFORMANCE

Mac Terzich

PLT® Division, Jones-Hamilton Co.
710 Camden Ave., Salisbury, MD 21801

INTRODUCTION

The volatilization of ammonia has been attributed to microbial decomposition of nitrogenous compounds (1), principally uric acid in poultry house litter. Litter pH plays a decisive role in NH_3 volatilization (2). Once formed, the free ammonia will be in one of two forms: as the uncharged NH_3 species or the ammonium ion (NH_4), depending on the pH of the litter. Ammonia concentration increases with increasing pH (3). Ammonia release is small when litter pH is below 7.0, but substantial when litter pH is above 8.0. Uric acid decomposition is most favored in alkaline pH conditions. Uricase, the enzyme that catalyzes uric acid breakdown, has maximum activity at a pH of 9 with uric acid disappearance decreasing nearly linearly for more acid or alkaline pH values. One principal ureolytic bacterium, *Bacillus pasteurii*, can not grow at neutral pH, but thrives in litter above pH 8.5.

Several chemicals have been used to control or reduce ammonia release from poultry litter. They act by either inhibiting microbial growth, and hence uric acid decomposition, or by neutralizing ammonia by combining with the released ammonia . Phosphoric acid liquid treatment of poultry litter lowered litter pH and decreased ammonia levels but caused concerns with phosphorus run-off (4). Sodium bisulfate (SBS) is a dry granular acid used by the poultry industry for ammonia control and litter acidification. Litter acidification may, apart from reducing ammonia production, decrease numbers of bacterial pathogens and beetles in the litter. This report summarizes a series of research trials conducted to document the effects of treating poultry litter with SBS on poultry house ammonia, litter pH, and bacterial pathogens and beetles in the litter.

MATERIALS AND METHODS

Poultry House Ammonia and Litter pH. Two hundred 40' x 500' poultry houses were used for this trial in the mid-Atlantic region during the winter of 1996, one hundred had the litter treated with sodium bisulfate at a rate of 2.5 kg/10m^2 by topdressing the litter the day before chick placement. The farms were paired and conditions in the matched control and treated houses were similar. Measurements were made before SBS treatment, immediately after treatment, and on a weekly basis for the duration of each flock. Ammonia levels were measured with a hand-held pump using detection tubes at floor level. Litter pH levels were determined by collecting 60 ml of litter and mixing with an equal amount of distilled water and emerging an electronic digital pH meter into the slurry. All samples were collected in six different locations in the house and the data represents averages of those readings. Data was collected on bird performance and fuel usage.

Litter Pathogens. Two trials were conducted, one in a laboratory utilizing 12 polyethylene containers (12"x12"x12") and another in 12 colony houses (11'x12'). Sterilized poultry litter (wood-shavings) was seeded with 1 x 10^9 colony forming units of Salmonella enteritidis strain 575. In half the containers and colony houses the litter was treated with SBS at a rate of 1.4 kg/10 m^2 by topdressing once. The litter in all containers and houses was dragged over the surface with a 2" x 2" swab before and after SBS application and at 3, 6, 24, 48, 72, and 168 hours after SBS application. The litter drag swabs were cultured on MacConkey and XLD agar. All potential Salmonella colonies were verified by biochemical assays and typed by anti-serum agglutination. Salmonella colonies were quantified as no growth, 1-10, and > 10 colonies. The pH of the litter was determined with an electronic digital pH meter.

Litter beetles. The purpose of this trial was to determine the effect of litter acidification with SBS on beetle populations in poultry houses and the effect of litter acidification on effective life of insecticides. Twelve commercial broiler houses were used for this study. SBS was applied at 2.5 kg/ 10 sq. m in two houses, two houses had litter untreated as controls, and two houses each had litter treated with an organophosphate insecticide, a pyrethroid insecticide, SBS with the organophosphate insecticide, and SBS with the pyrethroid insecticide. Beetle counts were done at several locations in each house on a weekly basis for the flock duration of seven weeks by using 1.5 inch diameter plastic tubes with corrugated cardboard inserts. The co[illegible] were averaged for each treatment.

RESULTS AND DISCUSSION

Poultry House Ammonia and Litter pH. In this study, SBS treated litter houses had significantly lower ammonia and litter pH than untreated litter control houses (Table 1). Bird performance is outlined in Table 2. Fuel usage was 43% greater in control than treated houses due to longer fan times and venting of heat.

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

		Before treat-ment	After treat-ment	Time of measurement in weeks						
				1	2	3	4	5	6	7
Ammonia										
levels	Treated	127	0	0	5	8	15	19	20	18
(PPM)	Untreated	119	119	125	125	138	114	128	98	97
Litter	Treated	8.5	1.7	2.1	3.4	4.5	5.0	5.5	5.9	6.4
pH	Untreated	8.9	8.9	8.7	9.1	8.5	9.3	8.6	8.1	8.9

Table 2. Average bird performance in houses in which litter was treated with sodium bisulfate compared with houses in which litter was untreated.

	# Birds	% Mortality	Age-Days	Avg. Weight (lbs.)	Avg. Daily Gain (lbs.)	% Air sac Lesion
Treated	1,282,256	7.14	51.7	5.39	.1043	1.80
Untreated	1,219,918	8.05	50.3	5.19	.1032	3.39

The detrimental effects of ammonia in poultry production have been known for years. Numerous laboratory and field studies have shown how ammonia affects bird health and performance. High ammonia levels damage the bird's respiratory system and allow viruses and bacteria to cause infection leading to declining flock health and performance (5). E. coli bacteria are significantly increased in the lungs, air sacs, and livers of birds exposed to ammonia following aerosol exposure to E. coli. Because of ammonia damaged tracheal cilia, clearance rate of E. coli from the bird is decreased compared to birds not exposed to ammonia (6). Body weight, feed conversion, and condemnation rates of ammonia exposed birds are poorer as ammonia levels rise (7) and resistance to respiratory diseases is decreased (8).

Litter pathogens. In these trials, SBS treated litter had significantly lower pH than control, non-treated litter. This litter acidification in the SBS treated litter resulted in significantly lower Salmonella counts (Table 3).

These findings have implications for bird health and performance and food safety. Mallinson *et al* (10) have shown that litter Salmonella has been linked to poor bird feed conversion, and increased condemnations with decreased weight gains. They have linked on-farm HACCP progra[illegible] success with reduction of Salmonella and other pathogens [illegible] manipulation of litter characteristics as part of these programs.

Litter beetles. The results showed that litter acidification is critical to insecticide efficacy with lower litter pH resulting in greatly increased persistence of insecticide and that SBS treatment helps lower beetle populations (Table 4).

The darkling beetle, *Alphitobius diaperinus*, also referred to as the lesser mealworm, litter beetle, black bug, and black poultry bug, is found abundantly in poultry house litter and manure worldwide. They originated in Africa, but have become well adapted pests in poultry houses feeding on dead birds, poultry feed, and manure. Untreated poultry litter is a perfect environment for beetle reproduction (11). Beetles threaten profitable poultry production in three ways: 1) they burrow into and damage poultry house insulation, destroying up to 30 % of the total insulation resulting in substantially higher fuel usage; 2) consumption of beetles and larvae by birds may result in decreased weight gain and feed efficiency; 3) beetles are well known transmitters of many costly poultry diseases (12, 13, 14).

Table 3. The effect of treating litter with sodium bisulfate on the growth of Salmonella enteritidis (SE).

		Treated litter		Untreated litter	
Trial	Hours After Treatment	SE Colony Count	pH	SE Colony Count	pH
Laboratory	0	++[a]	8.0	++	7.9
	3	NG[b]	2.1	++	7.8
	6	NG	2.3	++	7.5
	24	NG	2.4	++	7.9
	48	NG	2.3	++	8.1
	72	NG	2.5	+	7.8
	168	NG	2.8	+	7.9
Colony house	0	++	8.0	++	8.3
	3	NG	3.8	++	8.3
	6	NG	3.1	+	8.3
	24	NG	2.8	++	8.4
	48	NG	2.9	++	9.3
	72	NG	3.5	+	8.4
	168	NG	3.1	++	7.9

+[a] = 1 - 10 colonies, ++ = > 10 colonies, NG[b] = No Growth

Table 4. The effect of litter treatment with sodium bisulfate and insecticides on beetle populations. The data represent average counts of beetles made for each treatment.

	Time of measurement in weeks						
Treatment	1	2	3	4	5	6	7
Untreated	5	25	35	38	58	73	128
Sodium bisulfate	7	5	8	12	14	16	48
Organophosphate insecticide	3	5	6	15	12	23	35
Sodium bisulfate + organophosphate insecticide	3	3	4	8	7	10	9
Pyrethroid insecticide	2	5	7	12	18	28	45
Sodium bisulfate + pyrethroid insecticide	2	3	3	7	12	15	14

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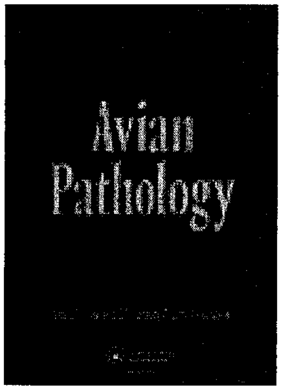
EVALUATION OF HATCHERY HYGIENE BY THE FLUFF TEST IN TAIWAN

Ching-Ho Wang and Chung-Hsi Chou

Department of Veterinary Medicine, National Taiwan University
142 Chow-Shan Road, Taipei 106, Taiwan

The surveillance of the hygiene in hatcheries in Taiwan by the fluff test commenced in January, 1996. All together, 6437 fluff samples were sent from 25 hatcheries around Taiwan to our laboratory between January and September. The fluff samples were tested for total bacterial counts, *Salmonella*, pathogenic *Staphylococcus* and fungi. The log bacterial counts of the samples were 1.4-5.9, 1.1-5.6, 1.0-6.0, in the first (January-March), second (April-June), and third (July-September) quarters, respectively. Fourteen hatcheries made significant progress in hygiene after this surveillance ($P<0.05$). The presence of *Salmonella* decreased greatly ($P<0.001$) from 2.7% to 0.3% and to 0.2% in the three quarters, respectively. Pathogenic *Staphylococcus* also decreased greatly from 8.6% to 2.6% and to 1% ($P<0.001$). However, the fungal contamination varied in different quarters (4.8%, 1.4%, and 5.8%, respectively). In conclusion, the fluff test is necessary for maintaining hygiene in hatcheries in Taiwan.

A-33



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Effect of Poultry Litter Treatment® (PLT®) on the development of respiratory tract lesions in broilers

M. Terzich [a] [b], C. Quarles [c], M. A. Goodwin [a] [f] & J. Brown [e]

[a] Jones-Hamilton Company , 1 Plaza East, Suite 505, Salisbury, MD, 21801

[b] Jones-Hamilton Company , 1 Plaza East, Suite 505, Salisbury, MD, 21801 Phone: 800 379 2243 Fax: 800 379 2243

[c] Colorado Quality Research Inc. , 400 E. County Road 72, Wellington, CO, 80549

[d] Department of Veterinary Pathology , University of Georgia , Athens, Georgia, 30602

[e] Department of Medical Microbiology, College of Veterinary Medicine , University of Georgia , Athens, Georgia, 30602

[f] Georgia Poultry Laboratory , P.O. Box 20, Oakwood, Georgia, 30566, USA

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Effect of Poultry Litter Treatment® (PLT®) on the development of respiratory tract lesions in broilers

M. Terzich[1]*, C. Quarles[2], M. A. Goodwin[3,5] & J. Brown[4]

[1]*Jones-Hamilton Company, 1 Plaza East, Suite 505, Salisbury, MD 21801,* [2]*Colorado Quality Research Inc., 400 E. County Road 72, Wellington, CO 80549, Departments of* [3]*Veterinary Pathology and* [4]*Medical Microbiology, College of Veterinary Medicine, University of Georgia, Athens, Georgia 30602, and* [5]*Georgia Poultry Laboratory, P.O. Box 20, Oakwood, Georgia 30566 USA*

In previous studies, Poultry Litter Treatment® (PLT®) was shown to reduce atmospheric ammonia levels and ascites death rates, and produce higher profit value in broiler chickens. The purpose of the present study was to determine the effect of PLT® on atmospheric ammonia levels, the development of respiratory tract lesions, and body weight gains in broiler chickens. Data were collected from chicks that were raised in containment conditions that resembled commercial settings. Atmospheric ammonia levels, gross thoracic air sac lesion scores, and the numbers and magnitudes of histopathologic tracheal mucosal injuries were significantly ($P = 0.001$) reduced in chickens that were raised on PLT®-treated litter than in their untreated-litter control counterparts. In addition, mean body weights and lung:body weight ratios were significantly ($P < 0.03$) larger in broilers that were raised on treated litter. The reductions in respiratory tract lesions among broilers raised on PLT®-treated litter were attributed to reductions in atmospheric ammonia levels.

Introduction

Poultry Litter Treatment® (PLT®); a proprietary product that is made by mixing sodium hydrogen sulphate [93.2%] with sodium sulphate [6.5%]) has been used to reduce atmospheric ammonia levels in horse barns (Sweeney *et al.*, 1997) and commercial and experimental chicken houses (Terzich, 1997; Terzich, unpublished). Concomitantly, reduced ascites death rates and higher profit values were seen in broiler chickens that were raised in these low-ammonia atmospheres.

The adverse effects of ammonia on poultry production parameters have been reviewed (Carlile, 1984; Owen, 1992). Controlled (reduced) atmospheric ammonia levels and improved litter quality could be central factors in improved poultry health and production performance in broiler chickens that are raised on PLT®-treated and atmospheric-ammonia-reduced-litter (Carlile, 1984; Owen, 1992; Terzich, 1997). The purpose of the present study was to determine the effect of PLT® on atmospheric ammonia levels and respiratory tract lesions in broiler chickens.

Materials and methods

Chicks and husbandry

Chick housing conditions simulated those found in most commercial settings. Two-thousand-six-hundred-and-forty-one-day-old male broiler chicks were housed in 40 wood-and-wire-enclosed pens (66 chicks per pen) with concrete floors that were covered with 10 cm of used poultry litter. This built-up pine shavings litter was obtained from a commercial chicken house in which only healthy broiler chickens had been reared during the past year. The lower parts of each pen were separated from each other by a 46-cm high plywood barrier. Available floor space was 0.06 m^2 per chick. Fan ventilation and space heating also simulated a commercial setting, in which excessive levels of atmospheric ammonia are commonly found. For the purpose of the present study, ammonia levels in excess of 25 ppm were considered to be excessive.

Chicks had been vaccinated for Marek's disease in the hatchery at one-day-old. When the chickens were 17 days old, a combination Newcastle disease/infectious bronchitis vaccine (1.5 dose/chick) was administered in the drinking water according to the manufacturer's instructions.

Chicks were fed a commercial diet and water *ad libitum*. At 6, 9, 10, 13 and 20, days of age, 496 ml of tap water was sprayed onto the litter in all 40 pens to promote the generation of ammonia gas. Prior to chick placement, PLT® was applied via a hand-held broadcast spreader to the litter in 20 pens. The rate of application in these pens was 2.27 kg per 9.29 m^2. Litter in the other 20 pens received no other treatment.

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Observations and measurements

Atmospheric ammonia levels were measured (Matheson toxic gas detector Model 8014KA; Precision gas detector tubes #105SC, 5 to 260 ppm; Fisher Scientific Co., Pittsburgh, Penn, USA) at chick eye level in each pen on the day before litter treatment (day −1), the day of litter treatment (day 0), and when chicks were 8, 15, 23 and 49 days old (days 7, 14, 22 and 48 post-treatment). When the chickens were 23 and 49 days old, six birds from each pen (120 birds per treatment, 240 birds total) were arbitrarily collected, humanely killed, weighed and examined for respiratory tract gross lesions.

Both lungs were removed and weighed. Lung weight expressed as a percentage of body weight was called the lung:body weight ratio. The thoracic air sacs were assigned gross lesion scores, where 0 = clear, 1 = cloudy, 2 = cloudy with minimal caseous exudate accumulation and 3 = severe caseous exudate accumulation. A 2.5-cm longitudinal hemi-sectioned portion of trachea from each chicken was immersion-fixed in a coded container that was three-quarters full of 10% neutral buffered formalin. Tracheas were processed through paraffin, sectioned, stained with haematoxylin and eosin and examined with a light microscope. The severity and distribution of mucosal morphological lesions (loss of cilia, epithelial cell hypertrophy and hyperplasia, inflammation and necrosis) in sections of trachea were recorded. A score was assigned to each lesion and its distribution, and was the sum of A + B, where A represented the severity of the lesion within the section and B represented the distribution of the lesion across the section.

For injury distribution, scores were either 0 = no injury, 1 = focal injury, 2 = multifocal injury or 3 = diffuse injury. For each of loss of cilia, epithelial cell hypertrophy/hyperplasia, and necrosis, a severity score was assigned where 0 = no cells (0%) affected, 1 = < 25% of cells affected, 2 = 25 to 50% of cells affected, 3 = 50 to 75% of cells affected and 4 = > 75% of cells affected. For inflammation, 0 = none, 1 = minimal: inflammatory cells were directed toward the lumenal epithelium; 2 = mild: inflammatory cells predominated within the epithelium, fewer inflammatory cells also were found in the lamina propria; 3 = moderate: inflammatory cells were found scattered throughout the mucosa; and 4 = marked: sheets of inflammatory cells filled the mucosa. After scores were assigned, the treatment code was revealed to the biostatistician. The numbers of chicks in each group with each magnitude (minimal, mild, moderate, marked) of mucosal injury were also recorded.

Biometrics

The atmospheric ammonia level, lung weight/bird weight, thoracic air sac score, and tracheal mucosal lesion score data were analyzed using a t-test (Zar, 1978). The number and magnitude of histopathologic tracheal mucosal injuries were analyzed using a chi-square test (Zar, 1978).

Results

The atmospheric ammonia levels in PLT®-treated pens were significantly lower than in pens that received no treatment (Table 1). No gross lesions were seen in lungs or tracheas from birds in either two treatment groups. The mean body weights were significantly larger in 23- and 49-day-old broilers that were raised on PLT®-treated litter compared to their control counterparts (Table 2). The lung:body weight ratios were significantly larger in 23- and 49-day-old broilers that were raised on PLT®-treated litter compared to their control counterparts (Table 2). Gross thoracic air sac lesion scores were significantly lower in 23- and 49-day-old broilers that were raised on PLT®-treated litter compared to their control counterparts (Table 2).

Table 1. *Mean atmospheric ammonia levels (ppm) in pens where litter was or was not treated with PLT®[a]*

Days after treatment[b]	Ammonia levels following litter treatment	
	None	PLT®
−1	96[c]	88
0	95	5*[,d]
7	72	14*
14	115	20*
22	115	22*
48	53	19*

[a]Poultry Litter Treatment®.
[b]Treatment was immediately prior to chick placement at 1-day-old.
[c]Mean ammonia levels are parts per million. In the present study, ammonia levels in excess of 25 ppm were considered to be excessive.
[d]Asterisk indicates a significant ($P < 0.001$) difference between treatments.

The numbers and magnitude of tracheal mucosal histopathological changes in broiler chickens that were raised on litter treated or not treated with PLT® are shown in Table 3. Tracheas from broiler chickens raised in pens that were treated with PLT® had significantly ($P < 0.0001$) lower mucosal microscopic lesion scores than their untreated-litter control counterparts (Table 3). Specifically, there was significantly ($P < 0.001$) less loss of cilia, epithelial cell hypertrophy and

Table 2. *Mean body weights, thoracic air sac gross lesion scores and lung:body-weight ratios in broiler chickens that were raised on litter treated or not treated with PLT®[a]*

Day of age	Measured parameter	Treatment	Effect on parameter	P value[e]
23	BW[b]	None	712	
		PLT®	767	<0.0001
	ASLS[c]	None	1.36	
		PLT®	0.12	<0.0001
	LBWR[d]	None	0.65	
		PLT®	0.69	<0.001
49	BW	None	2204	
		PLT®	2312	<0.01
	ASLS	None	1.36	
		PLT®	0.36	<0.0001
	LBWR	None	0.71	
		PLT®	0.75	<0.05

[a]Poultry Litter Treatment®.
[b]Mean body weight (g).
[c]Mean gross air sac lesion score; scores were 0 = clear, 1 = cloudy, 2 = cloudy with minimal caseous exudate accumulation and 3 = severe caseous exudate accumulation.
[d]Mean lung:body weight ratio (g).
[e]*T*-test; significance level is shown.

Table 3. *Histopathological findings in the mucosa of tracheas of 23-day-old broiler chickens raised in pens that were treated or not treated with PLT®*[a]

Lesion	Litter treatment	Histopathology score[b]	Numbers of chickens with these injury magnitudes[c]				P value[d]
			Minimal	Mild	Moderate	Marked	
Loss of cilia	None	4.00*	0	0	0	20	<0.001
	PLT	3.25	0	1	13	6	
Hypertrophy and hyperplasia	None	6.00*	0	0	0	20	<0.001
	PLT	5.10	0	18	0	2	
Inflammation	None	6.00*	0	0	20	0	<0.001
	PLT	5.20	0	16	4	0	
Necrosis	None	4.60*	0	8	12	0	<0.001
	PLT	3.65	10	8	2	0	

[a]Poultry Litter Treatment®.
[b]See text for scoring method. Numbers are mean scores. A t-test was used to analyse these data, and an asterisk indicates a significant ($P < 0.0001$) difference between treatments.
[c]Twenty chickens in each group.
[d]A chi-square test was used.

hyperplasia, inflammation, and necrosis in chickens that were raised on PLT®-treated litter (where the magnitude of injury was usually either minimal or mild, rarely moderate) than the controls (where the magnitude of injury was either moderate or marked, never minimal or mild).

Discussion

In the present study, atmospheric ammonia levels, gross thoracic air sac lesion scores, and the magnitude of histopathologic tracheal mucosal injury were significantly reduced in chickens that were raised on PLT®-treated litter compared to their untreated-litter control counterparts. In addition, mean body weights and lung:body weight ratios were significantly higher in broilers that were raised on treated litter. The reductions in respiratory tract lesions among broilers raised on PLT®-treated litter were attributed to reductions in atmospheric ammonia levels.

The fact that these respiratory changes could be attributable to atmospheric ammonia is supported by our work and the work of others who have determined ammonia's direct adverse effects upon tracheal mucosal morphology and function (Dalhamm, 1956; Anderson *et al.*, 1964; Anderson *et al.*, 1966; Moum *et al.*, 1969; Nagaraja *et al.*, 1983; Carlile, 1984; Nagaraja *et al.*, 1984; Owen, 1992). In addition, broilers that were raised on treated litter had significantly higher mean body weights and significantly higher lung:body weight ratios. Smaller body weights in broilers raised on untreated litter were attributed to the effects of higher atmospheric ammonia on body weight gain (Reece *et al.*, 1980; Terzich, 1997; Terzich, unpublished). We cannot explain why broilers raised on PLT®-treated litter had higher lung:body weight ratios than the controls; however, we have seen this effect previously in large and small broilers with respect to intestine weight:body weight ratios (J. Brown, unpublished). Our observations are supported by the work of others who found that fast-growing turkeys have unexplainably longer, heavier, and more dense intestines than their slow-growing counterparts (Fan *et al.*, 1997).

Results from the present study help explain why chickens raised on litter treated with PLT® have lower mortality rates (Terzich, 1997), lower ascites death rates, and higher profit values than chickens that are raised on untreated litter (Terzich, 1997; Terzich, unpublished). All the actions of PLT® in poultry litter are not known; however, when PLT® is applied to litter, the litter pH is lowered, free ammonium ions are converted to ammonium sulphate, and sodium binds with phosphates to form sodium phosphate. The effect of PLT® on litter microflora and biochemistry is currently being studied. The most important practical application of our findings is to use PLT® in follow-up studies in commercial settings to determine its value in abating respiratory disease in chickens.

Acknowledgements

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RÉSUMÉ

Effet du Poultry Litter Treatment® (PLT®) sur le développement des lésions du tractus respiratoire chez le poulet de chair

Lors d'études préliminaires, il a été démontré que le Poultry Litter Treatment® (PLT®) entraînait une diminution des niveaux d'ammoniac atmosphérique et des taux de mortalité dus à l'ascite, et avait pour conséquence de meilleurs résultats économiques chez le poulet de chair. Le but de cette étude a été de déterminer l'effet du PLT® sur les niveaux d'ammoniac atmosphérique, le développement des lésions du tractus respiratoire et les gains de poids chez le poulet de chair. Les données ont été récoltées chez des poulets élevés dans des conditions de confinées qui ressemblaient à celles des troupeaux commerciaux. Le niveau d'ammoniac atmosphérique, les notations des lésions macroscopiques des sacs aériens thoraciques, ainsi que le nombre et l'importance des lésions histopathologiques au niveau de la muqueuse trachéale ont été réduits significativement chez les poulets élevés sur des litières traitées PLT® ($P = 0.001$) comparé à ceux des témoins élevés sur des litières non-traitées. De plus, les rapports des poids moyens du corps et des poumons, sur le poids du corps ont été significativement plus importants chez les poulets élevés sur des litières traitées ($P < 0.03$). Les réductions des lésions du tractus respiratoire chez les poulets de chair élevés sur des litières traitées PLT® ont été attribuées à la réduction des niveaux d'ammoniac atmosphérique.

ZUSAMMENFASSUNG

Effekt von Poultry Litter Treatment® auf die Entstehung von Schädigungen im Respirationstrakt bei Broilern

In früheren Untersuchungen wurde gezeigt, daß Poultry Litter Treatment® (PLT®) die atmosphärischen Amoniakkonzentrationen und Aszites-Sterblichkeitsraten reduziert und dadurch einen höheren Gewinn bei Mastküken bewirkt. Das Ziel der vorliegenden Untersuchung war, den Effekt von PLT® auf die Ammoniakkonzentrationen in der Luft, die Entwicklung von Atemwegsschädigungen und die Körpergewichtszunahmen bei Mastküken zu ermitteln. Versuchsdaten wurden von Küken gesammelt, die unter Haltungsbedingungen aufgezogen wurden, die kommerziellen Umgebungen ähnlich waren. Die atmosphärische Ammoniakkonzentration, die Scores der makroskopischen Brustluftsackveränderungen und die Menge und das Ausmaß der histologischen Trachealschleimhaut-Schädigungen waren bei Küken, die auf PLT®-behandelter Einstreu aufgezogen wurden, im Vergleich zu den jeweiligen Kontroll-Küken auf unbehandelter Einstreu signifikant ($P = 0.001$) reduziert. Außerdem waren die mittleren Körpergewichte und die Quotienten von Lungengewicht:Körpergewicht bei Mastküken, die auf behandelter Einstreu aufgezogen wurden, signifikant ($P < 0.03$) größer. Die Reduzierung der Atemwegsveränderungen bei den auf PLT®-behandelter Einstreu aufgezogenen Küken wurde auf die Reduzierungen der atmosphärischen Ammoniak-Konzentrationen zurückgeführt.

RESUMEN

Efecto del Poultry Litter Treatment® (PLT®) en el desarrollo de lesiones respiratorias en broilers

En estudios previos, se ha demostrado que el Poultry Litter Treatment® (PLT®) reduce los niveles de amoníaco en el aire, los índices de muertes por ascitis y da lugar a un mayor valor de aprovechamiento en broilers. La finalidad de este estudio fue determinar el efecto del PLT® sobre los niveles de amoníaco en el aire, sobre el desarrollo de lesiones en el tracto respiratorio y sobre la ganancia de peso en broilers. Los datos se tomaron a partir de pollos criados en unas condiciones de mantenimiento similares a las comerciales. El nivel de amoníaco en el aire, las lesiones macroscópicas de sacos aéreos torácicos y el número y la magnitud de las lesiones histopatológicas de la mucosa traqueal fueron significativamente ($P = 0.001$) menores en los pollos criados sobre camas PLT® que en los pollos control, criados sobre camas no tratadas. Además, los pesos corporales medios y las relaciones de peso pulmón:cuerpo, fueron significativamente ($P < 0.03$) mayores en broilers criados sobre camas tratadas. La reducción de las lesiones en el tracto respiratorio en los broilers criados sobre camas PLT® se atribuyó a la reducción del nivel de amoníaco en el aire.

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Effect of Poultry Litter Treatment® (PLT®) on the development of respiratory tract lesions in broilers

M. Terzich[1]*, C. Quarles[2], M. A. Goodwin[3,5] & J. Brown[4]

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	LBWR[d]	None	0.65	
		PLT®	0.69	<0.001
49	BW	None	2204	
		PLT®	2312	<0.01
	ASLS	None	1.36	
		PLT®	0.36	<0.0001
	LBWR	None	0.71	
		PLT®	0.75	<0.05

[a]Poultry Litter Treatment®.
[b]Mean body weight (g).
[c]Mean gross air sac lesion score; scores were 0 = clear, 1 = cloudy, 2 = cloudy with minimal caseous exudate accumulation and 3 = severe caseous exudate accumulation.
[d]Mean lung:body weight ratio (g).
[e]*T*-test; significance level is shown.

Table 3. *Histopathological findings in the mucosa of tracheas of 23-day-old broiler chickens raised in pens that were treated or not treated with PLT®*[a]

Lesion	Litter treatment	Histopathology score[b]	Numbers of chickens with these injury magnitudes[c]				P value[d]
			Minimal	Mild	Moderate	Marked	
Loss of cilia	None	4.00*	0	0	0	20	<0.001
	PLT	3.25	0	1	13	6	
Hypertrophy and hyperplasia	None	6.00*	0	0	0	20	<0.001
	PLT	5.10	0	18	0	2	
Inflammation	None	6.00*	0	0	20	0	<0.001
	PLT	5.20	0	16	4	0	
Necrosis	None	4.60*	0	8	12	0	<0.001
	PLT	3.65	10	8	2	0	

[a]Poultry Litter Treatment®.
[b]See text for scoring method. Numbers are mean scores. A t-test was used to analyse these data, and an asterisk indicates a significant ($P<0.0001$) difference between treatments.
[c]Twenty chickens in each group.
[d]A chi-square test was used.

hyperplasia, inflammation, and necrosis in chickens that were raised on PLT®-treated litter (where the magnitude of injury was usually either minimal or mild, rarely moderate) than the controls (where the magnitude of injury was either moderate or marked, never minimal or mild).

Discussion

In the present study, atmospheric ammonia levels, gross thoracic air sac lesion scores, and the magnitude of histopathologic tracheal mucosal injury were significantly reduced in chickens that were raised on PLT®-treated litter compared to their untreated-litter control counterparts. In addition, mean body weights and lung:body weight ratios were significantly higher in broilers that were raised on treated litter. The reductions in respiratory tract lesions among broilers raised on PLT®-treated litter were attributed to reductions in atmospheric ammonia levels.

The fact that these respiratory changes could be attributable to atmospheric ammonia is supported by our work and the work of others who have determined ammonia's direct adverse effects upon tracheal mucosal morphology and function (Dalhamm, 1956; Anderson *et al.*, 1964; Anderson *et al.*, 1966; Moum *et al.*, 1969; Nagaraja *et al.*, 1983; Carlile, 1984; Nagaraja *et al.*, 1984; Owen, 1992). In addition, broilers that were raised on treated litter had significantly higher mean body weights and significantly higher lung:body weight ratios. Smaller body weights in broilers raised on untreated litter were attributed to the effects of higher atmospheric ammonia on body weight gain (Reece *et al.*, 1980; Terzich, 1997; Terzich, unpublished). We cannot explain why broilers raised on PLT®-treated litter had higher lung:body weight ratios than the controls; however, we have seen this effect previously in large and small broilers with respect to intestine weight:body weight ratios (J. Brown, unpublished). Our observations are supported by the work of others who found that fast-growing turkeys have unexplainably longer, heavier, and more dense intestines than their slow-growing counterparts (Fan *et al.*, 1997).

Results from the present study help explain why chickens raised on litter treated with PLT® have lower mortality rates (Terzich, 1997), lower ascites death rates, and higher profit values than chickens that are raised on untreated litter (Terzich, 1997; Terzich, unpublished). All the actions of PLT® in poultry litter are not known; however, when PLT® is applied to litter, the litter pH is lowered, free ammonium ions are converted to ammonium sulphate, and sodium binds with phosphates to form sodium phosphate. The effect of PLT® on litter microflora and biochemistry is currently being studied. The most important practical application of our findings is to use PLT® in follow-up studies in commercial settings to determine its value in abating respiratory disease in chickens.

Acknowledgements

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RÉSUMÉ

Effet du Poultry Litter Treatment® (PLT®) sur le développement des lésions du tractus respiratoire chez le poulet de chair

Lors d'études préliminaires, il a été démontré que le Poultry Litter Treatment® (PLT®) entraînait une diminution des niveaux d'ammoniac atmosphérique et des taux de mortalité dus à l'ascite, et avait pour conséquence de meilleurs résultats économiques chez le poulet de chair. Le but de cette étude a été de déterminer l'effet du PLT® sur les niveaux d'ammoniac atmosphérique, le développement des lésions du tractus respiratoire et les gains de poids chez le poulet de chair. Les données ont été récoltées chez des poulets élevés dans des conditions de confinées qui ressemblaient à celles des troupeaux commerciaux. Le niveau d'ammoniac atmosphérique, les notations des lésions macroscopiques des sacs aériens thoraciques, ainsi que le nombre et l'importance des lésions histopathologiques au niveau de la muqueuse trachéale ont été réduits significativement chez les poulets élevés sur des litières traitées PLT® ($P = 0.001$) comparé à ceux des témoins élevés sur des litières non-traitées. De plus, les rapports des poids moyens du corps et des poumons, sur le poids du corps ont été significativement plus importants chez les poulets élevés sur des litières traitées ($P < 0.03$). Les réductions des lésions du tractus respiratoire chez les poulets de chair élevés sur des litières traitées PLT® ont été attribuées à la réduction des niveaux d'ammoniac atmosphérique.

ZUSAMMENFASSUNG

Effekt von Poultry Litter Treatment® auf die Entstehung von Schädigungen im Respirationstrakt bei Broilern

In früheren Untersuchungen wurde gezeigt, daß Poultry Litter Treatment® (PLT®) die atmosphärischen Amoniakkonzentrationen und Aszites-Sterblichkeitsraten reduziert und dadurch einen höheren Gewinn bei Mastküken bewirkt. Das Ziel der vorliegenden Untersuchung war, den Effekt von PLT® auf die Ammoniakkonzentrationen in der Luft, die Entwicklung von Atemwegsschädigungen und die Körpergewichtszunahmen bei Mastküken zu ermitteln. Versuchsdaten wurden von Küken gesammelt, die unter Haltungsbedingungen aufgezogen wurden, die kommerziellen Umgebungen ähnlich waren. Die atmosphärische Ammoniakkonzentration, die Scores der makroskopischen Brustluftsackveränderungen und die Menge und das Ausmaß der histologischen Trachealschleimhaut-Schädigungen waren bei Küken, die auf PLT®-behandelter Einstreu aufgezogen wurden, im Vergleich zu den jeweiligen Kontroll-Küken auf unbehandelter Einstreu signifikant ($P = 0.001$) reduziert. Außerdem waren die mittleren Körpergewichte und die Quotienten von Lungengewicht:Körpergewicht bei Mastküken, die auf behandelter Einstreu aufgezogen wurden, signifikant ($P < 0.03$) größer. Die Reduzierung der Atemwegsveränderungen bei den auf PLT®-behandelter Einstreu aufgezogenen Küken wurde auf die Reduzierungen der atmosphärischen Ammoniak-Konzentrationen zurückgeführt.

RESUMEN

Efecto del Poultry Litter Treatment® (PLT®) en el desarrollo de lesiones respiratorias en broilers

En estudios previos, se ha demostrado que el Poultry Litter Treatment® (PLT®) reduce los niveles de amoníaco en el aire, los índices de muertes por ascitis y da lugar a un mayor valor de aprovechamiento en broilers. La finalidad de este estudio fue determinar el efecto del PLT® sobre los niveles de amoníaco en el aire, sobre el desarrollo de lesiones en el tracto respiratorio y sobre la ganancia de peso en broilers. Los datos se tomaron a partir de pollos criados en unas condiciones de mantenimiento similares a las comerciales. El nivel de amoníaco en el aire, las lesiones macroscópicas de sacos aéreos torácicos y el número y la magnitud de las lesiones histopatológicas de la mucosa traqueal fueron significativamente ($P = 0.001$) menores en los pollos criados sobre camas PLT® que en los pollos control, criados sobre camas no tratadas. Además, los pesos corporales medios y las relaciones de peso pulmón:cuerpo, fueron significativamente ($P < 0.03$) mayores en broilers criados sobre camas tratadas. La reducción de las lesiones en el tracto respiratorio en los broilers criados sobre camas PLT® se atribuyó a la reducción del nivel de amoníaco en el aire.

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Ammonia Emissions from USA Broiler Chicken Barns Managed with New Bedding, Built-up Litter, or Acid-Treated Litter

Eileen F. Wheeler
Pennsylvania State University

Kenneth D. Casey
Texas A&M

Richard S. Gates
University of Kentucky

Hongwei Xin
Iowa State University, hxin@iastate.edu

Patrick A. Topper
Pennsylvania State University

See next page for additional authors

Authors
Eileen F. Wheeler, Kenneth D. Casey, Richard S. Gates, Hongwei Xin, Patrick A. Topper, and Yi Liang

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Ammonia Emissions from USA Broiler Chicken Barns Managed with New Bedding, Built-up Litter, or Acid-Treated Litter

E. F. Wheeler[1], K. D. Casey[2], R. S. Gates[3], H. Xin[4], P. A. Topper[1], and Y. Liang[4]
[1]Agricultural and Biological Engineering, The Pennsylvania State University, University Park, Pennsylvania
[2] Texas AgriLife Research, Texas A&M System, Amarillo, Texas
[3] Biosystems and Agricultural Engineering, University of Kentucky, Lexington, Kentucky
[4] Agricultural and Biosystems Engineering, Iowa State University, Ames, Iowa
[4] Biological and Agricultural Engineering, University of Arkansas. Fayetteville, Arkansas

Abstract. Poultry producers in the United States have attempted to maintain barn aerial ammonia (NH_3) levels below 25 ppm to improve air quality, and more recently to decrease aerial emissions to the atmosphere. Our objective was to investigate the influence of litter management strategies on NH_3 emissions from commercial broiler barns employing new bedding, acid-treated built-up litter (sodium bisulphate), or untreated built-up litter (normal practice). Nearly 400 barn-days of NH_3 emissions data were collected from 12 broiler barns on four farms monitored in 48-hour episodes over one year. On each study farm, the barns were paired for repetition of conditions. Emission was calculated as the product of gas concentration of the exhaust air and barn ventilation rate. Use of new bedding for every flock led to consistently lower NH_3 emission (averaging 0.35 g NH_3/(bird d)) at day 21 of the 42-day flock grow-outs, followed by flocks raised on the annual cleanout with new bedding (0.52 g NH_3/(bird d)). Built-up litter without any treatment had the highest emission (0.73 g NH_3/(bird d)), followed by the built-up litter with acid treatment (0.63 g NH_3/(bird d)). One study site was managed with two barns using litter treatment and two identical barns with untreated, built-up litter for a side-by-side comparison of results under field conditions. Ammonia emissions from treated built-up litter barns were similar to those from untreated built-up litter barns, however, the temporal pattern of emissions provided evidence that ammonia held in the acid-treated litter at the beginning of the flock was released during the latter period of the flock cycle.
Keywords. Ammonia control, Poultry, NH_3, Emission rate

Introduction

A number of studies to characterize baseline U.S.A. ammonia emissions from broiler chicken facilities have been recently completed (Burns et al., 2003, 2007; Copeland, 2007; Gates et al., 2008; Lacey et al., 2003; Wheeler et al. 2006) and are being used by regulatory agencies and concerned citizens groups who are interested in regional and national air quality improvements.

Many instruments and techniques are available for measuring ammonia concentration (Ni and Heber, 2001). Ammonia monitoring instruments suffer from challenges of high cost for very accurate models and inconsistent accuracy and reliability for more affordable sensor technologies (Gates *et al.*, 2005) unless the lower cost sensors are built into an instrumentation system that can accommodate their shortcomings (Xin et al., 2002; Gates et al., 2005). Gas emission may be measured by several methods as outlined in Phillips et al. (2000). Within the currently accepted practices, one considered to be among the most accurate is estimating emission rate as the product of ammonia concentration and ventilation exhaust airflow rate.

Broiler chickens are floor-raised on litter that starts as new bedding (sawdust, wood shavings, rice hulls, etc.) and becomes a mixture of decomposing manure and bedding as birds grow. New bedding is typically placed in the barn once per year and then used repeatedly, also known as *built-up* litter, over several flocks. After about a year, the accumulated built-up litter is removed from the barn and fresh bedding is added. Built-up litter is the major source of volatilizing ammonia and its management is a key factor affecting emission rate. A minority of USA broiler barns receive new bedding for each flock although this is common practice in other countries, particularly in Europe, Australia and Brazil.

Controlling litter moisture content and pH are the major management strategies for reducing ammonia volatilization. The production and volatilization of ammonia is inhibited by litter pH below 7 because pH directly affects the equilibrium between ammonium (NH_4^+) and ammonia (NH_3). However, control of litter pH over the life of the flock has proven to be a difficult task, in part because litter pH is not commonly measured, the effect of treatment is not long-lasting (typically only 10-14 days), and repeated treatments are outdoor temperature (T) and relative humidity (RH) were monitored (±0.4°C [±0.7°F] and ±3% RH; HOBO Pro Series, Onset Computer Corporation, Bourne, Mass.)

Table 1. Flock placement start dates for study year from late 2002 through 2003. NBA = new bedding always; NBC = new bedding cleanout; TL = acid treated litter; BL = built-up litter

	Cold Climate				Mixed-Humid Climate			
	Farm PA-A 2 Barns		Farm PA-B 2 Barns		Farm KY-A 4 Barns		Farm KY-B 4 Barns	
Flock	Start date	Litter code	Start date	Litter code	Start date	Litter code (No. barns)	Start date	Litter code (No. barns)
1			Jan	TL	Nov	TL (4)	Nov	TL (2); BL (2)
2	Feb	NBA	Mar	NBC	Jan	TL (4)	Feb	TL (2); BL (2)
3	Apr	NBA	May	BL	Mar	NBC (1); TL (3)	Apr	TL (2); BL (2)
4	Jun	NBA	Jun	BL	May	NBC (3); BL (1)	Jul	TL (2); BL (2)
5	Aug	NBA	Aug	BL	Jul	BL (4)	Sep	TL (2); BL (2)
6	Oct	NBA	Oct	TL	Sep	BL (4)		

Ammonia Concentration Instrumentation

Portable Monitoring Units (PMUs) were designed to monitor gas concentration and static pressure difference between interior and exterior conditions on one-minute intervals. Detailed information about the design and performance of the PMU was provided by Xin et al. (2002), Xin et al. (2003) and Gates et al. (2005). Briefly, the PMU was a tight-closing panel-box that held instrumentation for emissions data collection that was portable and cleanable for use in multiple barns. At least one PMU was wall-mounted in each broiler barn during a study period to monitor conditions of exhaust air and fresh outside air.

Instrumentation within the PMU included two identical gas monitors for redundant measurement of ammonia concentration (0-200 ppm; PAC III, Dräger Safety, Inc, Pittsburgh, Pa.) with plumbing and controls (pump, solenoid valve, flow meters for controlled flow) for cycling fresh, outside air and poultry barn air past the sensors. The electrochemical sensors were purged with fresh air (for 24 minutes in PA; 14 minutes in KY) to reduce sensor saturation from continuous ammonia exposure. Sensors were exposed to barn air for 6 minutes between fresh air purge cycles. An ammonia value for emission rate calculation was selected from the 6-minute interval of barn air to represent ammonia level in the barn over the 20 or 30 minute house-air-purge-air cycle, as described in Xin et al. (2003).

Air samples were drawn into the PMU through two lengths of polyvinyl-chloride 9 mm (3/8-inch) o.d. transparent flexible tubing. The barn air sample tube was 2-3 m long with air intake positioned in front of the monitored exhaust fan. The purge air line intake was positioned outside the poultry barn, at the eaves in between fresh air inlet boxes on the barn sidewall that did not have exhaust fans. Filters were used to exclude larger particulates and insects from clogging the air collection lines.

Fan Ventilation Rate

Ventilation rate (VR) was calculated using actual fan performance and run-time data then corrected to conditions of standard temperature and pressure. Each PMU monitored static pressure difference (0-125 Pa, 0-0.5 in.H_2O, Model 264, Setra Systems, Inc, Boxborough, Mass.) used in calculation of ventilation rate. Fan run-time was recorded using on/off motor loggers (HOBO on/off motor, Onset Computer Corporation, Bourne, Mass.) installed on electric cable "pigtails" between the electric supply receptacle and plug to each fan. These loggers provided time of state change with a resolution of 0.5 second. Data were analyzed into 20-minute (KY) or 30-minute (PA) periods to match ammonia data analysis interval.

The "actual" exhaust fan ventilation capacity was determined *in situ* with a traversing anemometer array, the Fan Assessment Numeration System (FANS) unit (Gates et al. 2005; Casey et al., 2002). The FANS consisted of five vane anemometers positioned on a bar that traversed the entire airflow entry area to each fan. The FANS was used to develop performance curves for each individual fan in each barn (11, 14 or 15 fans per house) over a range of six typical building static pressure differences (0 to 50 Pa, 0 to 0.18 in. H_2O). The FANS was positioned on the intake side of the fan of interest and sealed against air leaks. Additional detail of procedures in using FANS to evaluation fan air flow rate is found in Wheeler et al. (2006, 2002) and performance of fans as determined by these tests in Casey et al. (2008).

Building ventilation rate was determined by multiplying fan capacity of each individual fan in relation to operating static pressure by that fan's actual run-time during that data collection interval. All fans running during that 20- or 30-minute interval were summed for the total building the end of the flock cycle. A diminishing advantage as the flock ages was also seen for the NBC flocks. The only treatment that was consistently lower in ammonia emission over the flock cycle was NBA while BL was always the highest.

Table 2. Summary of ammonia emission rate (ER) linear equation parameters for the litter management strategies under study and an estimate of daily per bird emission at various bird ages.

Litter code	slope	intercept	R^2	ER ($g\ NH_3$/bird d)			
				day of age			
	ER/d	ER		7	20	42	60
NBA	0.0240	-0.152	0.87	0.02	0.33	0.86	1.29*
NBC	0.0352	-0.218	0.80	0.03	0.49	1.26	1.89
TL	0.0295	0.0121	0.66	0.22	0.60	1.25	1.78
BL	0.0311	0.0824	0.60	0.30	0.70	1.39	1.95
AL	0.0308	-0.0321	0.64	0.18	0.58	1.26	1.82

NBA = new bedding always; NBC = new bedding after cleanout; TL = treated litter; BL = built-up litter; AL = all litter in this study. *extrapolated beyond 45-day data collection timeframe.

Emissions from NBA and NBC managed flocks were expected to be similar and the observed differences were likely caused by conditions not characterized by bird age and barn environment. The NBC flocks tended to be on longer flock cycles, which increased the overall ER-bird age regression slope. This does not fully explain the differences since even at similar ages, the NBC flocks tended to have higher ammonia ER than NBA flocks (Figure 1). Another reason for elevated ammonia emissions for NBC flocks include the absorbed nitrogen in the packed soil within the broiler barn from previous BL (or TL) flocks (Lomax et al., 1997; Wheeler et al., 1999) although this effect should have also been observed, but was not, in the first week of NBC flocks. The NBA flocks in this study were housed on concrete floors that do not readily absorb nitrogen products (Lomax et al., 1997) and are more easily scraped for thorough removal of the spent litter and manure material between flocks.

Treated and Built-up Litter Comparison on One Farm

Farm KY-B was studied with two barns using litter treatment and two identical barns with untreated, built-up litter for a side-by-side comparison of results under field conditions. Figure 2 presents ER versus age relationship for the BL and TL barns. All four barns were cleaned once at the same time during the study year and those new bedding data are excluded from Figure 2 (but included in Figure 1 as part of NBC flocks).

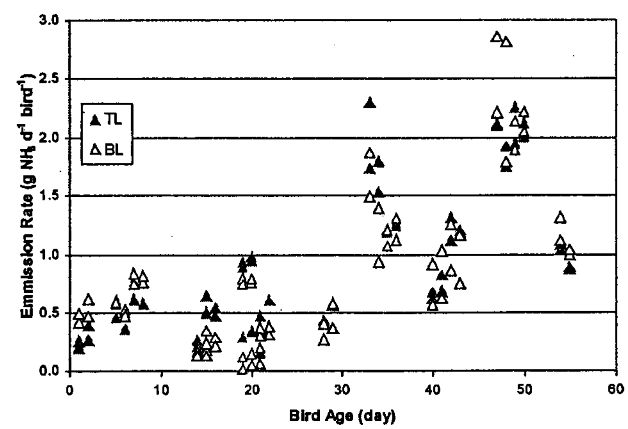

Figure 2. Sub-experiment of treated (TL) versus built-up (BL) litter in four barns (2 TL; 2 BL) on same farm for direct comparison. (New bedding (NBC) flocks removed from data set.)

Emissions from TL and BL barns were similar but the temporal pattern of emissions varied. At bird age less than 10 days the TL flocks produced lower ER compared to BL flocks. After the first two weeks, this

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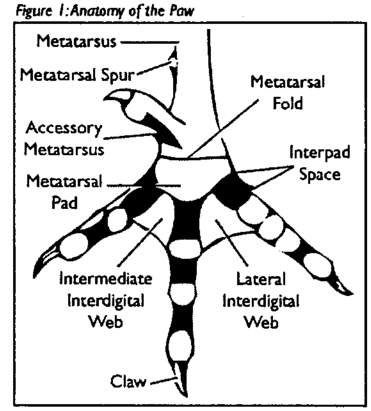
Poultry Litter Treatment
The Science of Litter Management

Prevention and Scoring of Paw Lesions: A New Approach

Fifteen years ago, who would have thought that chicken paws would have become such an important part of the U.S. poultry industry? Today, good paws are integral to a complex's profitability and are quite often the most profitable part of the chicken. The presence of paw or footpad lesions (pododermatitis or footpad dermatitis) is the number one cause of downgrades of chicken feet. Since there is no market for Grade "B" paws, the presence of footpad lesions can seriously erode a complex's bottom line.

Pododermatitis or footpad dermatitis (FPD) is an erosion or ulceration on the bottom of a bird's foot most frequently caused by ammonia burns. The large weight bearing, metatarsal pad is most frequently affected, while in severe cases the digital pads and the interdigital webs between the toes are also affected. In very severe cases, the hock region can also be involved. Hock involvement is most commonly seen with straw based litter and so it is rare to see this in U.S. poultry production. Refer to Figure 1 for understanding the anatomy of the paw.

Figure 1: Anatomy of the Paw



Factors In The Development Of FPD

Much attention has been paid to the condition of the litter in the last week or so of a bird's life in regards to FPD development. However, paw lesions begin to form in the first week of the bird's life. The formation of liquid ammonia at the litter surface occurs anywhere there is even the least bit of damp litter. The severity and moistness of the cake present in the houses seems to play the predominant role in lesion development. Common culprits are small wet spots under the drinkers (commonly referred to as donuts) and caked areas along the sidewalls. When newly hatched chicks step onto those damp areas, the litter sticks to their feet and ammonia in the litter begins to erode the skin. Visible paw lesions are evident by the time the bird is 7 days old and the lesions continue to worsen over time.

Impact Of PLT® Treatment On The Prevention Of Paw Lesions

The use of PLT to neutralize the ammonia at the litter surface is a good management tool to help prevent the formation of footpad lesions. A demonstration in the summer and fall of 2004 showed dramatic improvement in paw quality on farms that used PLT in the brood chamber. Ten farms (618, 204 birds) used the 50-lb rate of PLT and six farms (463,177 birds) did not treat the litter.

The birds raised on PLT showed significant improvement in paw quality with 55% of the birds having no paw lesions compared to only 16% of the control birds. The PLT group had 19% fewer major Paw Lesions and 20% fewer minor Paw Lesions than the control birds. Performance was also much improved for the birds raised on PLT with a three-point improvement in feed conversion (1.77 vs. 1.80) and a point better in weight.

Table 1: Foot Pad Scores (%)

	0	1	[redacted]
Control	10.3	11.0	[redacted]
PLT®	67.5	18.4	[redacted]
Al+Clear®	47.8	32.3	[redacted]
MicroTreat®"P"	35.6	23.0	[redacted]

In a controlled trial completed at Colorado Quality Research, the footpads of birds raised on untreated litter, PLT, Al+Clear, and Microtreat-P were compared at processing. Of the birds raised on PLT, 67.5% had no lesions compared with only 10.3% of the controls (see Table 1).

The use of PLT to acidify the litter along with proper ventilation for relative humidity is successful at maximizing the number of Grade "A" paws at processing.

Poultry Litter Treatment
The Science of Litter Management

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JH JONES-HAMILTON CO. Agricultural Division
30354 Tracy Rd. | Walbridge, Ohio 43465-9792 | aginfo@jones-hamilton.com
Phone: 419.666.9838 | Toll Free: 888.858.4425 | Fax: 419.666.1817

A469PLTE R0112006

Figure 2 shows severe lesions on a 7 day old bird. Serial examination of these birds shows that the lesions do not heal even if the litter dries out. Surprisingly, in houses with dry litter, the bottoms of the birds' feet are very clean and it is unusual to find a footpad lesion on a bird with clean feet.

Ambient ammonia levels do not seem to influence the development of FPD. The two factors that need to be present for lesion development are substantial levels of ammonia deep in the litter and moisture at the litter surface. Ammonia in the gas phase does not seem to be sufficiently irritating to the skin of the feet. Ammonia in solution, however, in the damp areas of the litter is corrosive to the skin and causes FPD development. Houses with no or low ammonia at bird level can still have a substantial percentage of FPD if the litter is damp. This is most commonly seen in brand new houses or on new litter where the relative humidity is high even though the ammonia is not, and litter slicking occurs. At the same time, houses that have quarter-size donuts under the drinkers due to leaky nipples but very dry litter otherwise, will still have a substantial number of birds with paw lesions.

Preventing FPD

The three keys to preventing paw lesions are to ventilate poultry houses for relative humidity (RH) in order to prevent moisture build-up around the drinker/feeder lines and the sidewalls, manage drinkers to prevent leaks, and acidify the litter surface to neutralize ammonia. In houses that are ventilated through a curtain crack or fixed inlet boards ventilating for RH is difficult as air entering the houses does not have sufficient velocity to flow across the ceiling but rather drops straight to the floor dumping moisture along with it. In a study conducted by Weaver and Meuerhof (1991), raising birds at a 45% RH compared to a 75% RH reduced paw lesions substantially. Birds in the 75% RH group had three times the ammonia burns on the feet and the severity of the lesions was greater than those birds raised in the 45% RH group. In addition to decreasing moisture at the litter surface, acidification of the litter with PLT® litter acidifier to neutralize the ammonia that is in solution is also important. Using the appropriate rate of PLT for the litter age and applying a little extra in the damp areas will help to neutralize the ammonia in solution.

3 Keys To Prevent FPD:

Figure 2: Severe Lesions, 7 Day Old Bird

Scoring System For FPD

In the European Union, FPD scoring is often used as an indicator of animal welfare conditions during the live production phase. The FPD scoring systems reported in the poultry literature such as the Ekstrand score (Ekstrand et al. 1998) and the modified Ekstrand score (Pagazaurtundua and Warriss, 2006) are the ones that have been developed in the EU strictly for this purpose. In these scoring systems, the total surface area that the lesions cover determines the foot score rather than the depth of the lesion. These scoring systems are also designed for use at processing in order to evaluate the performance of farms that may not be vertically integrated with the plant.

For processing plants in the United States, however, paws are evaluated for their export potential and not for animal welfare reasons. The USDA grading measurements are far stricter than the animal welfare measurements of the EU. USDA classifies ammonia burns as a "resolving or healing wound" and allows 13 small (≤0.5 inches), 6 medium (>0.5 to 1 inch), or 3 large (> 1 inch) lesions per sample size of 50 randomly selected feet.

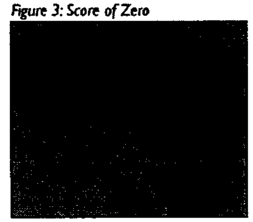
In order for a FPD scoring system to be useful in the US, a scale matching the USDA grading system is needed. In addition, a scoring system that can be used in the field on young birds as a predictor of how a flock will grade at processing is useful.

After several evaluations of a large number of birds on a wide variety of farms, the following 3 score system was devised for scoring birds at 7-10 days of age in order to predict how a flock will grade at the processing plant. Only the underside of the bird's foot is scored. Paws that have attached dirt should be washed prior to scoring. Both paws are scored with the higher score recorded. A minimum of 30 birds per house should be evaluated. Scoring birds at this age allows remedial action to be taken to prevent further deterioration of the paws, as well as makes the catching and handling easier on both the birds and the scorer.

Score of Zero

A score of zero reflects a bird with no sign of redness or minor hemorrhage due to broken capillaries that look like branching thin red lines under the skin (petechiation). The skin is intact. Some staining of the footpad may be present.

Figure 3: Score of Zero



Score of One

Birds with a score of one have footpads with minor redness or petechiation. A small crack in the skin may be present between individual scales. These may be as small as a pinpoint. If the foot has a callus or proliferation of the scales without a break in the skin it is classified as a one.

Figure 4: Score of One, Redness Without Erosion

Figure 5: Score of One, Staining in Interdigital Web

Score of Two

Birds with a score of two have erosions on the feet that have begun to break the skin. These can be circular or irregular shaped. Calluses or proliferation of the scales with a break in the skin are classified as a two.

Figure 6: Score of Two, Erosion and Cracking of the Metatarsal Pad

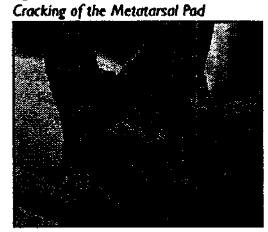
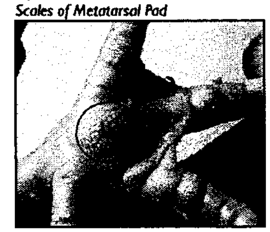


Figure 7: Score of Two, Crack Between Scales of Metatarsal Pad



Birds with a score of one will tend to present at the plant with a small lesion under ½ inch in size while birds with a score of two will present with lesions that are categorized as medium or large by the USDA grading system. The ratio of birds in each category may worsen by the time the birds are processing age but it rarely, if ever, gets better.

LITTER *forum*
by JONES-HAMILTON CO.
WINTER 2013

Midflock Treatment for Ammonia and pH Reduction

PLT® is the only litter amendment that is safe to apply with birds of any age in the house.

Application of PLT® for Mid-Flock Ammonia and pH Reduction

The benefits of using PLT®-litter treatment at chick placement are well documented and widely accepted. When applied prior to bird placement, PLT® will reduce ammonia to near zero and will hold ammonia to acceptable levels through move-down and up to 3 weeks after. As PLT® is used up over time, however, ventilation should be increased to control house ammonia levels. Keep in mind that while ventilation may seem to keep house ammonia levels at an acceptable level, ammonia is still purging off the floor and may be relatively high at bird level. A mid-flock application of PLT® will reduce floor level ammonia and pH thereby providing a better environment for bird growth.

These two trials document the benefits of reducing ammonia and pH 3 to 4 weeks into grow-out with an application of PLT®.

Trial 1 data was collected from 17 flocks at 14 farms over the course of 12 months. Data from these farms were compared to the weekly settlement from 3 flocks prior to treatment and 2 flocks post-treatment in addition to the current settlement. Over 3 million birds were treated in this trial and the data was compared to over 13 million birds in the weekly settlements. At 28 days into grow-out (range 22-34 days), PLT® was applied to the entire house by spreader truck or trailer at a rate of 75 pounds per 1,000 square feet.

Trial 2 data were collected from 5 flocks at 5 farms over the course of 12 months. Data from these farms were compared to weekly settlements from 3 flocks prior to treatment and one flock post-treatment in addition to the current settlement. At 21 days into grow-out, PLT® was applied to the entire house by a spreader trailer at a rate of 75 pounds per 1,000 square feet.

Trial 1

Settlement comparison of PLT® treated flocks with flocks settled concurrently and flocks prior to and post treatment.

Treatment	Age	Wk. Age	Live	Wk. Live	Avg Wt	Wk Wt	F:G	Wk F:G	Rank %
Prior	53.4	53.3	95.82%	95.82%	6.38	6.27	2.04	2.04	58.11%
PLT®	50.9	51.5	96.03%	96.11%	6.39	6.39	1.93	1.95	36.41%
Post	50.1	50.4	95.87%	95.94%	6.3	6.4	1.93	1.92	65.22%

Trial 2

Settlement comparison of PLT® treated flocks with flocks settled concurrently and flocks prior to and post treatment.

Treatment	Age	Wk Age	Live	Wk Live	Avg Wt	Wk Wt	F:G	Wk F:G	Rank%
Prior	55.6	55.6	94.62%	95.62%	7.29	7.22	2.01	2.01	55.92%
PLT®	58.9	58.3	96.68%	96.42%	7.83	7.71	2.02	2.04	35.50%
Post	54	55	96.13%	96.31%	7.45	7.18	2	2	41.11%

These trials show that feed to gain ratio and ranking were positively affected by mid-flock application of PLT®. Birds treated with PLT® had a 2 point advantage in feed conversion in both trials raising them from settling in the 58th percentile to the 36th in trial 1 and from the 56th percentile in to the 36th in trial 2. With no mid-flock PLT® application, subsequent flocks lost the feed conversion advantage and settled in the higher percentile when compared to treated flocks.

LITTER *forum*
by JONES-HAMILTON CO.
FALL 2012

Significant Profit Losses Seen From Ammonia-Caused Performance Decline

Ammonia is the most common cause of performance loss on broiler and turkey farms in terms of body weight gain and feed conversion. Extensive research has shown that ammonia levels as low as 25 PPM can cost growers at least 19 points of weight per bird which equates to a loss of $209 per house. Performance is greatly reduced by exposure to 50 PPM, but birds do no show signs of blindness until ammonia exceeds 100 PPM. Unfortunately, many growers and live production personnel do not respond to ammonia until they see blind birds. However, by the time blind birds are present, the damage has already been done in terms of performance. Prevention of ammonia release through proper litter management is the best way to prevent financial losses.

The Source of Ammonia Troubles

Aggressive litter handling during down-time or tilling during the grow-out increases surface area increasing ammonia levels. This is why houses with fine, dusty litter can have such high ammonia concentrations at bird level. It is important to keep litter moisture and other litter characteristics in the middle of the bell curve (not too dry and not too wet) in order to reduce the speed at which ammonia is released from the litter surface. Ammonia levels an inch beneath the litter surface are an indicator of what the litter will release over the next few days. Very fine, dusty litter often has deep litter ammonia concentrations over 600 PPM, whereas properly de-caked litter with a larger particles rarely exceeds 150-200 PPM of deep ammonia. Excessive moisture within a house or improper de-caking and litter handling will encourage ammonia production and release. Proper litter management, litter amendment use and ventilation to maintain ammonia levels below 25 PPM should be followed at all times to prevent performance losses.

Male broiler response to low levels of atmospheric ammonia

		Weight depression				Yield[2] (%)	
NH_3 (ppm)	BW[1] (g)	(g)	(%)	Feed/gain[1]	Mortality[1] (%)	Overall	Breast meat (pectoralis major + minor)
4 Weeks							
0 (near)	1,421^x	–	–	1.53^x			
25	1,395^x	26	2	1.52^x			
50	1,178^y	243	17	1.62^x			
75	1,128^y	293	21	1.62^x			
7 Weeks							
0 (near)	3,211^x	–	–	1.93^x	5.8^{xy}	73.2^x	19.8^x
25	3,202^x	9	0.3	1.91^x	2.8^{xy}	73.0^x	19.7^x
50	3,004^y	207	6.4	1.98^x	10.6^{yz}	72.7^x	19.0^x
75	2,920^y	291	9.0	1.97^x	13.9^z	72.4^x	19.0^x
SEM	(61.6)			(0.11)		(0.31)	(0.34)

$^{x\text{-}z}$ Means within a column lacking a common superscript differ ($P \leq 0.05$).

[1] There were 4 observations per mean for the near 0 treatment and 3 observations per mean for the 25, 50, and 75 ppm treatments. In the first trial, mechanical problems with ammonia control required 3 chambers (one each of the 25, 50, and 75 ppm treatments) to be discontinued.

[2] Yield observations per mean for the near 0, 25, 50, and 75 ppm treatments were 160, 107, 151, and 144, respectively.

Table 1. Performance Losses due to Ammonia Exposure the First Four Weeks of Grow-Out, (Miles et al. 2004)

Ammonia's Impact on Bird Performance

While high levels of ammonia can be detrimental to bird performance at any stage, poultry are most susceptible to ammonia insults during the first four weeks of life. Several studies over the last few years have shown the costly impact of ammonia exposure on bird performance. In one study (see Table 1), birds exposed to 50 PPM of ammonia for the first four weeks and no ammonia thereafter were 6.4% lighter and birds exposed to 75 PPM were 9% lighter than birds exposed to only 25 PPM. Ammonia levels of 75 PPM or greater during the first four weeks of life are quite common (even in the summertime) in houses not using a litter amendment at the beginning of each flock.

Controlling Ammonia with Litter Management

Prevention of ammonia release is the key to maximizing bird performance. This is done through proper litter management during the down time and in the grow-out house and proper usage of a litter amendment to lower litter pH and convert volatile ammonia into a stable fertilizer: ammonium sulfate. Using an acidic litter amendment just prior to bird placement or immediately after tilling brings ammonia levels down below 25 PPM houses to be minimally ventilated for relative humidity control. On farms where birds are released from the brood chamber before they are 14 days old, the litter amendment should be applied in the whole house to prevent production losses from ammonia.

Taking Action Against Ammonia: The Bottom Line and Smart Steps

20 years of research has shown the effects of ammonia on bird weight (Figure 2). At 50 PPM, birds lost ½ lb in weight causing a substantial production loss for any grower or integrator. According to this same study, birds challenged with ammonia lost 8 points of feed conversion. With feed at $325+/ton, the loss of feed conversion on 20,000 birds will cost $1,690. The loss can reach as high as $84,500 per week for a million bird complex.

In addition to applying PLT® litter acidifier according to manufacturer's directions, simple steps have been defined to avoid ammonia-induced performance losses:

- Take ammonia readings no more than one inch above litter.
- Remove all cake between flocks, but do not till.
- Pre-heat properly before bird placement to complete the ammonia purge from the litter.
- Maintain relative humidity between 50-70% during minimum ventilation.
- Properly manage water lines to avoid wet litter.

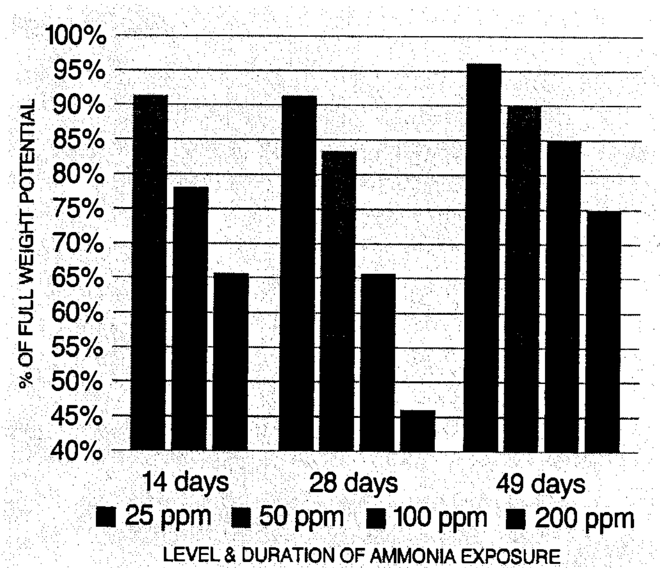


Figure 2. Body Weight Changes with Ammonia Exposure (Miles et al 2002)

30354 Tracy Road, Walbridge, Ohio 43465-9792 • Ph: 419.666.9838 • 888.858.4425 • Fax: 419.666.1817 • www.JonesHamiltonAg.com

The Science of Litter Management®

LITTER forum

by JONES-HAMILTON CO.

SPRING 2013

Accurately Measuring Ammonia Levels in Poultry Houses

Ammonia gas in poultry houses seriously affects bird health. The gas results from the chemical decomposition of uric acid in droppings by certain bacteria in the litter, and is further influenced by moisture content, pH and litter temperature. The main factors affecting atmospheric ammonia concentration in poultry houses are litter conditions and air movement (ventilation). Poor ventilation, loose droppings, and faulty, over filled or low positioned drinkers are common causes of wet litter in poultry houses. High levels of ammonia have a negative impact on overall livability, weight gain, feed conversion, condemnation rate at processing and the immune system of the birds.

Proper litter management and ventilation will minimize ammonia levels, improve productivity, reduce the likelihood of respiratory diseases, improve the birds' welfare and provide a pleasant, safe environment for workers. The problem is that many broiler producers have difficulty in measuring ammonia concentration in an affordable, reliable, and consistent way. Without measurement, they are unaware of harmful levels of ammonia in their houses and how to control it.

There are a number of tools available to producers that can help them determine ammonia levels in their houses. While some cost hundreds of dollars and require frequent calibration, there are a number of low cost, easy to use and relatively accurate options that can be used to determine whether ammonia has reached harmful levels (Table 1).

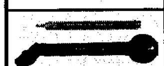
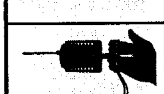
	Tool	Response Time	Degree of Maintenance	Portability	Approximate Cost	Suitability	Growout Stage
	Electro-chemical sensor	<3 minutes	Moderate, calibrate sensor every 3-4 month and replace sensor every year	Portable, easy to use	Base unit:$500 to $800; Sensor: $170 to $300	Time-weighted average; Spot check	All
	Passive colorimetric Tube	1 to 10 hours	N/A	Portable, easy to use	Tube holder: $50; Tube: $7-$8	Time-weighted average	All
	Active colorimetric Tube	<2 Minutes	N/A	Portable, easy to use	Pump: $300-$400 Tube: $7-$8	Spot check	Brooding and minimum ventilation
	Colorimetric paper	15 seconds	N/A	Portable, easy to use	Roll of tape: $6-$7	Spot check	Brooding and minimum ventilation
	Ammonia Gun	1-3 minutes	Recommend monthly cleaning. Apply grease to rubber gasket	Portable hand held unit; Approx 1 pound	$160-$200	Spot check	All

Table 1. Tools for measuring ammonia concentration

While these tools will help gauge ammonia levels, it is important to factor in the timing of your ammonia checks. Ammonia levels in poultry house may vary quite a bit during a day with air movement (ventilation). A few spot checks of ammonia levels during an afternoon may not represent the real high levels of ammonia during the night while fewer fans are on and ventilation drops significantly. Research has shown that ammonia levels are more stable during brooding period and when ventilation system runs with minimum ventilation. Therefore, ammonia levels need to be measured with a right tool at a right time or the readings may not properly represent the problem.

Any one of the tools listed in the table can be used to measure ammonia levels with spot check. However, when birds are older than three weeks and the ventilation system runs with transition ventilation (between the minimum vent and tunnel) during a day, a spot check will not be enough to determine the ammonia levels. For example, 30 PPM is read at 4 PM while 50 PPM is read at 6 AM. Passive tube and electronic sensors are recommended to measure ammonia level over a 6- to 10-hr period to determine the time-weighted average levels, which are more representative to the real concentrations.

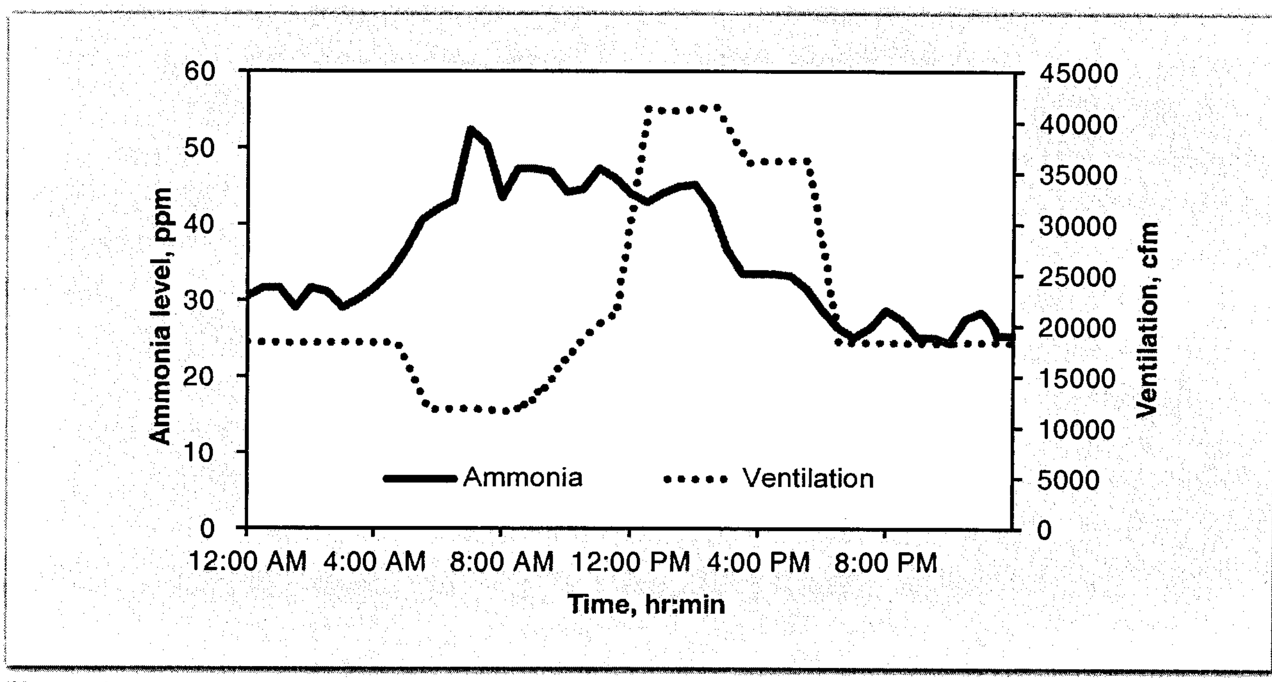


Figure 1.
Ammonia level and ventilation changes in a broiler house during a 24-hr period at 40 days of age.

LITTER forum
by JONES-HAMILTON CO.
The Science of Litter Management
WINTER 2013

Benefits of Pad Acidification with PLT® Litter Acidifier: A Field Study of 100 Broiler Houses

In the United States, the majority of poultry houses are constructed on top of a dirt pad. Many growers notice that their performance begins to slip as more and more flocks are raised in a house even though the houses are still well-managed. Growers also observe that no matter how thoroughly they clean and disinfect a house after a disease outbreak, the disease challenges tend to linger on. This is because the dirt pad in a poultry house will absorb ammonia increasing pad pH to a pH of 8-10. This high pH is very favorable to bacterial and viral growth and survival. In addition, most disinfectants are very high in pH and are inactivated in the presence of organic material so they are unable to disinfect the dirt pad in the house contributing to these lingering problems.

One way to combat these problems is by using the same litter acidifier you use at brooding in a new way: directly on the dirt pad itself. One hundred broiler houses on 25 farms in five complexes were selected to test the field efficacy of PLT® litter acidifier in reducing pad pH and improving broiler performance (Donald, 2003). Farms were selected that had slipped in performance as the farm aged or had lingering disease challenges even after a complete clean-out orin-house windrowing of litter. After a very thorough cleanout all the way down to the pad, the houses were washed down and disinfected as usual. PLT® was then applied directly to the pad at a rate of 100 lbs./1,000 sq. ft.

The improvements seen on these farms compared to their previous performance was conclusive. Farms saw a 12 point improvement in feed conversion, a 4% improvement in livability, and a cost improvement of $0.0075 per lb (Fig. 1 and Table 1) in the three flocks after treatment compared to the flocks the year prior to treatment. Growers were able to pay for the cost of the PLT® application and make a substantial profit from the improved performance.

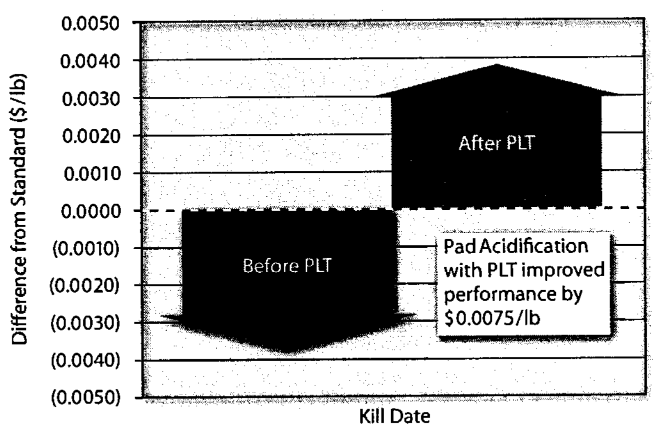


Figure 1. Difference in production performance from standard for the flocks one-year prior to PLT® pad acidification compared to the three flocks after PLT® treatment.

Treatment Group	Feed Conversion	Livability
PLT	1.96	96.3%
Control	2.08	92.24%

Table 1. Performance Improvements with PLT® Pad Acidification

The average pH of the houses before treatment was 7.8 while the average pH after PLT® treatment was 1.8. This low pH makes the dirt pad very hostile to bacterial, viral, and fungal pathogens. In one study completed by the University of Arkansas (Watkins et al, 2003), the use of PLT® for pad acidification reduced the bacterial counts in the dirt pad by six logs, a 99.999% reduction in bacteria (Table 2).

House	Pre-Application	24 Hours Post-Application	48 Hours Post-Application
Control	8,525,000	22,380,000	28,250,000
PLT Treated(100-lbs/1000 sqft)	6,732,500	91	22

Table 2. Bacterial Counts on the floor of a poultry house treated with PLT® Litter Acidifier (Total APC CFU/Sample.)

Proper Steps to Pad Acidification with PLT® Litter Acidifier

1. Wash down or blow down the ceilings and side walls of the house.
2. Spray the ceilings, sidewalls, and equipment with a disinfectant, preferably one that is acidic.
3. Completely clean out all the old litter from the house down to the dirt pad.
4. Remove all litter from the corners and under fans. Sweep around footings if necessary.
5. Make sure that absolutely no litter remains in the house.
6. Be certain to completely remove the tarry, black layer just above the pad prior to acidification. This layer is high in anaerobic pathogens such as Clostridium sp.
7. Apply PLT® evenly to the whole floor at a rate of 100-150 lbs./1,000 sq. ft.
8. Let the PLT® sit for several days before spreading new litter in the house.

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LITTER forum
by JONES-HAMILTON CO.

Ammonia Control: What is Really Important?

It seems that everyone is talking about ammonia control and litter management these days, but often the rhetoric doesn't match the reality of growing chickens. When exactly is ammonia control most important and how low do the levels really need to be? Given that the quality of the air in your chicken or turkey house is directly related to your birds' ability to respond to respiratory disease challenges and meet their genetic growth potential, ammonia control is most important during the first 14-21 days of the bird's life, with the first 7 days being the most critical.

Chickens are most susceptible to ammonia insults during ooding and when boosting respiratory vaccines in the field. Having ammonia levels at 25 PPM OR LESS AT BIRD PLACEMENT is an important target. Chicks at placement are the most susceptible to ammonia damage. At that time, they are also dealing with hatchery vaccine reactions. The litter amendment you chose has to be able to work immediately from day one. You cannot wait a week for activation to begin because the damage to the birds and your bottom line has already been done by that point. This is why PLT® litter acidifier is so widely used. With PLT® you can be sure that the air in your houses is right on target from the moment the chicks are delivered.

So what about ammonia control once birds are in the whole house? Once birds are 14-21 days old, the removal of bird heat becomes the main demand on ventilation. The ammoni present is exhausted along with the heat. If you are ventilating at the rates necessary to keep the houses from getting too hot, then your ammonia levels are going to be controlled by that air flow. Choosing a litter amendment that doesn't work at brooding but may provide ammonia control a the end of the flock is a losing proposition. You pay for ammonia control at a time when you don't need it and your birds' performance has already taken a substantial hit by the time the amendment finally begins to work.

Proper litter management and ventilation to maintain ammonia levels below 25 ppm should be followed at all time to ensure that your birds are able to maintain the defense mechanisms that Mother Nature gave them in order to fight off respiratory disease challenges. Birds exposed to ammoni during brooding have decreased resistance to Newcastle Disease virus (Anderson, 1964) and have more difficulty in clearing E. coli from the respiratory tract (Nagaraja, 1984). More importantly, they can be as much as a half pound lighter in weight (Miles, 2002). Don't let the wrong choice of litter amendment put you in that situation.

PLT® Provides Ammonia Control at Day 1 When You Need it Most

LITTER *forum*
by JONES-HAMILTON CO.
SPRING 2012

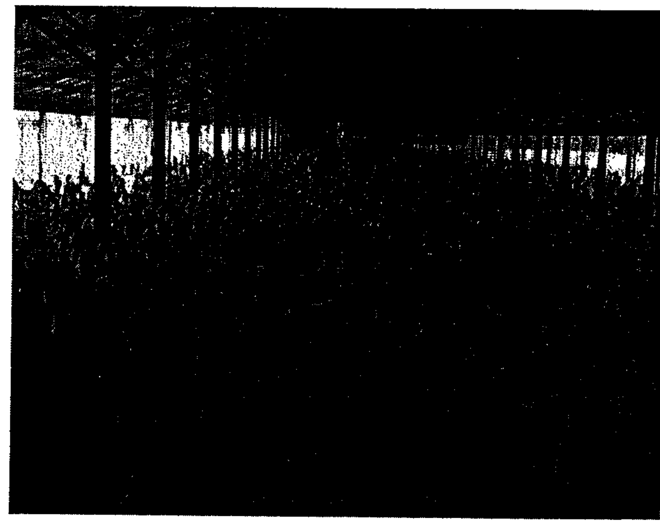
Using Proper Rates of PLT® Costs Less!

People are often tempted to cut corners and see if they can get by with using a little less of something than the directions state. Though tempting, the results often end up being a good example of "too little, too late." So how much does using too little PLT® in turkey grow-out houses cost a grower and integrator in poor performance?

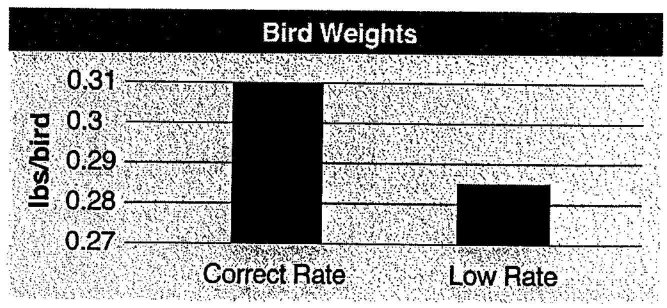
A demonstration project was undertaken in December 2010 to evaluate the impact of using proper PLT® application rates in turkey grow-out barns on bird performance when compared to the integrators usual rate which was below the manufacturer's recommendations. One house on the farm was selected to receive the recommended 100 lbs of PLT® per 1,000 sq ft rate and one house a rate of PLT® that was too low for the housing type (50 lbs of PLT® per 1,000 sq ft). In both houses PLT® was applied to the entire house just prior to bird movement from the brood barn.

The house receiving the 100-lb rate of PLT® for turkey grow-out barns out performed the house using the 50-lb rate in all performance parameters measured, including weight, average daily gain, feed conversion, condemnations and total prime cost. Adjusted feed conversion was 10 points better on the house using the 100-lb rate of PLT® (2.35 vs. 2.45). Also, the house using the 100-lb rate delivered 17,644 more pounds of turkey to the processing plant at a lower cost of $0.2915 cents per pound—compared to the control house cost of $0.2937 cents per pound.

It was pretty clear that "saving money" by using less PLT® just didn't happen. In fact, the cost per pound of turkey produced was much higher at the improper rate of 50 lbs per 1,000 sq ft. Given that the extra PLT® used only cost an additional $250 per house—but produced 17,644 more pounds of turkey at a much lower feed conversion—using the proper rate is clearly the wiser investment.



Turkeys raised on PLT® and PWT® had 10 points better feed conversion!



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LITTER forum
by JONES-HAMILTON CO.
The Science of Litter Management
SUMMER 2013

PLT® Protects Tracheal Health For Better Vaccine Reactions

It used to be that we vaccinated our birds while they were in the brood chamber and then turned them out into the whole house to react because the air was better in the off chamber. This was even more important when vaccines were spray applied. But my how times have changed!

We are still turning birds out whole house to react to their respiratory vaccinations but now the air in the off-chamber is worse than the air in the brood chamber. With so many growers and integrators using PLT® litter acidifier in the brood chamber at the proper rates for litter age, ammonia levels in the brood are at some of the lowest levels in a long time. This means that broilers now have normal, healthy tracheas with good cilia health and function leading up to the field boost with respiratory vaccines (see Figure 1). Ammonia damage to tracheas prior to the field boost is now very minimal.

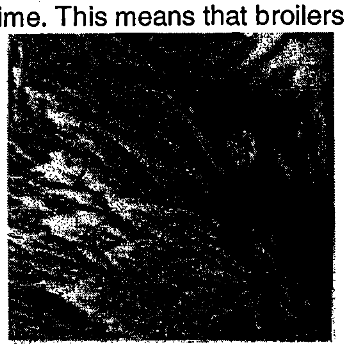

Figure 1. Healthy Trachea

Unfortunately, now when we turn birds down into the off-chamber, they experience ammonia levels far higher than they had been previously exposed. At 25 PPM of ammonia, the cilia will become paralyzed and at 40 PPM the cilia will die off (see figure 2). The first line of defense that birds have against respiratory challenges (including live vaccines) is the mucociliary elevator of the trachea. As a bird inhales, bacteria, viruses, and other particles become trapped in the mucus that covers the cilia in the bird's trachea. The cilia are small fibers that beat upward, in effect forming an elevator that lifts the trapped particles in the mucus out of the trachea where they can be either coughed out or swallowed by the bird. Proper functioning of this defense mechanism depends on the integrity of this tracheal lining. Any insult to the mucociliary elevator will impair the bird's ability to clear particles and disease organisms from the respiratory tract. If a bird is reacting to a respiratory vaccination at the same time it is exposed to higher levels of ammonia than before, it is unable to adequately clear the vaccine virus. Vaccine reactions will be drawn out and can be harsher than usual. Late airsac at the end of the flock is not uncommon when these conditions are present.

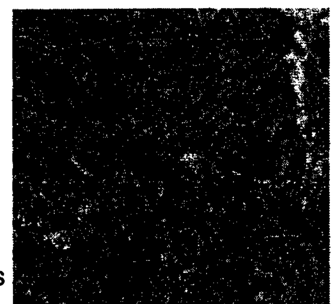

Figure 2. Ammonia Damage

The application of PLT® in the off chamber will eliminate the ammonia challenge during move-down. This protects the birds' tracheal health minimizing vaccine reactions and reducing respiratory lesions. The cilia in the trachea will only have to deal with the vaccine virus and not a second insult of ammonia. In a study published by Terzich, et al, birds raised on PLT® whole-house had significantly fewer respiratory tract lesions from vaccine reactions than those with ammonia-damaged tracheas.

The Bottom Line: PLT® in the Off-Chamber Protects Tracheal Health.

Reference: Terzich, M, et al. Effect of Poultry Litter Treatment (PLT) on the development of respiratory tract lesions in broilers. Av. Path. (1998) 27: 566-69.

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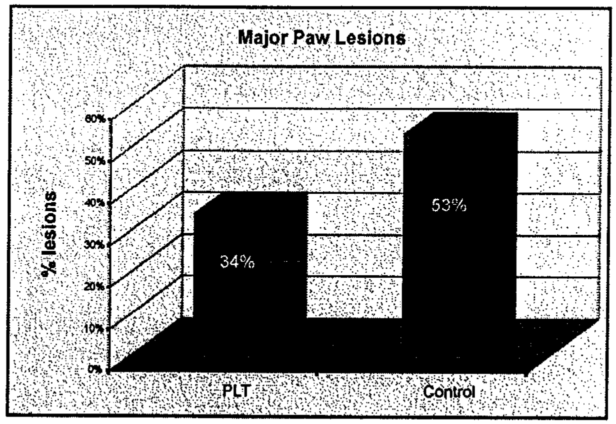
LITTER forum
by JONES HAMILTON CO.
The Science of Litter Management
SUMMER 2013

PLT® Puts Your Profits on Sound Footing

Ten years ago, who would have thought that chicken paws, would have become such an important part of your business? Today, good paws are integral to a complex's profitability. The presence of paw or footpad lesions (pododermatitis) is the number one cause of downgrades of chicken feet. Since the market for Grade "A" paws is more profitable than Grade "B" paws, the presence of footpad lesions can seriously erode a complex's bottom line.

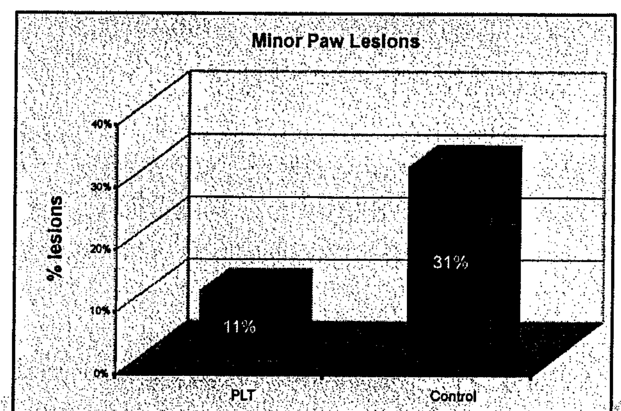


Paw lesions begin to form in the first week of the bird's life. The formation of liquid ammonia at the litter surface occurs anywhere there is even the least bit of damp litter. Common culprits are small wet spots under the drinkers and caked areas along the sidewalls. When baby chicks step onto those wet areas, the liquid ammonia begins to erode the skin on the bottom of the chick's feet. Visible paw lesions are evident by the time the bird is 7 days old and the lesions continue to worsen over time. They do not tend to heal even if the litter dries out.

The use of PLT® to neutralize the ammonia at the litter surface is a good management tool to help prevent the formation of footpad lesions. A demonstration in the Summer and Fall of 2004 showed dramatic improvement in paw quality on farms that used PLT® in the brood chamber. Ten farms (618, 204 birds) used the 50 lb rate of PLT® and six farms (463,177 birds) did not treat the litter.

The birds raised on PLT® showed significant improvement in paw quality with 55% of the birds having quality feet compared with only 16% of the control birds! The PLT® group had 19% fewer major paw lesions and 20% fewer minor paw lesions than the control birds. Performance was also much improved for the birds raised on PLT® with a three-point improvement in feed conversion (1.77 vs. 1.80) and a point better in weight.

The Bottom Line: PLT® Delivers Better Paws to the Plant.



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The Science of Litter Management

LITTER forum

by JONES-HAMILTON CO.

SUMMER 2013

PLT® & Al⁺ Clear Field Comparison of 44 Million Birds

A commercial broiler complex in the Southeast raising both a large (7.0 lb.) and small (4.5 lb.) birds evaluated the economic and performance benefits of using litter amendments. Contract growers were given a choice of either using PLT® or Al⁺ Clear (General Chemical Corp., Parsippany, NJ) at the rate 50 lbs. / 1,000 sq. ft. in the brood chamber (10,000 sq. ft.).

Eighty-seven percent of the big bird growers and eighty-two percent of small bird growers chose PLT®. The remaining thirteen percent of the big-bird and eighteen percent of the small-bird growers chose to use Al⁺ Clear in an identical manner to the PLT®. A total of 43.9 million birds were evaluated in this demonstration. The variety of housing and management types were similar between the treatment groups.

Results

Both the small and large bird groups raised on PLT® substantially out performed the birds raised on Al⁺ Clear (Table 1). In a complex of this size, the general rule of thumb is that an improvement in feed conversion of 0.01 lbs. of weight gain / lb. of feed consumption is worth $1 Million per year (Agrimetrics Associates, Inc., Midlothian, VA).

The large birds raised on PLT® had a feed conversion improved by 0.02 and the feed conversion of the small birds was improved by 0.04 over the birds raised on Al+ Clear. This reduced performance shown by the birds raised on Al⁺ Clear is consistent with production losses due to ammonia exposure reported in the literature (Miles, et al., 2004). This resulted in a net return of $2.7 million /yr over the cost of PLT® ($305,000) on improved feed conversion alone in that complex. Additional economic benefit would have also been realized by the grower and the poultry integrator from the increases in weight and livability observed in this trial.

44 Million Birds Don't Lie: PLT® Out Performs Al⁺ Clear by $2.7 Million in Better Feed Conversion Alone.

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

Table 1. Production Data from Southeast Commercial Broiler Complex for all flocks raised on SBS or Al⁺ Clear

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LITTER *forum*

by JONES-HAMILTON CO.

Litter Acidification

Jones-Hamilton Co. developed and introduced the concept of litter acidification with PLT® Poultry Litter Treatment as a beneficial management tool. PLT® has been used by the poultry industry since 1989 and today Jones-Hamilton is recognized as the innovator and leader in the Science of Litter Management. Hundreds of millions of birds have been grown more profitably with PLT® and the product has gained worldwide acceptance as the premier poultry litter treatment because of its efficacy and uniqueness. PLT® is not classified as a hazardous or toxic product and provides immediate ammonia control and effective litter acidification with one economical application.

Litter Acidification

There are many benefits of lowering the pH (acidification) of poultry house litter. These benefits include ammonia control with significant fuel usage savings, reduced brooding stress, and improved litter management. These benefits are an essential part of a comprehensive preharvest program.

Poultry litter has an average pH of 8.0-9.0, which is considered a high pH or alkaline. pH values are measured on a scale from 0 to 14. 7.0 is considered neutral, pH values below 7.0 are considered acidic and values above 7.0 are considered alkaline. The pH value is a measurement of the hydrogen ions (H+) in a solution. Effective litter acidification must drop the usual litter pH of 8.0-9.0 down to well below pH 4.0. PLT® lowers litter pH immediately upon application down to 1.5-2.5. A low litter pH, lower than 4.0, is essential for preharvest programs. An effective preharvest program with reduction of brooding stress allows birds to better achieve their maximum genetic potential and provides maximum revenue generation. PLT® effectively provides optimum litter acidification.

Achieving Litter Acidification

An acid is needed to lower litter pH and achieve litter acidification. Acids donate hydrogen ions. The more H+ donated, the lower the pH value. Because of the available hydrogen ion, it is easy to see why the following substances are considered acids.

- Hydrochloric Acid (HCl)
- Phosphoric Acid ($H3P0_4$)
- Sulfuric Acid (H_2SO)
- Nitric Acid ($HN0_3$)
- PLT® ($NaHSO_4$--one ingredient in PLT,® a proprietary non-hazardous dry acid)

Substances such as aluminum sulfate $A1_2$ $(S0_4)_3$ (alum) and bacterial based litter treatments do not contain hydrogen ions. Therefore, they can't directly lower litter pH litter. Alum is considered an environmentally hazardous substance by the Environmental Protection Agency (EPA) and the Department of Transportation (DOT). Alum will react with water in litter to gradually produce hydrogen ions. An equilibrium is reached when a small amount of hydrogen ions are released and the pH is lowered only slightly. USDA tests reveal that two tons (4000 lbs.) of alum are needed in a 16,000 sq. ft. chicken house to lower the litter pH to 5.7 on the day of application. Then the pH rises during the grow-out period. A pH value less than 4.0 is considered ideal for improved food safety. Immediately upon application PLT® effectively acidifies litter to a pH below 4.0.

Litter Acidification and Ammonia Control

Many economic benefits are derived from litter acidification with PLT®. The primary benefit is immediate ammonia reduction and long-term control for several weeks with just one application. Ammonia is produced from bird droppings and ammonium ions NH4+ are present in the litter. At normal untreated litter pH (average 8.0-9.0) the ammonium ions are volatilized into the atmosphere as harmful ammonia gas NH3.The reaction that converts ammonium ions in the litter into ammonia gas in the atmosphere is dependent upon litter pH. If the pH is low the ammonium ions stay in solution in the litter and are never converted into atmospheric ammonia gas. PLT® drops litter pH significantly immediately upon application and holds pH low for an extended period. Therefore, litter ammonium ions are not converted into atmospheric ammonia gas and your birds are never exposed to ammonia stress. Without the damaging effects of ammonia your flocks are better able to reach their full genetic potential and maximum profitability.

References

Environmental Protection Agency (EPA) and Department of Transportation (DOT) Classifications. HAACP: The Hazard Analysis and Critical Control Point System in the Meat and Poultry Industry American Meat Institute Foundation, Washington, D. C. 1994. Pg. Moore, P. Live Production Environmental Manure Management Reducing Phosphorus Runoff and Inhibiting Ammonia Volatilization from Poultry Litter with Aluminum Sulfate. Southeastern Poultry & Egg Association 1995 Poultry Environmental Seminar. Terzich, M. The Effects of Sodium Bisulfate on Poultry Litter House Ammonia, Litter pH, Litter Pathogens and Insects, and Bird Performance Proceedings of the 46th Western Poultry Disease Conference, Sacramento, California. 1997. Pg. 71-74.

LITTER *forum*
by JONES-HAMILTON CO.
SPRING 2011

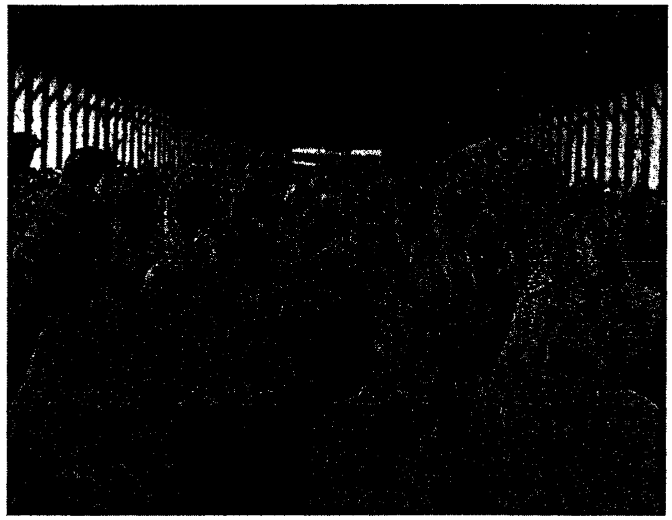
PLT® and PWT® Program Boosts Turkey Performance

A PLT® litter acidifier and PWT® water acidifier demonstration project began in 2009 with the turkey flock settling at the end of April 2010. The farm was chosen because it had a history of turkey dermatitis. Control birds were raised on the integrator's normal program while the treated birds were raised in the PLT®/PWT® turkey protocol. Even though the farm never broke with dermatitis, the birds on the acidification program took off and never looked back.

In the brood barns, the drinker system was cleaned with PWT® water acidifier and then charged with PWT® treated water at a pH of 3.5 in preparation for poult placement. PWT® was delivered continuously to the poults at a pH of 3.5 for 10 days, and then 3 days per week thereafter until the birds moved to the growout barn.

Turkeys were moved into the growout barn at 4 weeks of age. In the growout barn, the drinker system was cleaned with PWT® then filled with PWT®-treated water at a pH of 3.5. The litter was treated with 100 lbs/1,000 sq. ft. of PLT® the day before transfer of turkeys from the brood barn. PWT® was delivered continuously for the first 10 days after transfer, then 3 days per week throughout the rest of the growout. The target pH at bird level was always 3.5. PLT® was re-applied to the top of the litter at 8 weeks, again at 11 weeks at a rate of 100 lbs/1,000 sq. ft., and then hand applied underneath any mortality with a shaker can. The barns were not tilled.

The turkeys in the PLT®/PWT® group were processed at 141 days weighing 45.51 lbs. The control group was processed one day later but they still weighed less than the PLT®/PWT® group at only 45.31 lbs. The biggest difference in the group was in feed conversions with twelve points difference between the treated and controls in both gross and adjusted feed conversion (see Table 1). The increases in weights, feed conversion, and livability were so profound on the PLT®/PWT® program that both the grower and the integrator realized a substantial return on investment. On this farm, litter acidification and water acidification were a win/win situation!



Turkeys raised on PLT® and PWT® had 12 points better feed conversion!

Table 1	PLT Group	Controls
Finishing livability	87.20%	87.14%
Age	141 days	142 days
Sold weight	45.51 lb	45.31 lbs
Gain per day	.3228 lb/day	.3191 lb/day
Gross feed conversion	2.4313	2.545
FC adjusted to 42#	2.3681	2.4855

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30354 Tracy Road, Walbridge, Ohio 43465-9792 • Ph: 419.666.9838 • 888.858.4425 • Fax: 419.666.1817 • aginfo@jones-hamilton.com

Jones-Hamilton Co.
Agriculture Division
800.379.2243

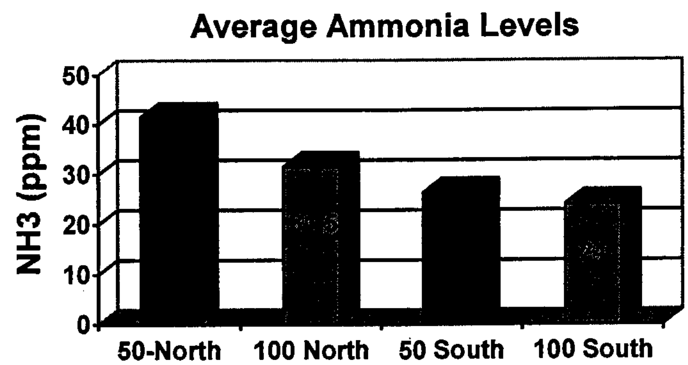
Poultry Litter Treatment

Higher Rates of PLT Cost Less & Save More Fuel!

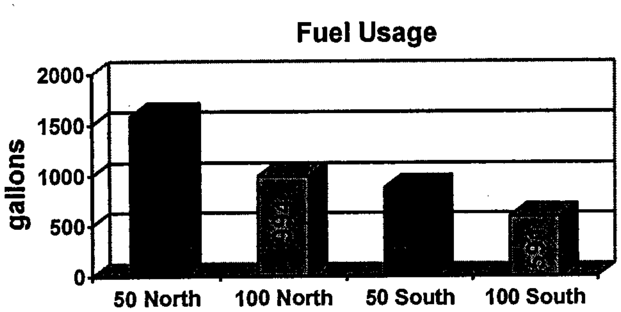
Everyone knows that higher application rates of PLT will bind more ammonia, but will it cost less than using the minimum rate of 50-lbs/1000 sqft? Our research says, "YES"!

Two farms were chosen to test this concept, one in Delmarva (North) and one in the Carolinas (South). The farm on Delmarva was half-house brooding in 16,000 sqft houses and the Carolina farm brooded in 2/3 of their 20,000-sqft houses. PLT was applied in some of the houses at 50-lbs/1000 sqft and in the others at 100-lbs/1000 sqft.

Ammonia levels in all of the North houses before PLT application was 120 PPM. The 50-lb South houses began at 160 PPM while the 100-lb South houses began at 300 PPM! As you can see from the graph at right, the houses treated with the 100-lbs/1000 sqft of PLT had significantly less ammonia at bird level than the houses with the minimum rate of PLT.



Most importantly for some, was that the houses where 100-lbs/1000 sqft of PLT was applied had far LESS fuel usage than the houses using the minimum rate on both North and South farms. Given that the average price of propane during this demonstration was $1.60 on the North farm and $1.48 on the South farm, the large difference in fuel use far outweighed the cost of the additional PLT. On the North farm, the **NET** savings was **$840.80** per house! Even with the more temperate climate on the South farm, the net savings was still **$336.76** per house. Not a bad return for less than $100 per house extra investment.



Using 100-lbs/1000 sqft of PLT costs $840.80 LESS!

Winter Economic Benefits:

The Effect of PLT® on Fuel Cost, Bird Performance, Ammonia and Litter pH on Broiler Farms

High levels of ammonia in the poultry house can lead to reduced bird body weight, higher feed conversion, more culls and condemnations, more respiratory disease and ascites. Ammonia levels were dramatically reduced in the PLT® treated houses. This allowed for a decrease in ventilation (fewer fans running with less fan time) conserving heat, resulting in a significant savings in fuel cost. Control houses required more ventilation and more fuel, and still had higher ammonia levels.

Fuel Savings

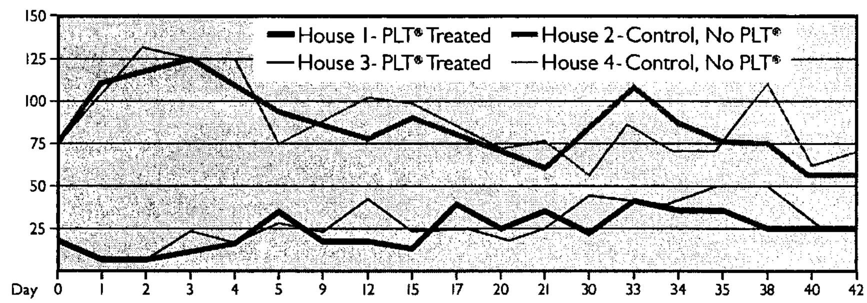
Fuel usage was monitored daily in each house. In the PLT® treated houses, ammonia levels were so low that ventilation could be kept to a minimum, resulting in significant fuel savings. PLT treated houses averaged $783 in fuel savings ($1.25/gal propane) compared to the control houses.

Protocol

Four, four-house broiler farms were used for this trial. Two farms were located on the Delmarva Peninsula where outside temperatures averaged 20°F at the time of PLT® application. The other two farms were located in South Carolina, where outside temperatures averaged 50°F at application time. Breeder flock source distribution was equalized between all four houses on each farm.

On each farm, litter in two of the houses was treated with PLT® at a rate of 50-lbs/1000 sqft. The other two houses served as controls, with litter left untreated. Size of all houses was 40X500 feet. Inside temperature at PLT application was 90 F, with litter temperature at 80° to 85°F. Built-up litter was was used on each farm with litter age ranging from 2 to 13 flocks.

Fuel Usage (gals.) During Grow-out



Average Weight (lbs.)/Farm

	PLT® Houses	Control Houses	[illegible]
Farm A	212,724	207,716	[illegible]
Farm B	229,560	228,220	[illegible]
Farm C	254,966	241,159	[illegible]
Farm D	266,957	258,001	[illegible]

Bird Performance

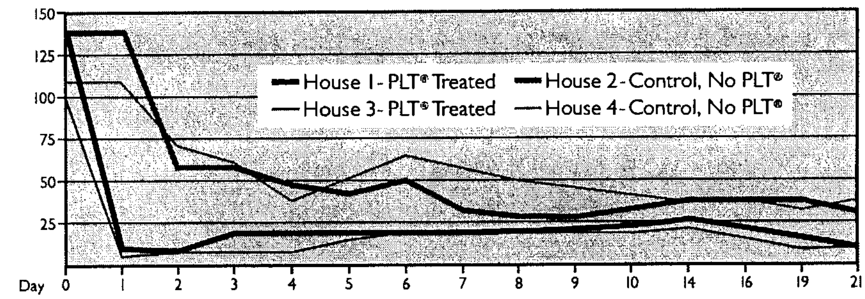
Birds in the PLT® treated houses had significant weight gains compared to those in the control houses. The energy they consumed was spent in growth and weight gain instead of fighting disease and stress caused by high ammonia levels.

PLT® treated houses produced an average of 3,640 extra pounds. At an average live cost of 25 cents/lb., the cost savings is $910 per house.

Litter Cost Savings

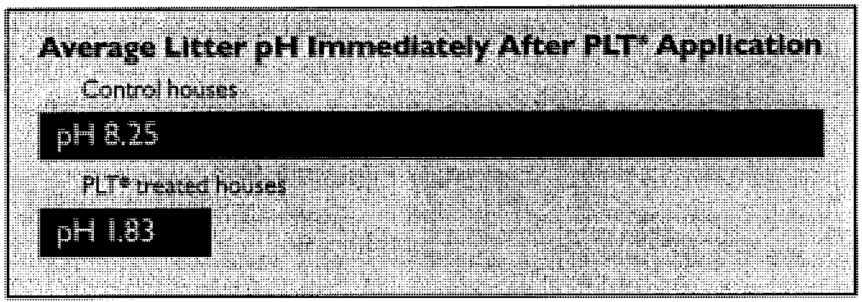
Ammonia levels in the treated houses were signifcantly lower than in the controls. PLT® acidifies the litter and binds ammonia, making it safe to re-use longer. Average litter savings per 40X500 foot PLT treated house is $1,700 (average cost of new litter).

Ammonia (ppm) Levels During Grow-out



Litter pH

The pH of litter in PLT® treated houses was significantly lower than that of the litter in the control houses.



Summary

PLT® more than pays for itself and generates significant revenue. The approximate cost to treat a house brood chamber with PLT is $125.00 (which is not reflected in the table below).

Average Savings in PLT® Treated House

Litter Cost Savings	$1,700
Fuel Savings	$783
Improved Bird Weight	$910
Total Savings Per House	**$3,393**

This PLT® research trial proves the cost saving benefits of PLT. Many producers use PLT year-round to cut costs, improve bird performance and increase profits.

Poultry Litter Treatment

The Science of Litter Management

JONES-HAMILTON CO.
Agricultural Division

30354 Tracy Rd. | Walbridge, Ohio 43465-9792 | aginfo@jones-hamilton.com
Phone: 419.666.9838 | Toll-Free: 888.858.4425 | Fax: 419.666.1817

A11PLTE R1011405

Spring and Summer Economic Benefits:

The Effect of PLT® on Fuel Cost, Bird Performance, Ammonia and Litter pH on Broiler Farms

High levels of ammonia lead to poor bird performance, increased culls and condemnations, reduced disease resistance and a wide variety of other negative effects to broiler production. In this study, PLT® treated houses had notably lower ammonia levels. The low ammonia levels allowed producers to greatly reduce fan times and conserve energy, especially during the critical brooding period. Control houses had higher ammonia, more ventilation and greater fuel usage.

Protocol

Sixteen two-house broiler farms (32 houses total) were used for this trial with a major poultry integrator. All houses measured 40X500 feet. PLT® was applied in one house on each farm at a rate of 50-lbs/1000 sqft. The control house on each farm was left untreated. Litter age on the farms varied from 3 flocks to 10 flocks (litter age same in both houses on each farm).

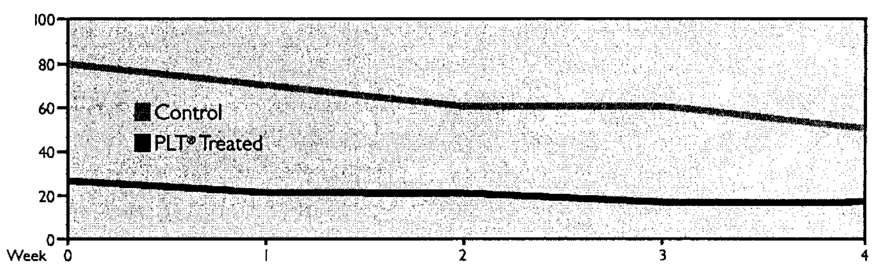
Breeder flock sources were paired between the houses on each farm to reduce variables. Ventilation systems were identical in both houses on each farm. Some farms had traditional summer ventilation with curtain sided houses and some farms had tunnel ventilation in both houses. Daytime outside temperatures varied from 64 F to 97 F during the trial period from April 1 through August 31.

Data was collected from each house before and after PLT® application and during the seven week grow-out.

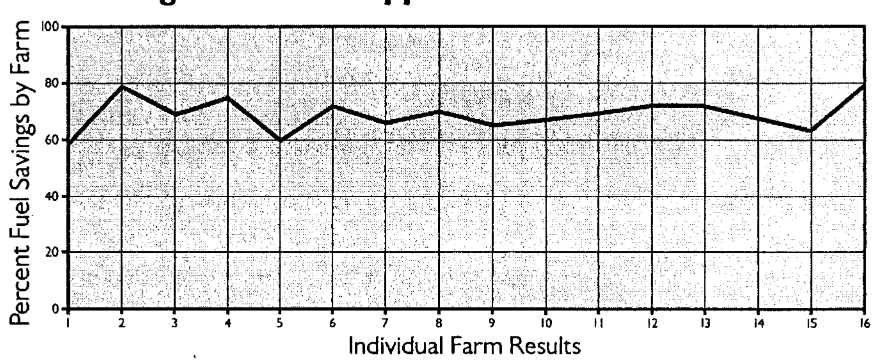
PLT® Pays For Itself In Fuel Savings Alone

Average fuel savings when using PLT® for all 16 farms is 68% compared to no litter treatment. This represents a significant cost savings, even during the spring and summer months.

Fuel Usage (gals.) During Grow-out



Fuel Savings from PLT® Application



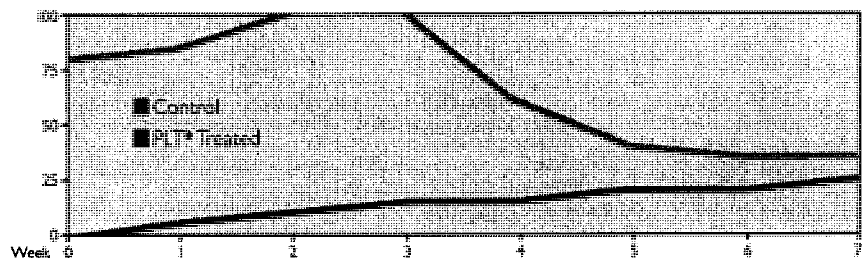
Bird Performance: PLT® Versus Controls Numbers represent averages for all 16 farms	PLT®	Control	[redacted]
% Livability	97.40	95.50	[redacted]
% Total Condemnations	1.23	1.68	[redacted]
% Airsac	.07	.29	[redacted]
% IP	.05	.14	[redacted]
Adjusted Feed Conversion	2.012	2.037	[redacted]
Total Bird Weight per house (lbs.)	241,051	233,774	[redacted]

Birds in the PLT® treated houses gained more weight due to minimized stresses, especially during the critical brooding period. PLT reduced ammonia and acidified the litter, helping to reduce challenges. Birds in the PLT treated houses gained more weight because their energy (feed) input was used to add weight instead of fighting stressors.

Ammonia: A Year-Round Concern

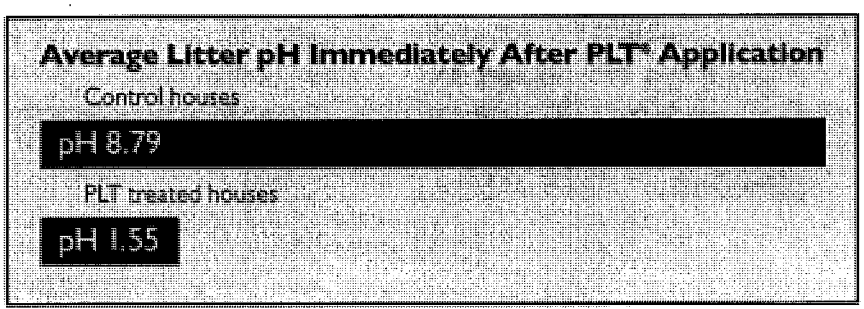
It's important to note that this trial demonstrates that ammonia levels were very high, even during a time of year when most broiler producers feel that ammonia is not a concern. Ammonia reduces flock performance year-round.

Ammonia (ppm) Levels During Grow-out



Litter Cost Savings

PLT® dramatically reduces litter pH and ammonia levels. This allows for safe litter reuse at a savings of about $1,700 per house in litter material costs.



Poultry Litter Treatment

The Science of Litter Management

Summary

PLT® isn't just for winter ammonia control. It's proven effective year-round for ammonia control, litter acidification, fuel savings, and improved bird performance. PLT more than pays for itself with improved bird performance, reduced culls and condemnations, extended safe litter reuse and fuel savings. Use PLT to dramatically cut production costs from one season to the next.

JONES-HAMILTON CO.
Agricultural Division

30354 Tracy Rd. | Walbridge, Ohio 43465-9792 | aginfo@jones-hamilton.com
Phone: 419.666.9838 | Toll-Free: 888.858.4425 | Fax: 419.666.1817

JONES-HAMILTON CO.
30354 Tracy Road
Walbridge, OH 43465

Phone: (419) 666-9838
Fax: (419) 666-1817
www.jones-hamilton.com

April 14, 2014

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Ave, SW
Room 2646, Ag stop 0268
Washington, DC 20250

To Whom It May Concern:

PLT® Litter treatment (sodium hydrogen sulfate or sodium bisulfate) has been an integral part of poultry production in the United States for over 20 years. The ability of PLT® litter treatment to bind ammonia and shift bacterial ecology of the litter has improved poultry house conditions allowing for better animal welfare, increased production with the same level of inputs and reduced fuel usage and ammonia emissions to the environment. Because no organic equivalent exists, poultry raised in organic production systems have been unable to benefit from the improved housing conditions that PLT® provides. In addition, organic farmers have been unable to benefit from the improvement in environmental stewardship that the use of PLT® allows.

Ammonia production is a normal by-product of the avian renal system. Because of the common urogenital-gastrointestinal opening of the chicken known as a cloaca, the urine and the feces of a chicken combine internally before excretion causing immediate ammonia release from the manure droppings. This is in contrast to mammals where the urine and the feces are eliminated separately and segregation of dry and liquid wastes in animal housing can be achieved to reduce ammonia production. Because of this, ammonia levels in poultry production systems of all types routinely exceed 25 PPM, the level considered appropriate for animal welfare. These higher ammonia levels can cause eye and respiratory changes in birds and also depress weights and feed conversions. In the absence of PLT®, farmers are forced to increase their ventilation in an attempt to exhaust the ammonia. This excessive ventilation can cause large temperature and humidity swings within the house decreasing bird comfort and welfare. In addition, this increased ventilation causes a higher level of fuel and electricity usage decreasing environmental sustainability.

By using an ammonia-binding litter amendment such as PLT® litter treatment, ammonia gas in the house environment can be converted into a solid (ammonium sulfate) and retained in the litter where it cannot harm birds. By binding the ammonia that is naturally released from the birds and turning it into a solid fertilizer, the use of PLT® allows houses to be ventilated for relative humidity as they were designed: conserving heat and allowing for a more uniform house environment for the bird which improves bird comfort and welfare. This also reduces fuel usage thereby decreasing greenhouse gas emissions. By preventing the reduction in feed efficiency and bird weights caused by ammonia, PLT®-treated houses require less grain and feed to produce the same number of chickens thereby reducing cropland and crop production inputs. This is especially important as organic livestock production has increased and need for organic grains has far exceeded domestic production.

In addition, the use of PLT® has been shown to reduce ammonia emissions by converting gaseous ammonia to a solid fertilizer (ammonium sulfate), reduces VOC emissions through shifting litter ecology, and GHG emissions by reducing fuel usage. This is why the US Environmental Protection Agency has included the use of sodium bisulfate as a best management practice in its Watershed Implementation Plan for Federal Lands in the Chesapeake Bay Watershed. USDA's Natural Resources Conservation Service cost-shares the usage of PLT® with farmers as part of its Environmental Quality Incentives Program under Conservation Practice Standard 591. In 2013, over 19 million pounds of ammonia were removed from the environment and converted into useful solid fertilizer through the use of sodium bisulfate (PLT®) in poultry housing.

Another concern in organic poultry production is the sensitivity of the birds to bacterial diseases. The sodium and hydrogen components of PLT® modifies litter bacterial ecology to promote the health of normal gut flora in the litter and reducing bacterial pathogens such as clostridium and salmonella. The reduction of clostridium improves the birds' response to coccidial vaccines and reduces the occurrence of necrotic enteritis, a common ailment of organically grown birds. By reducing the bacterial challenge in the environment, health and welfare of the birds are more easily maintained. Published field studies have also shown that the use of PLT® reduces the level of salmonella on the birds at processing improving food safety.

The improvements in litter microflora and reduction of ammonia released from the litter with PLT® use allows for the bedding to be safely recycled from one flock to the next. This not only improves bird comfort by providing better warmth and insulation, it improves bird health by exposing the day-old chick to normal gut flora in the recycled litter. In addition, the ability to recycle litter allows for reduced forestry inputs into the system and improved carbon sequestration since it requires far fewer trees to be harvested to produce shavings for bedding.

Unfortunately, there is no organic equivalent that provides sufficient ammonia reduction or bacterial control in the litter available for organic farmers to use. Organic acids have no sulfate component that can convert the ammonia gas into a solid preventing its re-release into the poultry house environment and therefore have not been effective in litter applications. Biological or plant extracts sold for ammonia reduction usually only reduce ammonia by 10-15%, if at all. This leaves ammonia levels still well above the 25 PPM needed for bird health and welfare.

For these reasons, Jones-Hamilton Co. respectfully requests that PLT® Litter treatment, sodium bisulfate, be allowed for use in organic poultry production and that litter treated with sodium bisulfate be allowed for use in organic crop production. Leaving organic farmers without an appropriate solution to control ammonia within their facilities not only degrades bird health and welfare but also reduces the environmental sustainability of such operations neither of which are in the spirit of the National Organic Program.

Respectfully submitted,

JONES-HAMILTON CO.

Bernard D Murphy

Bernard D. Murphy, Ph.D.
President

BDM/jf

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Avenue, SW
Room 2646, Ag Stop 0268
Washington, DC 20250

Date: **March 31, 2014**

Subject: Material Petition for Inclusion of Sodium Hydrogen Sulfate to the National List

To Whom It May Concern:

Our company is looking for ways improve bird health and welfare and to be more sustainable in our day to day operations. To achieve these goals, we are requesting that Sodium hydrogen sulfate (PLT) be allowed on the Nation Organic list. Sodium hydrogen sulfate has many benefits to produce high quality organic poultry. These benefits include:

- **<u>Bird health</u>**: Sodium hydrogen sulfate controls ammonia produced by the birds. Ammonia gas in the air affects bird health, welfare and performance. Continued exposure to high ammonia levels can damage the bird's eyes and respiratory system leading to infections and declining flock health and performance.

- **<u>Food Safety</u>**: Sodium hydrogen sulfate helps maintain a microflora in the litter that is more favorable for gut health. Bedding material treated with sodium hydrogen sulfate is also less favorable to pathogenic bacteria such as salmonella, clostridium and <u>E. coli</u> resulting in fewer bacteria on the carcasses at processing.

- **<u>Decreased fuel usage</u>**: Since ammonia release is controlled, houses no longer need to be over-ventilated to reduce ammonia, heat is conserved within the house and fuel usage is reduced. This improves bird comfort, controls ammonia emissions, and reduces carbon emissions to the environment.

- **<u>Improves fertilizer value of the litter</u>**: By reducing the release of ammonia from the litter, the nitrogen content will be greater and more in balance with phosphorous. This improves the fertilizer value for organic crops.

- **<u>Improves company sustainability</u>**: Greenhouse gas and ammonia emissions are reduced. Litter quality is improved, allowing litter to be recycled for more flocks. This reduces new bedding inputs to the system and allows for greater carbon sequestration.

We thank you for considering our request and look forward to the approval of Sodium Hydrogen Sulfate to the NOP National List.

Sincerely,

N. Lyle Johnston

N. Lyle Johnston, Ph.D.
Director of live Production
Petaluma Poultry

Cell#: 707-217-3263
Email: Ljohnston@colemannatural.com

js west
AND COMPANIES

501 9th Street
Modesto, CA 95354
209-577-3221 tel
209-523-9828 fax

www.jswest.com

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Avenue SW
Room 2646, Ag Stop 0268
Washington, DC 20250

Date: 3/5/2014

Subject: Material Petition for Inclusion of Sodium Hydrogen Sulfate to the National List

To Whom It May Concern:

J.S. West Milling Company is responsible for the egg production of 2 million laying hens in California. The ammonia control we are able to achieve, by using PLT (Sodium Hydrogen Sulfate) has allowed us to maintain operations in an area that has neighbors in close proximity. The reduced odor from the manure because of the Sodium Hydrogen Sulfate as we dry and compost has been invaluable. I understand Sodium Hydrogen Sulfate is used extensively by the poultry industry for over 20 years as a litter treatment to support the production of high quality poultry. We have found no organic alternative to this material.

When applied to the poultry litter as directed, the product has proven to have a positive effect on animal welfare, environmental conditions, nutrient value and sustainability. The most notable benefits are controlling the release of ammonia from the litter and manure, the plant available nitrogen content will be greater. This will improve the fertilizer value for organic crops.

We are hereby requesting that the NOSB and the NOP formerly approve Sodium Hydrogen Sulfate to be added to the NOP National Materials List for use on organic poultry litter for application to organic cropland and other related uses. With this approval, the organic poultry industry can produce higher quality product, contribute to a more sustainable environment and enhance food safety.

We thank you for considering our request and look forward to the approval of Sodium Hydrogen Sulfate to the NOP National List.

Sincerely,

John Bedell
Production Manager
J.S. West Milling Company
209-664-3980 Office
209-495-2416 Cell
jbedell@jswest.com

Perdue Foods

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Avenue, SW
Room 2646, Ag Stop 0268
Washington, DC 20250

Date: March 26, 2014

Subject: Material Petition for Inclusion of Sodium Hydrogen Sulfate to the National List

To Whom It May Concern:

We have been using Sodium Hydrogen Sulfate successfully, labeled as Poultry Litter Treatment (PLT®), on our poultry litter for several years. When applied as required directly to the poultry litter, it has proven to be most effective.

It has many beneficial aspects to the health and well-being of the birds, reduces ammonia significantly, improves living conditions, has no waste and produces an overall better environment inside the poultry house. This material is GRAS Approved, phosphate free, and DOT classified Non-Regulated.

We are hereby requesting that the NOSB and the NOP formerly approve Sodium Hydrogen Sulfat to be added to the NOP National Materials List for use on organic poultry litter, for application to organic cropland and other related uses. We have a sincere interest in having options for ammonia control products in our Organic programs.

We thank you for considering our request and look forward to the approval of Sodium Hydrogen Sulfate to the NOP National List.

Sincerely yours,

Michael K. Levengood
Vice President of Live Production
Perdue Foods, LLC.

Marshall Durbin

Marshall Durbin Companies
County Road 20, P.O. Box 39, Delmar, Alabama 35551
(205) 486-2273

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Avenue,SW
Room 2646, Ag Stop 0268
Washington, DC 20250

Date: 4/23/14

Subject: Material Petition for Inclusion of Sodium Hydrogen Sulfate to the National List

To Whom It May Concern:

I have been using PLT(Sodium Hydrogen Sulfate) for at least the last 14 years of my career in live production of poultry. I know of no organic alternative that provides sufficient ammonia reduction or bacterial control in the litter as Sodium Hydrogen Sulfate.

Here are 4 of the main reasons that I recommend the use of PLT to my producers:

1.) Healthy Birds-Without the ability to control ammonia, we will invariably have numerous and costly health problems because of blinded birds and respiratory problems in our birds.

2.) Saves propane-Fuel usage is lower saving growers on their production cost. This is because we will not have to run exhaust fans unnecessarily because of high ammonia in our houses.

3.) Increase nitrogen- When growers use PLT on their litter it improves the plant available nitrogen. This will improve the fertilizer value of litter applied to organic crops.

4.) Saves on bedding- With the use of PLT, growers can reuse their litter. This saves on the number of trees to be harvested as shavings for the use of litter in my area.

I hereby request that the NOSB and the NOP formerly approve Sodium Hydrogen Sulfate to be added to the NOP National Materials List for use on organic poultry litter, for application to organic cropland and other related uses.

I thank you for considering our request and look forward to the approval of Sodium Hydrogen Sulfate to the NOP National List.

Sincerely yours,

Thomas Lewis

PROUD to be
a part of the
AG INDUSTRY!

Klaphake FEED MILL INC.

36177 County Rd 186
Melrose, MN 56352

Phone: 1-320-256-4273
Fax: 1-320-256-7304

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Avenue, SW
Room 2646, Ag Stop 0268
Washington, DC 20250

Date: 3/11/14

Subject: Material Petition for Inclusion of Sodium Hydrogen Sulfate to the National List

To Whom It May Concern:
Our company is looking for ways improve bird health and welfare and to be more sustainable in our day to day operations. To achieve these goals, we are requesting that Sodium hydrogen sulfate (PLT) be allowed on the Nation Organic list. Sodium hydrogen sulfate has many benefits to produce high quality organic poultry and we have found no organic alternative. These benefits include:

Bird health: Sodium hydrogen sulfate controls ammonia produced by the birds. Ammonia gas in the air affects bird health, welfare and performance. Continued exposure to ammonia levels above 25 parts per million (ppm) can damage the bird's eyes and respiratory system leading to infections and declining flock health and performance.

Food Safety: Sodium hydrogen sulfate helps maintain a microflora in the litter that is more favorable for gut health. Bedding material treated with sodium hydrogen sulfate is also less favorable to pathogenic bacteria such as salmonella, clostridium and E. coli resulting in fewer bacteria on the carcasses at processing.

Decreased fuel usage: Since ammonia release is controlled, houses no longer need to be over-ventilated to reduce ammonia, heat is conserved within the house and fuel usage is reduced by 50% or more. This improves bird comfort, controls ammonia emissions, and reduces carbon emissions to the environment.

Improves fertilizer value of the litter: By reducing the release of ammonia from the litter, the nitrogen content will be greater and more in balance with phosphorous. This improves the fertilizer value for organic crops and allows us to sell our fertilizer to organic farmers.

Improves company sustainability: By reducing the negative impacts of ammonia and promoting healthy litter ecology, less grain is needed to feed the birds. Greenhouse gas and ammonia emissions are reduced. Litter quality is improved allowing litter to be recycled reducing forestry inputs to the system and allowing for greater carbon sequestration.

Because there are currently no organic alternatives that perform the same function as successfully as sodium hydrogen sulfate, the only alternative we have now to control ammonia levels within the house is excessive ventilation. This causes a tremendous amount of temperature fluctuation during brooding that greatly decreases bird comfort and causes high fuel usage.

We thank you for considering our request and look forward to the approval of Sodium Hydrogen Sulfate to the NOP National List.

Sincerely,

Pete Klaphake
Vice President
Klaphake Feed Mill, Inc.

FLINTROCK FARMS
16 East Brubaker Valley Road, Lititz, PA 17543
phone 717.627.4269 facsimile 717.627.0838

National Organic Standards Board
National Organic Program
United States Department of Agriculture
1400 Independence Avenue, SW
Room 2646, Ag Stop 0268
Washington, DC 20250

March 26, 2014

Subject: Material Petition for Inclusion of Sodium Hydrogen Sulfate to the National List

To Whom It May Concern:

We have been using successfully Sodium Hydrogen Sulfate, labeled as Poultry Litter Treatment (PLT®) on our poultry litter for many years. When applied as required, directly to the poultry litter it has proven to be most effective.

It has many beneficial aspects to the health and well-being of the birds, reduces ammonia significantly, improves living conditions humanely, has no waste and produces a very clean environment inside and outside of the housing. This material is GRAS Approved, phosphate free, and DOT classified Non-Regulated.

Having converted some of our farming operations to organic production, we are left with no good alternative to achieve the benefits mentioned.

We are hereby requesting that the NOSB and the NOP formerly approve Sodium Hydrogen Sulfate to be added to the NOP National Materials List for use on organic poultry litter, for application to organic cropland and other related uses.

We thank you for considering our request and look forward to the approval of Sodium Hydrogen Sulfate to the NOP National List.

Sincerely yours,

Daniel C. Heller
President

PLT® Litter Treatment Usage Consistent with the USDA-EPA Unified National Strategy for Animal Feeding Operations

Manure handling and storage is addressed in the USDA-EPA Unified National Strategy under Section 3.3 Comprehensive Nutrient Management Plan Components (page 9). The section entitled "Manure Treatments" read as follows:

> ***Manure treatments* - Manure should be handled and treated to reduce the loss of nutrients to the atmosphere during storage, to make the material a more stable fertilizer when land-applied or to reduce pathogens, vector attraction and odors, as appropriate.**

PLT litter treatment is a dry, granular acid salt designed to be applied to animal manure for the purpose of reducing ammonia and decreasing bacterial counts in the litter 3-4 logs. Its usage is consistent with the USDA-EPA Unified AFO strategy and meets all requirements as outlined under "Manure Treatments" in Section 3.3.

1. **REDUCE THE LOSS OF NUTRIENTS TO THE ATMOSPHERE DURING STORAGE** – The usage of PLT litter treatment during the rearing phase of livestock or poultry binds the ammonia volatilized from the litter. This ammonia gas is converted to ammonium sulfate and will not be released in the gaseous phase during storage. A layer of PLT litter treatment can also be applied on top of the litter surface during storage or composting to provide an additional barrier to prevent ammonia volatilization into the atmosphere.

2. **MAKE THE LITTER A MORE STABLE FERTILIZER WHEN LAND APPLIED** – PLT litter treatment will bind to the ammonia being volatilized from the litter and convert it into ammonium sulfate. This increases the stability of and the amount of the nitrogen present in the litter during land application improving the N: P ratio of animal manures.

3. **REDUCE PATHOGENS** - PLT litter acidifier is the only litter treatment that has been approved by the EPA for a 3-4 log bacterial reduction of litter though it is not currently labeled for this use. There is a volume of data in the published literature as to the efficacy of PLT litter treatment in the reduction of Salmonella, Campylobacter, and *E. coli* in the litter and on the carcasses of processed poultry.

4. **REDUCE VECTOR ATTRACTION** – PLT litter treatment has been shown to reduce the load of darkling beetles in treated litter though it currently is not labeled as an insecticide (currently EPA registered but not marketed). The stability of insecticides is also improved when they are applied in an acidic environment.

5. **REDUCE ODORS** – Ammonia is on of the largest components of odor emanating from animal manures. Other odors are generated through bacterial decomposition of the litter. PLT litter treatment binds the ammonia in the litter to prevent volatilization and thereby odor generation. PLT litter acidifier also reduces the bacterial population of the litter 3-4 logs thereby reducing odors of bacterial origin.

Selected Bibliography of Sodium Bisulfate (PLT®, Parlor Pal ®, Comfort Zone ®)

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Effect of daily floor treatment with sodium bisulfate on the fly population of horse stalls.
Am J Vet Res. 2000 Aug;61(8):910-3.
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Effect of sodium bisulfate on ammonia concentration, fly population, and manure pH in a horse barn.
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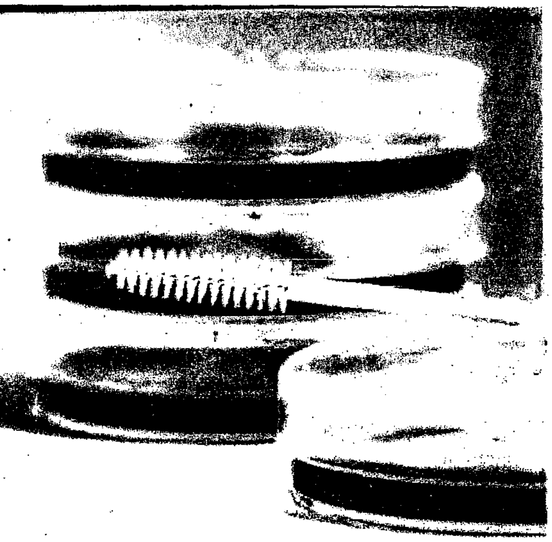


Food safety interventions that reduce Salmonella in poultry live production

Vaccination, organic acids and probiotics are among the interventions that work to reduce Salmonella levels of broilers arriving at the slaughter plant, but a carefully focused plan is required for success.

BY GARY THORNTON

Reducing *Salmonella* in poultry live-production operations can be an effective means of reducing the food pathogen in the poultry processing plant and the final consumer product.

Speaking at the International Production and Processing Expo, Dr. Charles "Chuck" Hofacre, University of Georgia, outlined food safety interventions that work to reduce *Salmonella* in poultry live-production operations.

The secret to effective *Salmonella* reduction at the farm level is focusing interventions at key control points, especially at the breeder flock level, he said.

Hofacre explained why it is ineffective to attempt to control *Salmonella* only at the poultry processing level.

Why Salmonella prevalence on the farm matters
Salmonella prevalence in 55 broiler flocks

Location	Percentage positive
Outside the plant	46
Rehang	[illegible]
Pre-chill	18
Post-chill	[illegible]

Source: Applied Environmental Microbiology, Vol. 79, No. 13, pp. 4106-13. 2013; Hofacre presentation IPPE 2014

Food safety programs are most effective when the overall pathogen load reaching the plant is not too high.

and he discussed the following interventions for lowering *Salmonella* in live-production operations:

- *Salmonella*-free breeders
- *Salmonella*-free feed
- Competitive exclusion
- Breeder vaccination
- Organic acids in feed or water

Why reduce Salmonella on the poultry farm?

"By reducing the level of *Salmonella* coming into the poultry slaughter plant, it is quite a bit more effective to reduce *Salmonella* there and in the final product," Hofacre said.

He presented data showing that in-plant interventions work to reduce *Salmonella* levels (see chart, "Why *Salmonella* prevalence on the farm matters"), but food safety programs are most effective when the overall pathogen load reaching the plant is not too high.

"Poultry processors do quite a good job of reducing the *Salmonella* levels in their plants," he said, "but there is a wide distribution of *Salmonella* loads coming into the plants."

In a study that collected 20 samples from 55 broiler flocks arriving at the processing plant, there were six flocks in which no *Salmonella* was detected but four flocks with *Salmonella* detected in all 20 birds sampled. There was a wide distribution of *Salmonella* prevalence in the samples from the remaining 45 flocks.

"Those flocks with the highest *Salmonella* levels — the high outliers — are of the greatest concern for food safety," he said.

Salmonella control: Start at the breeder level!

What works to reduce *Salmonella* levels in poultry live-production operations? The answer varies by company and complex, Hofacre said, and every aspect of a poultry operation needs to be evaluated for its contribution to the level of *Salmonella*. Achieving meaningful overall reductions in the levels of *Salmonella* reaching the processing plant will require interventions at multiple steps of the live-production operation.

The phase of live-production that should receive primary focus in *Salmonella* control, however, is the breeder operation, according to Hofacre.

"If I owned this broiler company, called the U.S. broiler industry, which has 70 million breeders, and which produces 8.5 billion broilers annually, I would first put my money on reducing *Salmonella* levels in the 70 million breeders, rather than in the 8.5 billion broilers," he said.

Evidence of Salmonella's vertical transmission

There's evidence to show that vertical transmission is a significant factor in *Salmonella*'s prevalence. Hofacre and other researchers conducted a study in which 7,408 samples were collected from 49 breeder and broiler farms. About 22 percent of the samples (1,642 isolates) were positive for *Salmonella*. The most prevalent strain among the isolations was *Salmonella Kentucky*. DNA testing of the isolates showed the identical fingerprint of *Salmonella Kentucky* at all levels of the broiler integration — from primary breeder to parent pullets to hens to broiler houses to ceca in the slaughter plant.

"I believe 80 percent of the *Salmonella* on broiler farms is from vertical transmission, or from the hens to the chicks," he continued. "Now, I don't mean that the *Salmonella* load on the broiler farms all came from the breeders. What I am saying is that if there's *Salmonella Montevideo* on a broiler farm it probably originated from

Salmonella prevalence in ceca at 42 days of age (percentage) *Bacillus licheniformis probiotic in feed*

Treatment	Percentage positive
Control	59a
Bacillus	[illegible]
Bacillus/Sacox/BMD	25b

Notes: 10 ceca/pen x 8 replicates. Prevalence with same superscript do not differ with a level of significance of 5 percent over all comparisons.

Source: Hofacre presentation IPPE 2014

Bacillus licheniformis significantly reduced the presence of Salmonella in broilers when they were challenged with Salmonella Heidelberg.

Organic acid in drinking water reduced Salmonella incidence and shedding Salmonella, percent positive

Treatment	Days of age	Days of age
None	40	67
Organic acid 0.04%	[illegible]	17
Organic acid 0.08%	25	33

Source: Hofacre presentation IPPE 2014

Organic acid in drinking water reduced Salmonella incidence and shedding when administered at days 1-14 and 42-49.

the breeders. If a breeder flock is shedding a high level of *Salmonella* then that high level ends up on the broiler farm.

"My 30 years of experience tells me that about 80 percent of *Salmonella* at the broiler farms comes from upstream in the production chain. You can think of it like a faucet dripping into a bucket. The bucket ends up being full after a period of time. The *Salmonella* being transmitted from the breeder flocks to the broiler farms is like that. Our job is to try to turn that *Salmonella* off at the tap."

Feed management: Breeder feeds need special consideration

Feed is a potential *Salmonella* vector that gets a lot of blame, and must be considered in control programs, but Hofacre is not convinced it is a major source of *Salmonella* in poultry. Nonetheless, ingredient purchasing, especially for breeders, can be a factor in

FOOD SAFETY OF POULTRY

Among the broilers that were the progeny of the vaccinated pullets, there was significantly less Salmonella when they arrived at the processing plant.

Correlation between vaccination of pullet flocks and Salmonella prevalence in broiler chicken meat birds

Bird type	Sample	No vaccination	Vaccination	P value
Pullets	Hatchery tray liners	0	0.8	0.033
	[redacted]	40.7	40.6	0.987
	Feed	2.6	8	0.006
	[redacted]	17.2	16.5	0.617
Breeders	Environment	34	35.4	0.741
	[redacted]	64.2	38.3	<0.001
	Ovaries	51.7	14.2	<0.001
Broilers	[redacted]	33.8	18.5	<0.001
	Environment	30.5	15.1	<0.001
	[redacted]	5.6	0	0.246
	Ceca	29.1	17	<0.001

Source: F.C. Dorea, et al. AEM, Vol. 76, No. 23. 2010; Holocre presentation IPPE 2014

controlling *Salmonella*. Strategies to consider include feed decontamination through heat treatment.

"I am not convinced that feed is a major source of *Salmonella* in broilers. Also, I am not convinced that feed is a major source of *Salmonella* in breeders. However, the use of feed ingredients with a high level of *Salmonella* — for example, poultry byproducts and meat and bone meal — can lead to the presence of *Salmonella* in the finished feed. Since breeder feed is not pelleted, and as such is not heat condi-

Intestinal disease effect on gut flora and Salmonella				
Treatment	Cecal cocci score	N.E. mortality percentage	D.S. percent positive, 42 days	Ceca percent positive, 42 days
Negative control	0.2	0	67	67
N.E. positive control	[redacted]	38	33	7
Roxarsone	0	21	0	0
BMD	[redacted]	16	33	13
Roxarsone + BMD	0.1	12	0	0

Source: Hofacre, 2007, Journal of Applied Poultry Research

While controlling coccidio resulted in less Salmonella in flocks, controlling necrotic enteritis did not reduce Salmonella.

tioned, *Salmonella* can be an issue in breeder flocks."

Hofacre said the use of organic acid/formaldehyde can be an effective *Salmonella* control, especially in breeder feeds. He cited a study by Maltho in which the use of propionic acid (0.2 percent) along with heat treatment (71.1 C for 80 seconds) resulted in 2 log10 lower *Salmonella* than heat treatment alone.

Cleaning and disinfection: Raising the bar?

Hofacre said the proper cleaning of growing houses between flocks can play an important role in reducing *Salmonella* in live poultry. He also said U.S. poultry producers should evaluate the possible benefits of disinfecting growing facilities.

"No, we don't disinfect broiler houses in the United States," he said. "though outside the U.S. it done. But we may need to begin considering the possibility of doing so, especially in breeder pullets."

His recommendations for cleaning and disinfection included the following:

» Bait for rodents, first
» Blow down dust
» Remove all litter/manure and properly dispose of away from the farms
» Use hot water to wash facilities/equipment
» Use detergents to wash facilities/equipment
» Use disinfectants
» Apply insecticides, last

Drinking water: It's a numbers game

While drinking water may not be a source of *Salmonella* in poultry flocks, it can be a means of the spread of the organism from bird to bird.

Why pay attention to this seemingly less important factor?

"*Salmonella* control is a numbers game, he explained. "It is not a matter of suddenly eliminating *Salmonella* in poultry flocks. There will be a bird or two or even a hundred in a flock that are *Salmonella* positive. And we want to keep it at a bird or two or a hundred that are *Salmonella* positive. We don't want the numbers of positive birds to grow to a thousand or 10,000 in a 30,000-bird flock. And drinking water is one way that *Salmonella* can easily spread from bird to bird."

Hofacre cited a study by Jones in which flocks given chlorinated water at least one per week had significantly less *Salmonella*.

Contaminated litter: Managing with the right tools

Managing the moisture and pH levels in poultry litter is essential to reducing and controlling *Salmonella* in live-production operations.

Hofacre cited another study by Jones which showed water activity affects survival of *Salmonella* in poultry litter, with 20 percent to 25 percent less *Salmonella* when it is managed correctly. Treatment with propionic acid (50 percent), aluminum sulfate and sodium bisulfate was effective. All of these agents work by lowering litter pH (from 8.0 to 9.0 down to 4.0).

FOOD SAFETY OF POULTRY

Managing gut flora to prevent Salmonella colonization

Managing gut flora can be an effective means of preventing *Salmonella* colonization in broilers. The establishment of normal avian gut flora (NAGF), for example, in day-old chicks has been shown to prevent birds from being colonized with *Salmonella*.

"Production managers have to find those interventions that work well in their company's live-production system," Hofacre said. "Some interventions that might work well in a neighboring complex might not work so well for your complex."

Feeding probiotics

Hofacre cited a study in which a *Bacillus licheniformis* probiotic was fed to birds. "The survey results show that the treatment with *Bacillus licheniformis* significantly reduced the presence of *Salmonella* in broilers when they were challenged with *Salmonella Heidelberg*."

He prefers to use *Bacillus* products in the feed over those used in the water. "A grower may fail to place the treatment in the water. However, addition of the treatment in the feed is a sure way to get it administered."

Other ways in which the normal intestinal flora can be altered include the use of botanicals and natural oil products. "Some of those work very well to help develop the normal flora within the intestine," he said.

Organic acids in drinking water

Administration of organic acids in drinking water has been shown to significantly reduced the amount of *Salmonella* in broilers. In a study, organic acid in the drinking water reduced *Salmonella* incidence and shedding. Treatment included two inclusion rates. At the higher inclusion rate, the birds reduced their water consumption.

Vaccination is a key Salmonella control strategy

Following are Dr. Hofacre's opinions about the use of live vaccines to control *Salmonella*:

» The use of live vaccines will not make *Salmonella*-positive chicks negative

» *Salmonella typhimurium* vaccines do not give protection for *Salmonella enteritidis*.

» Live vaccines do not provide immunity to all *Salmonella* serotypes

» Live vaccines will reduce fecal shed

» Live vaccines provide early protection almost like competitive exclusion

» Live vaccines don't prime the bird's immune system for the killed vaccines

Prevalence of Salmonella-positive ceca at 42 days *(percentage)*

Control	[illegible]
Control vaccine	51
Salinomycin	[illegible]
10 ceca/pen x 8 replicates	[illegible]
Not significantly different	[illegible]

Source: Hofacre presentation IPPE 2014

The method of controlling coccidiosis can impact the level of Salmonella in a poultry flock.

Killed vaccines

Dr. Hofacre shared the following points about the use of killed vaccines to protect against *Salmonella*:

» Birds respond poorly to bacterial vaccines

» Two injections are needed before the start of lay

» They provide protection only to serotypes in the vaccine

» Killed *Salmonella enteritidis* vaccine won't protect against *Salmonella Heidelberg*

How pullet vaccination changes Salmonella prevalence in broilers

What is the correlation between vaccination of pullet flocks and *Salmonella* prevalence in broiler chicken meat birds? Hofacre cited a 2010 study involving two poultry integrators. One integrator was vaccinating for *Salmonella* — giving two live vaccines and two killed vaccines — and the other was not vaccinating. Results of the study are presented in the Table, "Correlation between pullet vaccination and *Salmonella* prevalence in broilers."

Among the broiler progeny of the vaccinated pullets, there was significantly less *Salmonella* when they arrived at the processing plant.

While the *Salmonella* levels in the environments of the vaccinated hens did not change materially, the hens became antibody positive and maternal antibody positive.

What's more, the chick papers in the bottoms of the hatcher trays for day-old chicks had half as much *Salmonella*. Also, the environments in those broiler houses had half as much *Salmonella*.

In a similar vaccination study of 58 broiler flocks ceca were collected at rehang. *Salmonella* levels in broilers from vaccinated breeders were half that of broilers from unvaccinated breeders. It was also found that the 14 percent that were positive were about 50 percent lower in *Salmonella* level in the vaccinated flocks.

Intestinal health impact on Salmonella levels

In a study to determine how intestinal disease effects gut flora and *Salmonella* levels, it was found that controlling coccidia resulted in less *Salmonella*. Controlling necrotic enteritis, on the other hand, had no effect on *Salmonella* levels. See Table, "Intestinal disease effect on gut flora and *Salmonella*."

"The WATT webinar in December 2013 presented data from a study where we looked at vaccinating broilers with Cocci-Vac compared to broilers that received Salinomycin for control of coccidiosis on built-up litter.

"In the study, with the administration of a coccidial vaccine there was less *Salmonella* colonization. Controlling coccidiosis can significantly impact *Salmonella* levels."

Limitations of on-farm interventions for Salmonella

Hofacre stated the following limitations:

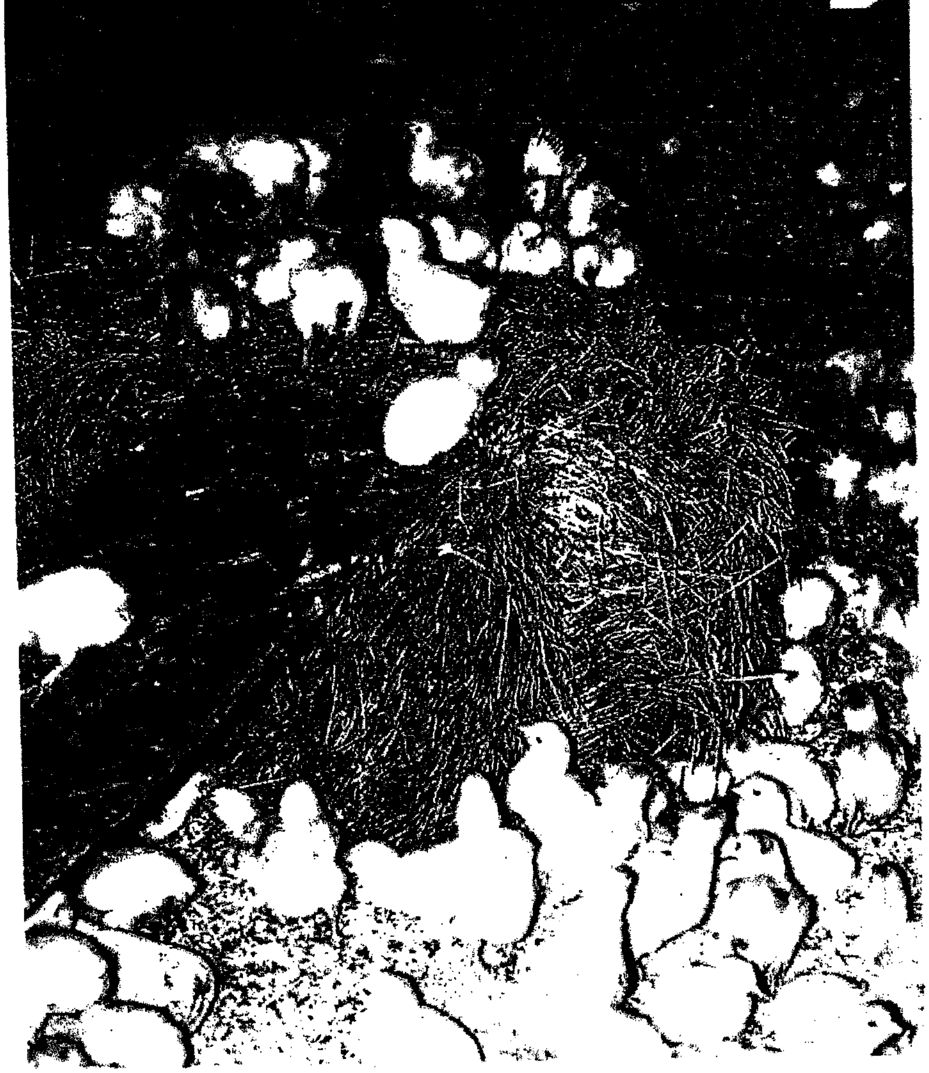
- "When it comes to on-farm interventions for *Salmonella*, in my experience nothing works all the time."
- "Nothing works if the *Salmonella* level is too high."
- "Nothing works as well once the flock is colonized."
- "Interventions may work at one point in time but not another and in one complex but not another."

Reducing Salmonella in live production is not a simple task. A focused program of interventions is required. ■

Coccidiosis Vaccination: A New Approach to Salmonella Control
Watch the webinar Charles Hofacre references on-demand:

NEW POULTRY VENTURE

Virginia poultry growers seize the organic opportunity



» Corwin Heatwole's broiler flocks are provided with house enrichments such as hay bales, ramps and cardboard boxes to peck at and climb on.

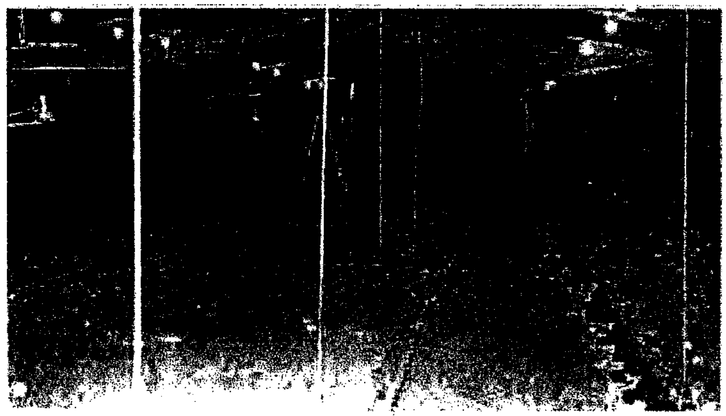
Two young entrepreneurs are convinced that demand for organic chicken will continue to grow and make the decision to open their own processing plant pay off.

BY TERRENCE O'KEEFE

» Anyone who has ever worked for or contracted with an integrated poultry company has heard some of the stories of how the modern industry got started. For most companies, an entrepreneur or group of entrepreneurs contracted with growers to raise birds and these industry pioneers gradually assembled the assets of a modern poultry complex: feed mill, hatchery and processing plant. This model was repeated numerous times across the country from the 1930s on.

As the U.S. broiler industry has matured, economies of scale have made it quite a bit harder for new start-up companies to compete in a marketplace where most chicken is sold as a commodity. Two longtime friends and business partners, Corwin Heatwole and Wayne Billhimer, are betting that demand for organic chicken will give their fledgling grow-out and processing operations — Shenandoah Processing LLC — in the Shenandoah Valley of Virginia a chance to grow and succeed.

■ NEW POULTRY VENTURE



» The maximum housing density allowed under the Humane Farm Animal Care Certified Humane Raised and Handled standards is 6.0 pounds per square foot.

Longtime partnership

Heatwole and Billhimer are both in their early 30s and have been around farming and livestock all of their lives. The duo had partnered in a number of business ventures, when Heatwole, who owns seven poultry houses, decided he wanted to own the birds and not contract with an integrator. He thought that raising organic broilers might provide the opportunity he was looking for, so he and Billhimer, who is a K-9 officer for the Virginia Department of Game and Inland Fisheries in his day job, partnered on raising organic birds in one of Heatwole's houses.

» Two Virginia entrepreneurs, Corwin Heatwole, left, and Wayne Billhimer, are getting into the organic broiler processing business in Harrisonburg, Va.

They found organic chicks and feed in Pennsylvania and a small plant in Northern Virginia to process the broilers, and the pair was in the organic chicken business. With each successive 2,000-bird organic flock produced, the partners became more convinced that serving the organic market could provide a unique opportunity for them to operate their own poultry plant.

Finding growers

Heatwole has contracted to raise both turkeys and broilers for several integrators over the years and has seen the pros and cons of the contract growing system. The Harrisonburg, Va., area has had significant contract poultry production since the 1940s, and there were a number of older, smaller poultry houses that were no longer under contract with integrators. Heatwole saw the owners of these out-of-service houses as potential suppliers of live birds for a local plant specializing in processing organic birds.

"The growers said that they would like to own their own birds and be their own boss," Heatwole explained. "They are taking on more risk, so they will expect a little more return." He said the growers will own the chickens and will pay for the feed. Certified organic feed and chicks will be trucked in from Pennsylvania suppliers. The growers' contract with Shenandoah Processing LLC is a cost-plus contract. The cost used in calculating the grower's payment will be an average cost based on performance of all the growers. Individual growers are paid plus or minus how their flocks perform versus the average cost.

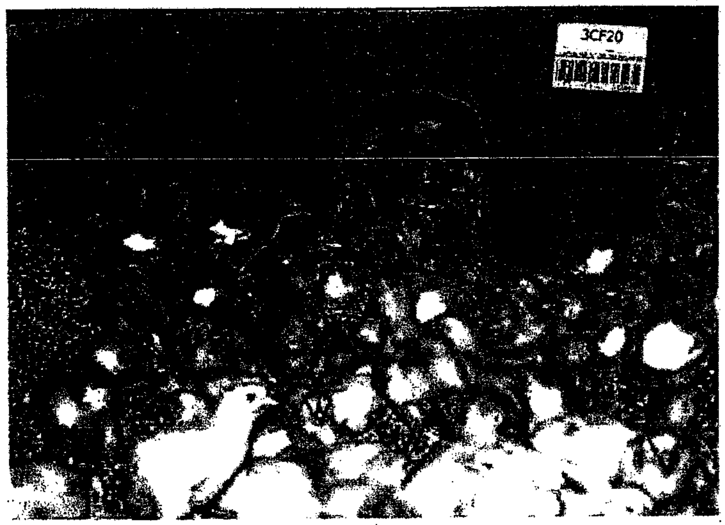
Heatwole said that there are enough out-of-service houses in the Harrisonburg area to meet the goal

BROILERS ARE RAISED TO THE STANDARDS OF THE HUMANE FARM ANIMAL CARE CERTIFIED HUMANE RAISED AND HANDLED PROGRAM AND USDA'S ORGANIC PROGRAM.

NEW POULTRY VENTURE

of producing 50,000 organic broilers per week by the end of 2014. He said no houses have been signed that previously had an active contract.

"Some of the houses are a little older and need a little TLC," he said, and some "had been purchased out of bankruptcy by other farmers who were looking for a contract." Heatwole said the plan for the company is to process more than 50,000 organic birds per week in subsequent years of operation. This would likely require new housing to be built.



» Cardboard boxes with cutouts provide sheltering for chicks.

An old plant gets new life

The poultry plant on North Liberty Street in Harrisonburg has been out of operation for over 15 years. Before that, it served as turkey slaughter and whole bird packing plant for Wampler Foods and as a tom slaughter and deboning plant for Golden Acre Foods before that. The plant was acquired by Pilgrim's when the company purchased Wampler Foods and was later sold to private investors who gutted the plant and rented it out as warehouse space.

Heatwole and Billhimer signed a lease-to-own agreement for the plant and purchased 20 trailer loads of used broiler processing equipment at a bankruptcy sale in Mississippi. Shenandoah Processing was slated to open in March of 2014 with one, 70 bird-per-minute evisceration line. The birds will be manually opened and drawn, much like at a turkey plant. The live hang area is setup to allow for birds to be hung from cages that are dumped, as is common in the broiler industry, or from cages attached to the trailer, as is common in the turkey industry. Manual evisceration and the flexibility in live hang will allow the plant to process spent fowl in addition to organic broilers.

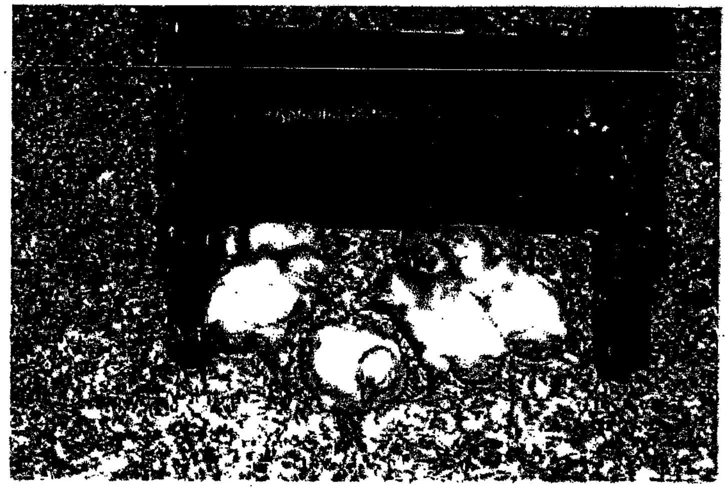
Heatwole said that processing spent fowl will provide volume for the plant while the organic business is given time to grow. Ultimately, the plant has room for a second evisceration line and could run a total of 140 birds per minute.

Heatwole was pleased with the number of job applications received, without advertising. Employees for the plant and live-haul crew will total around 70 at start-up.

Shenandoah Processing received two $50,000 grants, one from the state and one from the city, to help offset some of the estimated $2.2 million investment. Heatwole said that the acquisition of the idle plant and the equipment from a bankruptcy sale has allowed the company to pay "pennies on the dollar for our assets."

Points of differentiation

Broilers raised for Shenandoah Processing will be raised according to standards established by



» Enrichments include objects such as empty wire spools.

the Humane Farm Animal Care Certified Humane Raised and Handled Program as well by the standards of the USDA's organic program. Each farm selling birds to the company will be audited to ensure compliance.

The organic standards require that broilers have access to outdoors and that they be housed at no more than 6.0 pounds per square foot. The company is targeting a live weight of 5.75 pounds per bird, but birds will be placed assuming 5.5 pounds per square foot to give wiggle room if the birds are bigger than expected. Heatwole is recommending that growers clean out the litter from their houses before each flock since litter treatments are not allowed under organic standards. If complete cleanout is not performed by growers, he recommends that they top dress the litter after caking out.

The Certified Humane Raised and Handled program requires that chickens kept indoors be kept active by providing an "enriching environment." Suggested enrichments include "straw or hay bales and/or perches and the scattering of whole grain, or cabbages throughout the house."

Servicing further processors

Heatwole and Billhimer plan to sell output from the plant through their company, Shenandoah Valley Organics. Billhimer will serve as sales manager and Heatwole is the general manager. Upon start up, Heatwole said that the company plans on selling ice-pack carcasses to distributors who will either further process or repackage for retail sale. The company has a cone line and cut-up equipment and plans to offer these services sometime after start-up.

Heatwole said that there is strong demand for organic chicken meat and that word of mouth has already brought contacts from several companies asking about meat availability. ■

DATA FROM UGA Follows:

JHL-02-01 PROTOCOL FOR EVALUATION OF NITROGEN RETENTION IN PLT® AND AL⁺CLEAR TREATED BROILER LITTER

PURPOSE: To quantify the amount of nitrogen retained in broiler litter treated with either PLT litter acidifier (PLT) or Al+Clear litter amendment (AC).

PRINICIPALS: Trisha Marsh Johnson
Carl Kneuven
Blake Gibson (or other salesman)

LOCATION: Jones-Hamilton Co., Athens, GA and Walbridge, OH

MATERIALS & METHODS:

1. Identify a broiler house with litter older than one. Record the number of flocks raised on the litter.
2. Use a 1/2 square foot template to mark the area of litter to be collected. Remove the litter from each sample area to the level of the dirt pad.
3. Collect 15 samples according to the attached diagram (fig 1).
4. Place all 15 samples into a large container and mix thoroughly.
5. Evenly divide the resulting composite by weight into 15 separate Rubbermaid containers and cover tightly.
6. Label 5 containers PLT, 5 containers AC, and 5 containers Control.
7. Add PLT to each container in the PLT-treated group as follows: 0.025 lbs. for each of the first 5 flocks and 0.0375 lbs. for each flock thereafter [i.e. if the litter is 10 flocks old, add 0.3125 lbs PLT- (.025 x 5) + (.0375 x 5) = 0.3125]. Mix together thoroughly and leave uncovered.
8. Add Al+Clear to each container in the AC treated group as follows: 0.025 lbs. for each of the first 5 flocks and 0.0375 lbs. for each flock thereafter [i.e. if the litter is 10 flocks old, add 0.3125 lbs AC- (.05 x 5) + (.075 x 5) = 0.3125]. Mix together thoroughly and leave uncovered.
9. Leave containers undisturbed at room temperature for 48 hours.
10. Thoroughly mix the contents of each container.

* Litter Used was 10 Flocks old (2yrs old)
Amendments applied equivolen to:
50lb/1000 sqFt 1st Five Flocks
then 75lbs/1000 sqFt next Five Flocks

11. Measure pH of treated litter to make sure it has returned to above a 7.0.

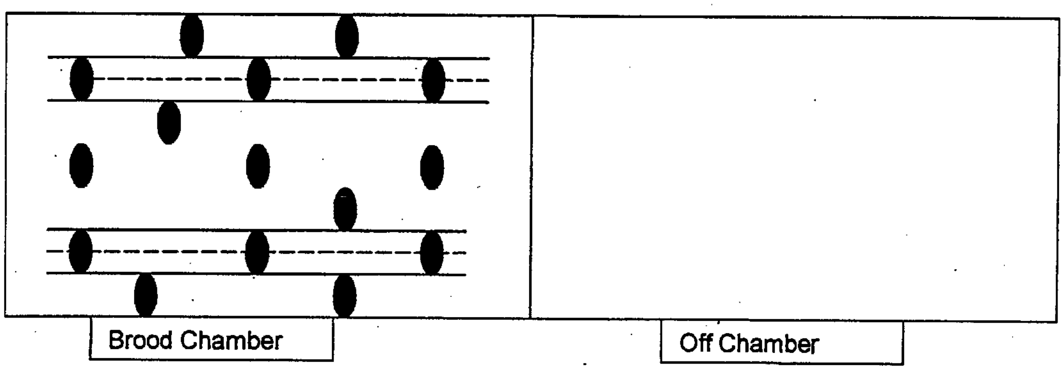
12. Fill a 500-ml Nalgene bottle with litter from each container (no dead space) and label accordingly. Make sure the lids are on tightly and secure with tape.

13. Heat each sample, uncovered, to 110F for 48-72 hours to purge the ammonia.

14. Repackage each sample into an airtight container and label accordingly.

15. Pack samples and send overnight to Trisha and she will take them to the UGA soil test lab

Figure 1. Distribution of litter samples.



Sample Key

1. PLT
2. Al+Clear (alum)
3. Al+Clear
4. Control
5. Al+Clear
6. Al+Clear
7. Control
8. PLT
9. Control
10. Al+Clear
11. PLT
12. Control
13. PLT
14. Control
15. PLT

UGA Animal Waste Analysis Report

Soil, Plant and Water Laboratory

Grower Information	Lab Information	County Information
Client: **Trisha Marsh Johnson** P O Box 7997 Athens, GA 30604 Type: Litter-Broiler	Completed: 03/14/2003 Printed: 03/19/2003	**Clarke County** 2152 W. Broad Street Athens, GA 30606 706-613-3640

Results

		PLT	Alum	Alum	Control	Alum	Alum	Control
Lab		990	991	992	993	994	995	996
Sample		1	2	3	4	5	6	7
N	(%)	3.660	3.650	3.750	3.660	3.620	3.550	3.370
Al	(ppm)	6060	11832	11208	5444	8540	13368	4048
B	(ppm)	45.24	43.12	37.24	43.28	39.36	41.32	48.08
Ca	(ppm)	15004	19268	13376	19272	15220	15004	20764
Cd	(ppm)	<2.0000	<2.0000	<2.0000	<2.0000	<2.0000	<2.0000	<2.0000
Cr	(ppm)	6.600	12.08	13.92	5.840	9.520	13.16	5.840
Cu	(ppm)	290.4	307.7	250.4	314.5	255.7	299.7	316.4
Fe	(ppm)	3506	3886	3182	3371	3245	4692	2710
K	(ppm)	22244	24152	20376	26336	23596	24152	27528
Mg	(ppm)	4156	4452	3697	4732	4240	4492	4752
Mn	(ppm)	404.0	446.4	363.0	453.6	396.3	440.4	458.4
Mo	(ppm)	5.480	4.680	4.680	4.680	4.680	5.480	6.280
Na	(ppm)	13944	6292	5388	6552	5972	6140	6984
NH4-N	(ppm)	5992	7350	7301	2916	6381	7473	2366
Ni	(ppm)	8.600	10.04	10.32	8.040	8.600	9.200	9.200
P	(ppm)	10620	11600	9412	11980	10992	11224	11864
Pb	(ppm)	<10.0000	<10.0000	<10.0000	<10.0000	<10.0000	<10.0000	<10.0000
S	(ppm)	13860	13492	14732	5024	10480	12416	5004
Zn	(ppm)	334.5	345.5	296.2	384.9	327.5	[illegible]	[illegible]

UGA Animal Waste Analysis Report

Soil, Plant and Water Laboratory

Grower Information	Lab Information	County Information
Client: Trisha Marsh Johnson P O Box 7997 Athens, GA 30604 Type: Litter-Broiler	Completed: 03/14/2003 Printed: 03/19/2003	Clarke County 2152 W. Broad Street Athens, GA 30606 706-613-3640

Results

		PLT	Control	Alum	PLT	Control	PLT	Control
Lab		997	998	999	1000	1001	1002	1003
Sample		8	9	10	11	12	13	14
N	(%)	3.740	3.350	3.830	3.900	3.550	3.740	3.600
Al	(ppm)	4228	6668	8248	6468	6036	6216	9716
B	(ppm)	31.36	42.68	44.48	41.00	43.28	32.40	42.08
Ca	(ppm)	11100	19264	19052	19848	18920	13728	20044
Cd	(ppm)	<2.0000	<2.0000	<2.0000	<2.0000	<2.0000	<2.0000	2.120
Cr	(ppm)	4.760	6.600	9.880	6.960	6.960	5.120	10.24
Cu	(ppm)	221.4	321.5	313.0	313.4	287.8	239.8	319.5
Fe	(ppm)	2811	4052	3521	3908	3546	3724	5284
K	(ppm)	18112	24788	25104	25740	26772	19780	24788
Mg	(ppm)	3334	4676	4772	4676	4668	3687	4896
Mn	(ppm)	327.1	449.6	448.0	456.0	442.8	378.9	478.8
Mo	(ppm)	3.920	6.280	5.480	11.76	5.480	3.920	5.480
Na	(ppm)	17852	6420	6592	23548	7012	17320	6300
NH4-N	(ppm)	7434	3483	5681	7217	3679	7049	2405
Ni	(ppm)	6.600	9.200	9.200	8.600	10.04	5.720	9.200
P	(ppm)	8416	11936	11960	12052	11404	9592	12264
Pb	(ppm)	<10.0000	<10.0000	<10.0000	<10.0000	<10.0000	<10.0000	<10.0000
S	(ppm)	20520	5120	10244	28396	4992	21224	5084
Zn	(ppm)	264.8	372.4	405.2	374.6	362.1	290.7	375.6

UGA Animal Waste Analysis Report

Soil, Plant and Water Laboratory

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Results

PKT

Lab		1004
Sample		15
N	(%)	3.610
Al	(ppm)	5916
B	(ppm)	41.32
Ca	(ppm)	15592
Cd	(ppm)	<2.0000
Cr	(ppm)	6.960
Cu	(ppm)	298.3
Fe	(ppm)	3525
K	(ppm)	24548
Mg	(ppm)	4488
Mn	(ppm)	435.6
Mo	(ppm)	5.480
Na	(ppm)	18940
NH4-N	(ppm)	6353
Ni	(ppm)	10.32
P	(ppm)	11484
Pb	(ppm)	<10.0000
S	(ppm)	19748
Zn	(ppm)	354.2

Ammonium-Nitrogen

PLT	Al-Clear	Control
5992	7350	2916
7434	7301	2366
7217	6381	3483
7049	7473	3679
6353	5681	2405

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Al-Clear*
Mean	6809	6837.2
Variance	372528.5	606808.2
Observations	5	5
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.063718874	
P(T<=t) one-tail	0.475378716 NS	
t Critical one-tail	2.896467777	
P(T<=t) two-tail	0.950757431 NS	
t Critical two-tail	3.355380613	

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Control*
Mean	6809	2969.8
Variance	372528.5	363201.7
Observations	5	5
Hypothesized Mean Difference	0	
df	8	
t Stat	10.00844133	
P(T<=t) one-tail	4.21744E-06 ***	
t Critical one-tail	2.896467777	
P(T<=t) two-tail	8.43487E-06 ***	
t Critical two-tail	3.355380613	

UGA Soils lab analysis of data

Sodium

PLT	Al-Clear	Control
13944	6292	6552
17852	5388	6984
23548	5972	6420
17320	6140	7012
18940	6592	6300

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Al-Clear*
Mean	18320.8	6076.8
Variance	12021195	200291.2
Observations	5	5
Hypothesized Mean Difference	0	
df	4	
t Stat	7.831524	
P(T<=t) one-tail	0.000718 **	
t Critical one-tail	3.746936	
P(T<=t) two-tail	0.001435 **	
t Critical two-tail	4.60408	

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Control*
Mean	18320.8	6653.6
Variance	12021195	106884.8
Observations	5	5
Hypothesized Mean Difference	0	
df	4	
t Stat	7.491273	
P(T<=t) one-tail	0.000849 **	
t Critical one-tail	3.746936	
P(T<=t) two-tail	0.001698 **	
t Critical two-tail	4.60408	

Aluminum

PLT	Al-Clear	Control
6060	11832	5444
4228	11208	4048
6468	8540	6668
6216	13368	6036
5916	8248	9716

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Al-Clear*
Mean	5777.6	10639.2
Variance	792252.8	4829283
Observations	5	5
Hypothesized Mean Difference	0	
df	5	
t Stat	-4.58497	
P(T<=t) one-tail	0.00296 ***	
t Critical one-tail	3.36493	
P(T<=t) two-tail	0.005921 ***	
t Critical two-tail	4.032117	

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Control*
Mean	5777.6	6382.4
Variance	792252.8	4411117
Observations	5	5
Hypothesized Mean Difference	0	
df	5	
t Stat	-0.59286	
P(T<=t) one-tail	0.289535 NS	
t Critical one-tail	3.36493	
P(T<=t) two-tail	0.579069 NS	
t Critical two-tail	4.032117	

Sulfur

PLT	AL Clear	Control
13860	13492	5024
20520	14732	5004
28396	10480	5120
21224	12416	4992
19748	10244	5084

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*AL Clear*
Mean	20749.6	12272.8
Variance	26803749	3721195
Observations	5	5
Hypothesized Mean Difference	0	
df	5	
t Stat	3.430753	
P(T<=t) one-tail	0.00931	
t Critical one-tail	3.36493	
P(T<=t) two-tail	0.01862	
t Critical two-tail	4.032117	

t-Test: Two-Sample Assuming Unequal Variances

	PLT	*Control*
Mean	20749.6	5044.8
Variance	26803749	3019.2
Observations	5	5
Hypothesized Mean Difference	0	
df	4	
t Stat	6.782584	
P(T<=t) one-tail	0.001233	
t Critical one-tail	3.746936	
P(T<=t) two-tail	0.002467	
t Critical two-tail	4.60408	

t-Test: Two-Sample Assuming Unequal Variances

	AL Clear	*Control*
Mean	12272.8	5044.8
Variance	3721195	3019.2
Observations	5	5
Hypothesized Mean Difference	0	
df	4	
t Stat	8.375019	
P(T<=t) one-tail	0.000556	
t Critical one-tail	3.746936	
P(T<=t) two-tail	0.001112	
t Critical two-tail	4.60408	

all signif
different

The Use of Sodium Bisulfate as a Best Management Practice for Reducing Ammonia and VOC Emissions from Poultry and Dairy Manures

Trisha Marsh Johnson[1], Bernie Murphy[2], Randy Chick[3], Brian Fairchild[4], and Casey W. Ritz[4]
[1]Veterinary and Environmental Technical Solutions, Athens, GA 30606, USA;
[2]Jones-Hamilton Co., Walbridge, OH 43465, USA;
[3]Jones-Hamilton Co., Fayetteville, AR 72704, USA;
[4]Department of Poultry Science, University of Georgia, Athens, GA 30602, USA.

Abstract

Sodium bisulfate is used extensively by commercial broiler integrators and growers in the United States, Canada, and Latin America to reduce ammonia and pathogen levels in the presence of birds as a Best Management Practice for animal welfare and bird health. This paper will discuss the usage of sodium bisulfate as a Best Management Practice for reducing ammonia emissions from both commercial broiler and commercial layer facilities and the economic benefits in bird production associated with its use. Data from an ongoing 2-yr ammonia emissions study in a broiler facility in Georgia will be presented along with data on ammonia emissions and fly control from a commercial egg facility in Pennsylvania. The use of sodium bisulfate for reducing ammonia and VOC emissions from dairy manure will also be discussed.

Introduction

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

This has left livestock and poultry producers with the need to implement effective best management practices to control both ammonia and VOCs emissions from animal housing and manure storage facilities (Dragosits, et al. 2002). This is also critical to European livestock & poultry producers as the BMPs implemented there were not enough to reach the emissions targets set in the Netherlands for the year 2000. It has been suggested that the only way to reach the target goals for NH_3 emissions (30GgNH_3/yr) set for 2030 in the Netherlands would be to completely eliminate all poultry & swine production and house all cattle in low-emission stables year-round (de Vries, et al. 2001). In addition, tremendous consumer focus on animal welfare has instituted strict limits on ammonia levels inside confinement animal facilities, mostly poultry & swine. Since the current management strategies often rely on being able to exhaust as much ammonia from the house as possible, alternatives are clearly needed (Ritz, et al. 2004).

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

Sodium Bisulfate Characteristics

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

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

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

Ammonia emission from animal housing is calculated by multiplying ammonia concentration by airflow. The use of sodium bisulfate reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. Sodium bisulfate is hygroscopic. As water is adsorbed into the SBS bead from the humidity in the air, the SBS is dissolved into its Na^+, H^+ and $SO_4^=$ constituents. The hydrogen ion reduces the pH of the litter and protonates the ammonia molecule. The resulting ammonium is then bound by the sulfate component. This formation of ammonium sulfate is non reversible therefore the nitrogen in the litter is not released as the pH increases (Ullman, et al., 2004). The sodium and hydrogen ions exert negative pressure on the bacterial populations of the litter; decreasing total aerobic population counts 2-3 logs (Pope and Cherry, 2000). This may also serve to decrease urease concentration in the litter for additional ammonia reductions (Ullman, et al., 2004). Once the ammonia concentration at bird level has been reduced, the poultry houses can be minimally ventilated for relative humidity control as they were designed rather than over-ventilated for NH_3 removal (Czarick and Lacey, 1998).

SBS Use in Poultry- Literature Review

Reduction of ambient ammonia levels in broiler housing has been demonstrated in a variety of studies. Pope and Cherry (2000) applied PLT® litter treatment 12-24 hours prior to bird placement at a rate of 2.27 kg/9.29m^2 in three houses each on two 12-house farms. The average litter pH was 1.2 in the houses treated with PLT compared with 8.0 in the untreated controls. Ammonia levels were 90% lower post PLT application with an average of 6.2 PPM of NH_3 in the treated houses and 62.3 PPM in the control houses. Two weeks after application, the ammonia levels in the treated houses were still reduced by 50% compared to control houses. In the winter of 1996, 200 commercial broiler houses were studied in Delaware and Maryland by Terzich (1997) with 100 houses treated with PLT® and 100 houses serving as control. Ammonia levels averaged 127 PPM pre-treatment and were all 0 PPM post-treatment (Table 1). Consequent to the improved air quality, bird performance was significantly improved in the treated houses (1,282,256 birds) with better mortality rates, average weights, average daily gain, and percentage of respiratory lesions at processing compared to controls (1,219,918 birds). Fuel usage was also reported to be 43% less in the treated houses. At a cost of $120/house for the PLT® litter treatment, the resulting production increases and fuel savings provided the producer with a substantial return on investment that would support increased PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998; Terzich et al, Apr 1998).

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

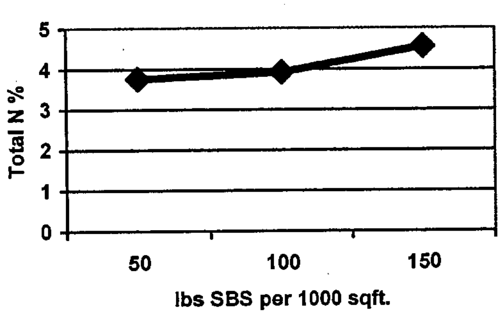
		Pre-Treatment	Post-Treatment	Time (weeks)						
				1	2	3	4	5	6	7
Ammonia (PPM)	Treated	127	0	0	5	8	15	19	20	18
	Control	119	119	125	125	138	114	128	98	97
Litter pH	Treated	8.5	1.7	2.1	3.4	4.5	5.0	5.5	5.9	6.4
	Control	8.9	8.9	8.7	9.1	8.5	9.3	8.6	8.1	8.9

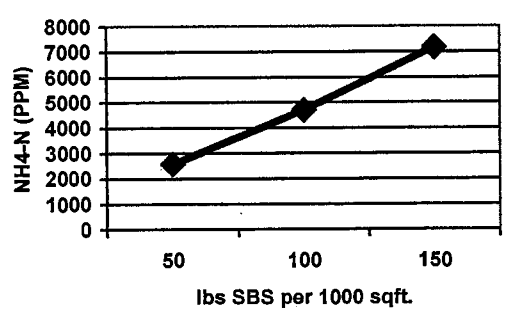
Current SBS Research in Poultry

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

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

The initial experimental design called for the use of Dosi-tubes two days a week to establish a time weighted average as well as the use of Drager-Pac III electrochemical sensors to evaluate ammonia levels. Due to the lack of reliability of these sensors in a dry-litter broiler house, the rate of ammonia leaving the house is now being evaluated using the modified nitrogen mass-balance model (Carey, et al., 2005; Keener and Michel, 2005). Given that the amount of nitrogen entering the system (birds, feed, & sawdust litter) is identical for all three houses, increases in the amount of nitrogen retained in the litter are indicative of a decrease in the amount of ammonia being exhausted from the house. After 3 flocks, a linear increase is evident in both N and NH_4-N retained in the litter as the amount of PLT applied is increased (Fig. 2 & 3). The higher amounts of retained nitrogen in the litter of the 150-lb. treatment group, indicates a reduction in ammonia emissions in this house over the lower treatment rates based on the mass-balance model. Interestingly, total phosphorus levels were 20% lower in the 100 lb. & 150 lb. houses when compared to the 50 lb. house. The mechanism for the decrease in total phosphorus is unknown.





Figures 2 & 3. Amount of retained Total Nitrogen and NH4-N in broiler litter after three flocks of SBS usage on re-used litter.

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

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

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

Economics of SBS Use in Poultry

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

A commercial broiler complex in the Southeast raising both a large (7.0 lb. or 3.2 kg) and small (4.5 lb. or 2.05 kg) bird evaluated the economic and performance benefits of using litter amendments from January – August 2000. Contract growers were given a choice of either using PLT® or an alum litter amendment (Al+Clear, General Chemical Corp., Parsippany, NJ) at the rate of 2.27 kg/9.29m^2 (50 lbs. /1000 sq ft) in the brood chamber (10,000 sq ft). Eighty-seven percent of the big bird growers and eighty-two percent of small bird growers chose PLT. The remaining thirteen percent of the big-bird and eighteen percent of the small-bird growers chose to use alum in an identical manner to the PLT. A total of 43.9 million birds were evaluated in this demonstration. There were no differences in housing or management between the treatment groups. Both the small and large bird groups raised on PLT substantially out performed the birds raised on alum (table3). In a complex of this size, the general rule of thumb used in the U.S. poultry industry is that an improvement in feed conversion of 0.01 lbs. of weight gain / lb. of feed consumption is worth $1 Million per year (Agrimetrics Associates, Inc., Midlothian, VA). The large birds raised on PLT had a feed conversion improved by 0.02 and the feed conversion of the small birds was improved by 0.04 over the birds raised on alum. This reduced performance shown by the birds raised on alum is consistent with production losses due to ammonia exposure reported in the literature (Miles, et al., 2004). This resulted in a net return of $2.7 million /yr over the cost of PLT ($305,000) on improved feed conversion alone in that complex. Additional economic benefit would have also been realized by the grower and the poultry integrator from the increases in weight and livability observed in this trial. The monetary return on investment observed would easily support an increased PLT application rate for the objective of ammonia emissions control. Similar results were achieved in another complex in the South-Central part of the U.S. where the same rate of PLT application was compared with untreated litter (table 4). The economic viability of the use of PLT for reducing ammonia emissions is the reason why so many poultry growers have voluntarily adopted this BMP.

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

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

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

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

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

SBS Dairy

After the passage of California State Bill 700 and subsequent EPA Title V permitting of dairies in California, dairy farmers, particularly those in the San Joaquin Valley, began looking for practical and economical control technologies for VOCs and ammonia. Much effort has been spent on control technologies that deal with dairy slurry during storage such as solids separation and anaerobic digesters.

Ammonia losses from freshly excreted manures occur very rapidly and NH_3 conservation interventions need to be implemented within a few hours in order to be most effective (Meisinger, et al., 2001). Acidification of barn floors and gutters has been suggested as one possible intervention strategy (Ferguson, et al., 2001) but would require care in acid selection, as few liquid acids are compatible with the presence of animals. Acidification of manure slurry has also been suggested (Meisinger, et al., 2001; Clemens, et al., 2002; Lefcourt and Meisinger, 2001). Recent work by Frank Mitloehner, PhD (2005) at the University of California-Davis indicates that the majority of VOC emission occurs within hours after manure excretion prior to liquid manure storage as well. This new information requires a shift in focus to discover control technologies that can be applied to the free stalls or dry lots in the presence of cows. Sodium bisulfate was chosen for evaluation due to its efficacy in reducing ammonia levels and bacterial populations in equine and poultry bedding and its current use for environmental mastitis control in a few large Western dairies.

An experiment was conducted at the University of California - Davis by Frank Mitloehner, PhD to evaluate the efficacy of sodium bisulfate (Parlor Pal® bedding treatment, Jones-Hamilton Co, Walbridge, OH) surface application in reducing pH and ammonia emissions from dairy slurry at three different addition rates equal to 25, 50, 75 lbs. SBS/1000 Sq Ft compared to an untreated control. The EPA TO-15 VOC Panel was also measured. A 4x4 Latin square design was used with the 4 treatment levels and 4 cows. Urine and feces from each of the cows were blended on an "as excreted" basis and 2kg of each mixture were placed in a 4-inch high by 20-inch diameter well plate. pH readings were taken from 5 sites immediately pre and post SBS treatment. The well plate was then immediately placed in the emissions Flux Chamber for ammonia and TO-15 VOC evaluation. Ammonia and VOCs were evaluated at time 0, 24, 48 hrs and pH was measured again at 72 hrs. Three replicates were completed one week apart. Control and pre-treatment sample pH throughout the study ranged from pH 7.45 – 7.79. The 25, 50, & 75 lb. post treatment groups ranged from pH 2.98-4.16, 1.47-2.13, and 1.13-1.28 respectively. The variation seen in the 25 lb. treatment group is due to the difficulty in uniform surface application at the lower rate. Visual observations after SBS application include bubbles deep in the slurry and "leavening" of the slurry, which was increased at the higher application rates. This is most likely due to the interaction of SBS with carbonates in the slurry creating carbonic acid bubbles and the subsequent rise similar in action to a leavening agent. At 72 hrs, pH ranged from 7.68 – 9-00 with no real differences between treatments (Fig. 4). Ammonia flux was dramatically reduced immediately after SBS treatment with control flux ranging from 127.73 – 263.58 mg/hr/m^2 and all treated samples at 0 Flux (mg/hr/m^2).

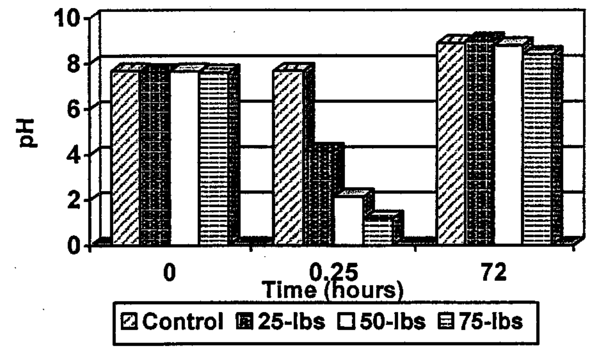


Figure 4. pH readings of dairy slurry treated with SBS (lbs/1000 sqft) over time.

Ammonia flux increased as time increased but there was always a linear decrease in NH_3 flux as treatment rate increased (Fig. 5-7). Most interestingly, NH_3 flux at 72 hrs was still substantively decreased over control even though pH levels between treatment groups were not significantly different and most were above a pH of 8.0. This indicates that the ammonia being produced by the slurry is being converted to and retained as ammonium sulfate and is not released as pH rises.

No changes in VOCs in the EPA TO-15 panel were noted. Even though this was the standard methodology at the time, the VOCs in the panel are unlikely to be produced by the bacterial degradation of animal manures. Subsequent work by Mitloehner (2006) has highlighted 5 oxygenated VOCs among others as the predominant VOCs produced by freshly excreted dairy manure. A similar study to the one outlined above is being repeated but with the dairy specific VOCs replacing the EPA TO-15 panel.

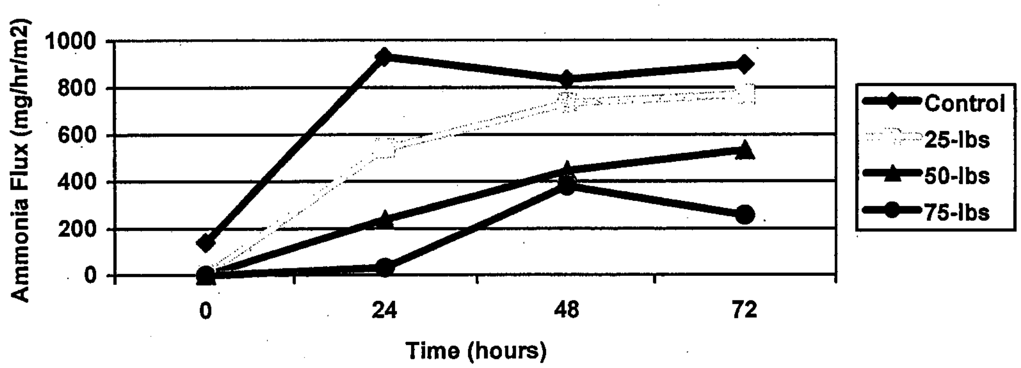


Figure 5. Week 1 Ammonia Flux (mg/hr/m^2) of dairy slurry treated with SBS (lbs/1000 sqft).

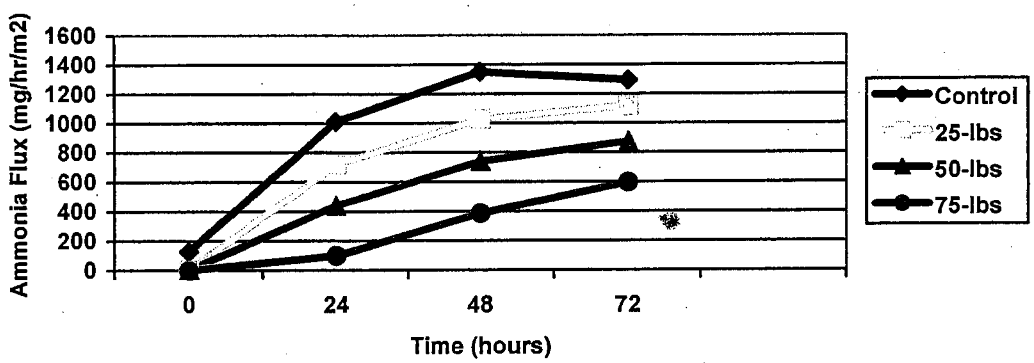


Figure 6. Week 2 Ammonia Flux (mg/hr/m^2) of dairy slurry treated with SBS (lbs/1000 sqft).

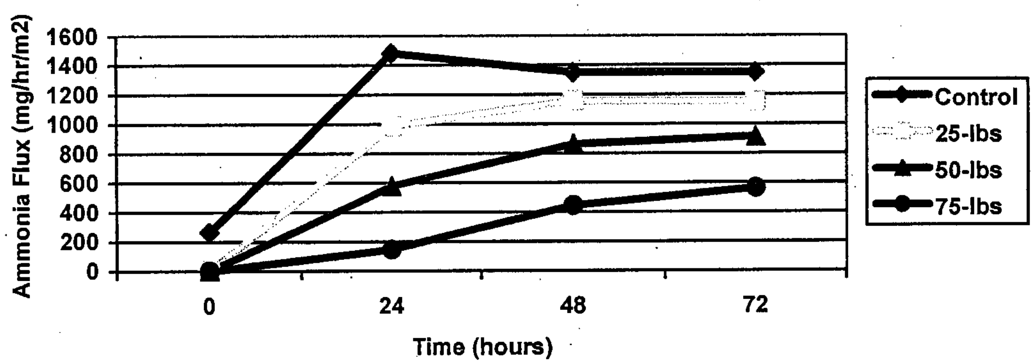


Figure 7. Week 3 Ammonia Flux (mg/hr/m^2) of dairy slurry treated with SBS (lbs/1000 sqft).

Summary

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

Note: PLT® and ParlorPal® are registered trademarks of Jones-Hamilton Co., Walbridge, OH.

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Effects of Sodium Bisulfate on Alcohol, Amine, and Ammonia Emissions from Dairy Slurry

Huawei Sun, Yuee Pan, Yongjing Zhao, Wendi A. Jackson, Lisa M. Nuckles, Irina L. Malkina, Veronica E. Arteaga, and Frank M. Mitloehner* University of California–Davis

Sodium bisulfate (SBS) is extensively used in the poultry industry to reduce ammonia and bacterial levels in litter. It is also used in the dairy industry to reduce bacterial counts in bedding and ammonia emissions, preventing environmental mastitis and calf respiratory stress. The present study measured the effect of SBS on the air emission of ammonia, amine, and alcohol from a dairy slurry mix. Amine flux was undetectable (<5 ng L^{-1}) across treatments. Application of SBS decreased ammonia, methanol, and ethanol emissions from fresh dairy slurry. Ammonia emissions decreased with increasing levels of SBS treatment. The 3-d average ammonia flux from the control (no SBS applied) and the three different SBS surface application levels of 0.125, 0.250, and 0.375 kg m^{-2} were 513.4, 407.2, 294.8, and 204.5 mg h^{-1} m^{-2}, respectively. The ammonia emission reduction potentials were 0, 21, 43, and 60%, respectively. Methanol and ethanol emissions decreased with an increase in the amount of SBS applied. The 3-d average methanol emissions were 223.7, 178.0, 131.6, and 87.0 mg h^{-1} m^{-2} for SBS surface application level of 0, 0.125, 0.250, and 0.375 kg m^{-2}, with corresponding reduction potentials of 0, 20, 41, and 61, respectively. Similar emission reduction potentials of 0, 18, 35, and 58% were obtained for ethanol. Sodium bisulfate was shown to be effective in the mitigation of ammonia and alcohol emissions from fresh dairy slurry.

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*Corresponding author (fmmitloehner@ucdavis.edu).
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677 S. Segoe Rd., Madison, WI 53711 USA

California is the leading dairy state in the USA, producing 21% of the nation's milk supply. The state is also home to two of the three worst air-sheds with respect to ozone (smog) pollution (Schwehr, 2004). Ozone is formed through the interaction of volatile organic compounds (VOCs) and oxides of nitrogen in the presence of sunlight. Volatile organic compound emissions from San Joaquin Valley (SJV) stationary sources have been reduced by 85% since 1975 (California Air Resources Board, 2006). However, further reductions in SJV air district emissions of oxides of nitrogen are required (by the state) to reach the ozone attainment standard.

Air emissions from agricultural processes in California have been regulated since 2003. Current regulatory estimates suggest that SJV dairies emit VOCs (aka reactive organic gas) at even higher rates than passenger vehicles (San Joaquin Valley Air Pollution Control District, 2004). Current SJV air district rules are intended to reduce VOC emissions from dairies, cattle feedlots, poultry ranches, and other animal husbandry operations by 15.8 tons or 26% d^{-1} (San Joaquin Valley Air Pollution Control District, 2005).

A total of 1.74 million lactating dairy cows are housed on 2107 dairies in California, and within the last 10 yr the number of cows per dairy has more than doubled to an average of 825. The majority of SJV dairies house lactating dairy cows in concrete-floored, open-sided, freestall barns. Each cow produces approximately 60 kg of manure daily, which is flushed with water from the milking parlor and freestalls into large manure ponds. Nonlactating dry cows and heifers are generally housed in dirt-floored drylot corrals, which are not flushed with water but scraped several times per year. Emission studies conducted in our lab have shown that fresh slurry and fermented feed (silage) are the main sources of VOCs from dairies, with the main compound groups being alcohols (ethanol and methanol). Furthermore, dairy slurry is known to emit substantial amounts of ammonia shortly after excretion of urine, which mixes with feces (Lefcourt and Meisinger, 2001). These gaseous releases are mainly produced by microbial and enzymatic activity on excreted nitrogenous and carbonaceous compounds in the feces and/or urine (Carey et al., 2005; Mutlu et al., 2005).

H. Sun, Dep. of Biological & Agricultural Engineering, Univ. of California, Davis, 3060 Bainer Hall, One Shields Avenue, Davis, CA 95616; F.M. Mitloehner, Y. Pan, W.A. Jackson, L.M. Nuckles, I.L. Malkina, and V.E. Arteaga, Dep. of Animal Science, Univ. of California, Davis, 2151 Meyer Hall, One Shields Avenue, Davis, CA 95616; Y. Zhao, Dep. of Mechanical and Aeronautical Engineering, Univ. of California, Davis, One Shields Avenue, Davis, CA 95616.

Abbreviations: SBS, sodium bisulfate; VOC, volatile organic compound; SJV, San Joaquin Valley.

After the passage of California State Senate Bill 700 and subsequent Environmental Protection Agency (EPA) Title V permitting requirements of dairies in California, farmers began identifying practical and economical control technologies for VOC and ammonia. Although research efforts in the past have focused on control technologies that deal with liquid dairy waste storage and treatment, ongoing research identified fresh slurry in the animal housing areas to be a major source of VOC and ammonia. Therefore, management practices have to be implemented to effectively address emissions from fresh slurry (Dragosits et al., 2002).

Ehanol and methanol are produced during anaerobic fermentation in the cow's rumen by microbial strains like *Streptococcus bovis* and *Ruminococcus albus* (J. Russell, personal communication, 2006). Fresh slurry contains both of these alcohols in the liquid phase. Environmental drivers like pH, temperature, and oxygenation of the slurry influence the microbial and physical processes that determine which alcohols are produced, metabolized by bacteria, and transferred from liquid to gas phase. The production and emissions of gaseous ammonia from animal manure is dependent on urea content in urine, the pH and temperature of the manure, and urease activity (Monteny et al., 1998; Gay and Knowlton, 2005). Therefore, mitigation must address at least one of the main environmental drivers (e.g., pH) to effectively disrupt microbial and enzymatic activity and reduce atmospheric releases (Jongebreur and Monteny, 2001).

Streptococcus bovis does not grow in the presence of elevated sodium concentrations (5–6%), and there is a cessation of *R. albus* growth at a pH of 6.0 or below, so the application of acidifying sodium bisulfate (SBS) could conceivably reduce the growth and survival of these alcohol-producing organisms (Montefiore Medical Center and Albert Einstein College of Medicine, 2001; Schlegel et al., 2003; Thurston et al., 1993). Alcohol, amine, and ammonia losses from freshly excreted manures to the atmosphere occur very rapidly, and effective mitigation needs to be implemented shortly after excretion (Meisinger et al., 2001). Acidification of barn floors and gutters has been suggested as one possible intervention strategy (Ferguson et al., 2001). The selection of acids would need to be done carefully because few are compatible with the presence of animals. Acidification of manure slurry has also been suggested in the literature (Meisinger et al., 2001; Clemens et al., 2002; Lefcourt and Meisinger, 2001).

Sodium Bisulfate

Sodium bisulfate is a dry, granular acid salt that has been used for many years as a pH reducer in a variety of agricultural, industrial, and food applications (Sweeney et al., 1996; Sweeney et al., 2000). It is categorized as a mineral acid by the EPA (Registration Eligibility Decision Mineral Acids, EPA 738-R-029). In general, mineral acids dissociate and release hydrogen ions, thus decreasing the pH. The extent and duration of the pH decrease depends on the amount of neutralizing ions present, the buffering capacity of the medium to which it is applied, and the amount of dilution. The antibacterial properties of SBS have been exploited in its application as a sanitizer (EPA Reg #1913-24-AA) and as a preservative (EPA method #5035) to prevent microbial activity leading to VOC release. These pH-reducing and antimicrobial properties have led to its use for ammonia binding and bacterial reduction in poultry, dairy, and equine manure and bedding materials (Ullman et al., 2004; Sweeney et al., 1996; Harper, 2002). Currently, 30 to 40% of all broiler chickens produced in the USA are raised on SBS-treated litter (PLT litter acidifier; Jones-Hamilton Co., Walbridge, OH). Sodium bisulfate has been established as an effective surface amendment to reduce ammonia and bacterial counts in poultry systems (Pope and Cherry, 2000; Terzich, 1997).

Sodium bisulfate is hygroscopic, and as ambient moisture is adsorbed into the SBS bead, the compound dissolves into its sodium (Na^+), hydrogen (H^+), and sulfate (SO_4^-) constituents. The hydrogen ion reduces the pH of the litter or bedding and protonates the ammonia molecule, converting it to ammonium ($NH_3 + H^+ \rightarrow NH_4^+$). The ammonium is then bound by the sulfate component (Ullman et al., 2004). The newly formed ammonium sulfate does not aerosolize but is retained in the manure in its solid form (similar to ammonium sulfate inorganic fertilizer). Theoretically, 100 kg SBS can bind 14 kg ammonia based on the reaction $2\ NaHSO_4 + 2\ NH_4OH \rightarrow (NH_4)_2SO_4 + Na_2SO_4 + 2\ H_2O$. Sodium and hydrogen ions exert synergistic negative pressure on the bacterial populations within the manure, decreasing total aerobic population counts by 2 to 3 logs (Pope and Cherry, 2000). This may also serve to further decrease urease concentrations in the manure slurry, leading to additional ammonia reductions (Ullman et al., 2004).

Material and Methods

General Design

The study was conducted using experimental flux chambers, a range of potential SBS treatment levels, and freshly excreted dairy cow slurry. The slurry and treatments were placed in open containers and covered by surface isolation flux chambers. The four flux chambers (Odotech Inc., Montreal, Quebec, Canada) were built from acrylic resin with a volume of 64.5 L. Each chamber consisted of a cylindrical enclosure with a spherical top. Teflon tubing (50 cm, 6.35 mm OD) was installed around the inside circumference of the chamber. This tubing was perforated to allow air to circulate throughout the chamber when connected to a compressed air distribution system. An opening on each chamber (fitted with a stainless steel Swagelok connector) was used to sample air for ammonia, amine, and alcohol. Of the remaining two openings on the flux chamber top, the smaller one was used for the thermocouple, and the larger opening to allowed extra air to escape and equalized inside pressure while sweeping air and sampling. A square piece of Teflon sheet was used underneath the flux chambers to minimize absorption of the emitted gases by the counter surface.

Urine and fecal samples were collected directly from mid-lactating Holstein cows that were on a California typical total mixed ration diet. A combination (1:1) of feces and was mixed in a homogenizer to ensure a homogeneous slurry mixture. The slurry mixture was divided (each containing 1 kg) into four circular trays (25.4 × 3 cm) for each of the four SBS treatments. The depth of the slurry in the tray was approximately 2 cm, which simulates the depth of the slurry in freestall barns in the dairy industry. The slurry pH was measured and recorded immediately

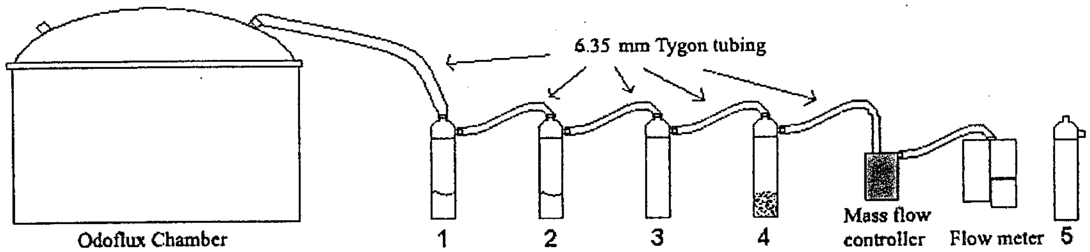

Fig. 1. Amine sampling system.

after mixing using the Accumet Research AR 15 pH meter (Fisher Scientific, Pittsburgh, PA). Appropriate amounts of SBS (0, 6.4, 12.8, and 19.2 g) were added to each tray (i.e., to the slurry) to bring the treatments to an equivalent of 0, 0.125, 0.250, and 0.375 kg m^{-2}. Sodium bisulfate was applied to the surface of the slurry. The pH was measured 15 min after SBS treatments were applied. After the pH was recorded and slurry samples were taken, each tray was placed under its respective flux chamber.

Experimental Design and Statistical Analysis

The experimental design was a 4 × 4 Latin Square with four treatment levels and four manure series; thus, each treatment experienced each flux chamber ($n = 4$).

The SAS PROC MIXED procedure (SAS Inst. Inc, Cary, NC) was used for statistical analysis. The model included the fixed effects of SBS treatment, time, and SBS treatment by time interaction with the flux chamber as the random factor. For all measures, the predicted difference test in PROC MIXED procedure in SAS was used to separate means when the overall F-value was significant ($P < 0.05$). All data are presented as least squares means, and variability is expressed as pooled SEM.

Air Sampling

The air inside the flux chamber was continuously replaced with clean air at a rate of 10 L min^{-1}. Sampled amine species were methylamine, dimethylamine, ethylamine, trimethylamine, isoprophylamine, propylamine, and butylamine. Amines were collected with an impinger sampling train (Fig. 1) connected to the sampling port of the flux chamber. The sampling train consisted of two midget bubblers and two midget impingers (Kimble/Kontes Vineland, NJ). The first two impingers (#1 and #2) each contained 15 mL of 0.1N H_2SO_4 solution. The first bubbler captured most of the amines emitted from the sample source. However, if the acid solution were to become saturated due to high amine concentrations, the second bubbler would retain the surplus amines. The third impinger (#3) was empty to trap any overflow of sulfuric acid from the second bubbler. The fourth impinger (#4) was filled with 15 mL tarred silica gel (6–12 mesh). A field blank was used (fifth impinger) and filled with 15 mL of 0.1N sulfuric acid to absorb any background ammonia and amines in the room. Sampling ports between impingers were connected with Tygon tubing (6.35 mm ID; Saint-Gobain Performance Plastics Corp., Akron, OH). The sampling train was assembled in a test tube rack for stability and placed into a plastic container containing sufficient crushed ice to cover the 15-mL line of the impingers. Air was pulled through the sampling train at a rate of 1 L min^{-1}. Each sampling period was 2 h. Each treatment chamber was sampled independently, and all four chambers were measured simultaneously. Amine concentrations were sampled every 24 h for 72 h. After 72 h, each bubbler was rinsed three times with 0.1N H_2SO_4 and brought to volume in a 50-mL Falcon tube. The samples were diluted using USEPA Method 3500B, and the amine concentration was measured by ion-chromatography (ICS-2000; Dionex Corporation, Sunnyvale, CA) using a 4-mm IonPac CS17 cation exchange column and a Cation Self-Regenerating Suppressor (CSRS ULTRA). The minimum detectable level of methylamine was 10 μg N L^{-1}, which is comparable to results reported by Hutchinson et al. (1983) and Schade and Crutzen (1995). The minimum detectable methylamine concentration in air corresponding to 0.12 m^3 sampling volume was approximately 5 ng L^{-1}.

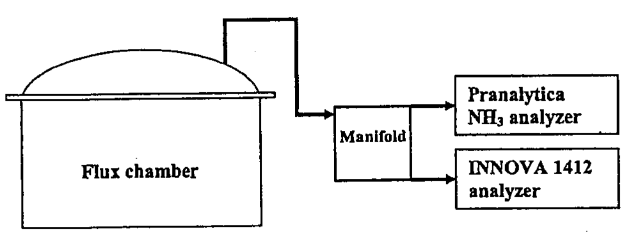

Fig. 2. Ammonia and alcohol sampling system.

Ammonia emissions from four flux chambers and one inlet were sequentially and continuously measured for 20 min each using a NITROLUX ammonia analyzer (Pranalytica, Santa Monica, CA) (Fig. 2). The NITROLUX analyzer is based on near-infrared diode lasers and fiber-amplifier–enhanced photoacoustic spectroscopy that was designed to address the problem of monitoring ambient agricultural ammonia (Webber et al., 2005).

Alcohols measured were ethanol and methanol. The four flux chambers and one inlet were sequentially sampled for these two compounds and analyzed for 20 min each, using a photoacoustic INNOVA model 1412 field gas monitor (Fig. 2). The instrument has been approved as a standard reference method by California Air Resource Board (CARB, MSO 2000-08) and the Environmental Protection Agency (EPA-VS-SCM-28) for measurement of ethanol and chlorinated VOC.

The emission flux rate was calculated using the following equation:

$$E=\frac{\sum_{i} Q\times(C_{out}-C_{in})}{n} \quad [1]$$

where E = gas emission rate from the chamber ($mg\ h^{-1}$), C_{out} = mass concentration in the exhaust air ($mg\ m^{-3}$), C_{in} = mass concentration in the compressed air ($mg\ m^{-3}$), Q = ventilation rate at 20°C and 1 atm ($m^3\ h^{-1}$), and n = total effective measurement numbers.

In this study, reduction potential was used to evaluate the effect of SBS on ammonia and alcohols emissions from slurry. Reduction potential was calculated using the following equation:

$$RP = \frac{EF_C - EF_T}{EF_C} \times 100\% \qquad [2]$$

Where EF_C = ammonia or alcohol emission flux from the control ($mg\ h^{-1}\ m^{-2}$), and EF_T = ammonia or alcohol emission flux from the SBS treatment ($mg\ h^{-1}\ m^{-2}$).

Binding efficiency (BE) was used to illustrate the fraction of applied SBS that ties up ammonia. The BE was calculated by:

$$BE = \frac{(EF_C - EF_T) \times T}{W_{SBS} \times BC} \times 100\% \qquad [3]$$

where T = time (h); W_{SBS} = weight of SBS used per m^2 (mg SBS m^{-2}); and BC = theoretical binding capacity of SBS to ammonia, which equals 14 mg NH_3 per 100 mg SBS.

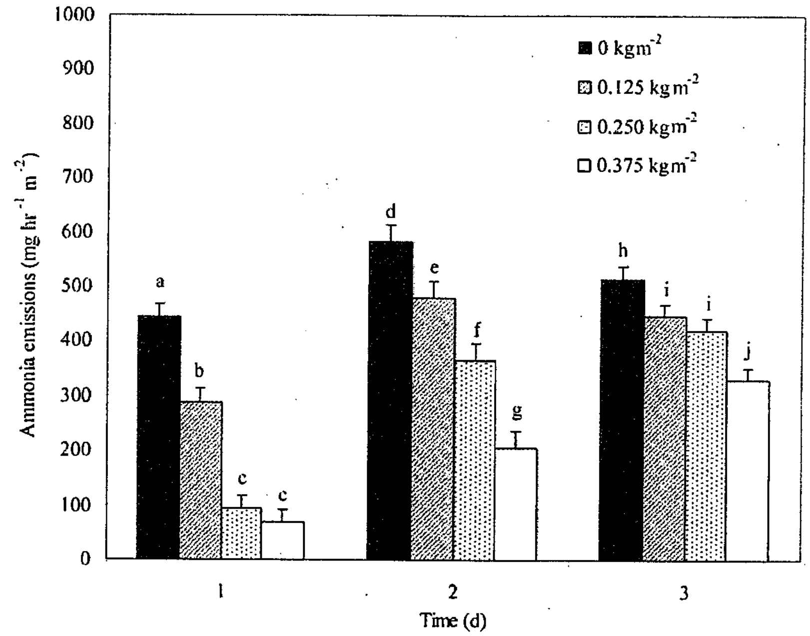

Fig. 3. Least squares means and pooled SEM of ammonia emission flux from three levels of sodium bisulfate–treated vs. untreated control slurry over a 3-d period. Least squares means with different superscripts differ ($P < 0.01$).

Results and Discussion

Surface application of SBS significantly decreased ($P < 0.01$) ammonia emission flux from fresh dairy slurry (Fig. 3) in a dose-response manner. Ammonia emission reduction potentials were 0, 21, 43, and 60% from application levels of 0, 0.125, 0.250, and 0.375 kg SBS m^{-2}, respectively. The binding efficiencies of SBS across treatments were almost identical (average, 44%), which indicated a linear relationship between the amounts of SBS applied per unit area of slurry and the ammonia flux over the entire experimental period. Ammonia emissions from the control (0 SBS) treatment reached a peak between the first and second day, after which the emission flux decreased. This pattern was also found in the lower SBS treatment (0.125 kg m^{-2}) but not in the two higher (0.250 and 0.375 kg m^{-2}) treatments. After 72 h, all four treatments had an ammonia flux of approximately 420 mg h^{-1} m^{-2} ($P > 0.01$). The most effective reduction of ammonia emission occurred during the first day (Fig. 3). The emission reduction potentials were 35, 79, and 84%, respectively, from application levels of 0.125, 0.250, and 0.375 kg m^{-2}. After 24 h, the reduction rate decreased ($P < 0.01$). By day 3, the reduction rates between 0.125 and 0.250 kg m^{-2} treatments were no longer different ($P > 0.05$).

Amine emissions were undetectable in the present study. Previous studies have shown very low amine fluxes from feedyards (Schade and Crutzen, 1995; Hutchinson et al., 1983). Schade and Crutzen (1995) and Hutchinson et al. (1983) conducted work in open feedyards where additional non-waste–related sources (e.g., feed) could have contributed to amine emissions.

Surface application of SBS also decreased ($P < 0.01$) methanol and ethanol emissions from fresh dairy slurry (Fig. 4 and 5). The 3-d average methanol emissions were 223.7, 178.0, 131.6, and 87.0 mg h^{-1} m^{-2} for SBS surface application levels of 0, 0.125, 0.250, and 0.375 kg m^{-2}, respectively, and the corresponding methanol emission reduction potentials were 0, 20, 41, and 61%, respectively (Fig. 4). The 3-d average ethanol emissions were 356.4, 291.2, 232.4, and 150.8 mg h^{-1} m^{-2} for SBS surface application levels of 0, 0.125, 0.250, and 0.375 kg m^{-2}, respectively. The corresponding ethanol reduction potentials were 0, 18, 35, and 58% (Fig. 5).

Like ammonia, methanol and ethanol emission flux was a function of the SBS treatment level and time. Methanol and ethanol emissions were most effectively reduced during the first treatment day (Fig. 4 and 5). For methanol, the initial emission reduction potentials were 40, 70, and 86% from application levels 0.125, 0.250, and 0.375 kg SBS m^{-2}, respectively. For ethanol, they were 39, 63, and 87%. By the third day, however, methanol and ethanol emissions were not well controlled by SBS treatment. Emission flux from the lowest treatment level (12.5 kg 100 m^{-2}) was the same as that from the control ($P > 0.05$).

The change of pH in the slurry after applying SBS may explain the reduction of ammonia, methanol, and ethanol emissions from cow slurry. Within 15 min, SBS decreased the slurry pH from 7.8 to 1.4–3.5 ($P < 0.01$) (Table 1). Based on the ammonia dissociation constant in water at a pH <5, ammonia in the slurry was most likely converted to ammonium ($NH_3 + H^+ \Leftrightarrow NH_4^+$) and combined with SO_4^{2-}. Furthermore, the low pH may have quickly deactivated the enzyme urease and microorgan-

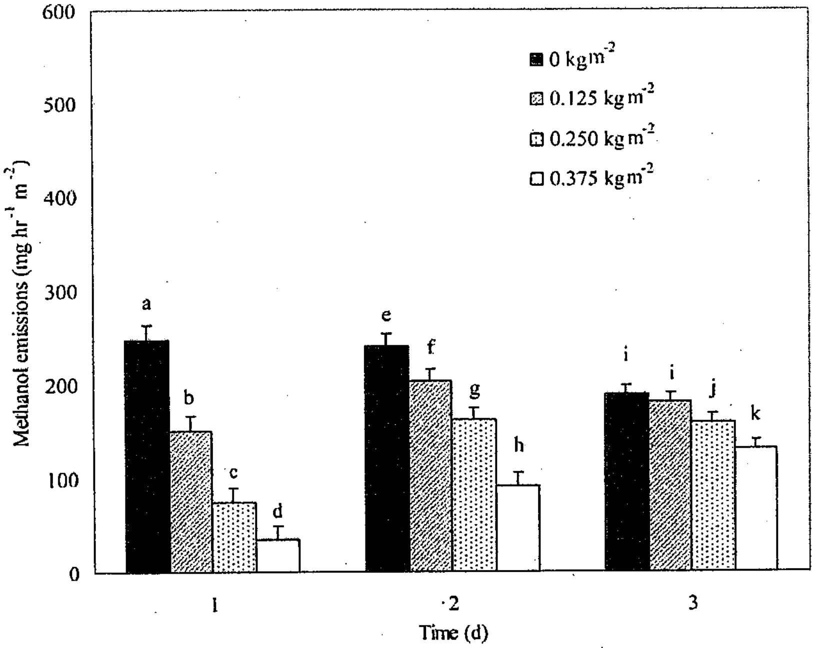

Fig. 4. Least squares means and pooled SEM of methanol emissions from three levels of sodium bisulfate–treated vs. untreated control slurry over a 3-d period. Least squares means with different superscripts differ ($P < 0.01$).

isms in the slurry (Mulrooney et al., 2001; Pearson et al., 2000; Laidler, 1955). Ammonium and alcohols would stay in the liquid phase and not be released into the gas phase. Molloy and Tunney (1983) found that ammonia volatilization of cattle slurry effectively stopped at pH 4.0. Stevens et al. (1989) demonstrated that the treatment of manure with sulfuric acid to a pH range of 4.0 to 5.5 reduced ammonia emissions. In work by Shi et al. (2001), ammonia emissions in a simulated beef cattle feedyard dropped to almost zero at a pH of 4.2. Ammonia reductions of up to 60% were achieved on a dairy by Monteny and Erisman (1998) using a combination of the acidification of slurry in a shallow pit with regular flushing of the slats with the acidified slurry. Acidification of dairy slurry to a pH <5 reduced ammonia volatization by 60% in a study conducted by Meisinger et al. (2001). In swine confinement buildings, Jensen (2002) sprayed a dilute sulfuric acid mixture on the floor and added sulfuric acid to the pooled manure. Ambient ammonia concentrations in the building were reduced from 5.6 to 7.0 mg L^{-1} to 0.7 to 1.4 mg L^{-1} for the duration of the study. Acidification of manure to a pH below 7.0 before land application has also been shown to be effective in reducing ammonia emissions (Sommer and Hutchings, 1995; Meisinger and Jokela, 2000). Miller and Varel (2001) reported the inhibition of VFA production from fresh manure when the pH decreased below 4.5. Additionally, acidification of slurry seems to reduce greenhouse gases. Keeping the pH of manure at approximately 4.5 almost completely eliminated CH_4, CO_2, and N_2O losses (Clemens et al., 2002). Berg et al. (1998) and Clemens and Huschka (2001) reported similar reductions in greenhouse gases when the pH of manure was kept below a pH of 5.0 to 6.0.

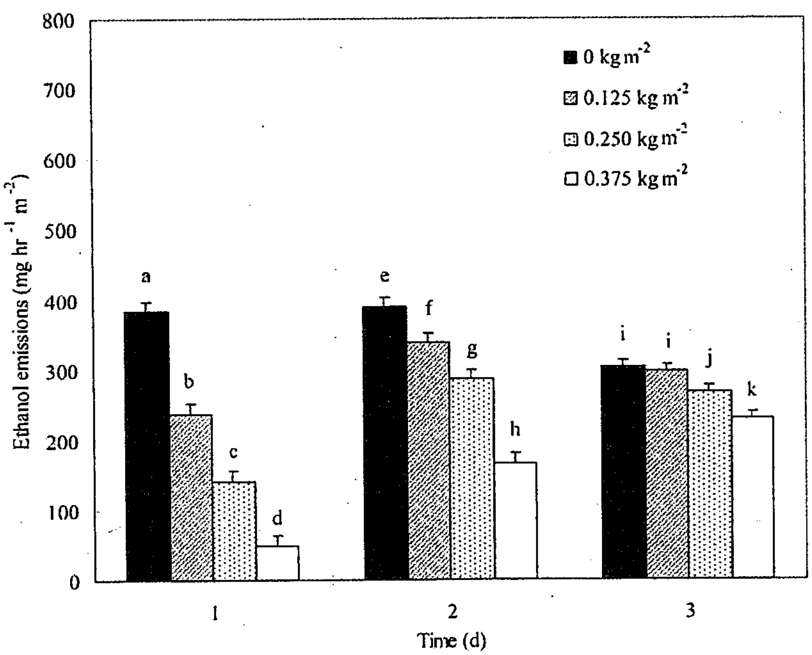

Fig. 5. Least squares means and pooled SEM of ethanol emissions from three levels of sodium bisulfate–treated vs. untreated control slurry over a 3-d period. Least squares means with different superscripts differ ($P < 0.01$).

In the present study, SBS reduced the pH of the slurry mix, which may have led to inactivation of enzymes and microbes associated with emissions of ammonia and VOCs (Mulrooney et al., 2001; Pearson et al., 2000; Laidler, 1955). After approximately 72 h, the pH of the slurry increased to pretreatment levels. The portion of ammonia in the slurry that had been converted to ammonium sulfate prevented a sharp increase in ammonia flux after the pH of the treated samples had returned to neutral conditions. Alcohol emissions were remarkably reduced during treatment with the acidifying agent. In summary, the acidification of the slurry has been shown to be effective to reduce ammonia and alcohol emissions from fresh slurry.

Conclusions

Federal, state, and regional air regulatory agencies view commercial dairies as a major source of regulated air pollutants. Recent dairy emission research conducted in our lab has identified alcohols (ethanol and methanol) as

Table 1. Least squares means and standard errors of initial pH, 15-min pH, and final pH after 72 h from sodium bisulfate–treated and untreated slurry.

Parameter	SBS treatment†			
	0	0.12.5	0.250	0.375
	kg m^{-2}			
Initial pH	7.7 ± 0.1	7.8 ± 0.1	7.8 ± 0.1	7.8 ± 0.1
pH after 15 min	7.7 ± 0.2	3.5 ± 0.2	1.9 ± 0.2	1.4 ± 0.2
pH after 72 h	9.0 ± 0.1	8.7 ± 0.1	8.9 ± 0.1	8.7 ± 0.1

† SBS, sodium bisulfate.

the major volatile organic compound group originating from fresh slurry and fermented feedstuffs. Effective control of alcohols and ammonia emissions will help meet regulatory standards, satisfy public concerns, and improve local and regional air quality. Sodium bisulfate may provide an effective, low-cost management practice for the reduction of alcohol and ammonia emissions from dairy housing conditions. Sodium bisulfate has been shown here to be effective in the mitigation of ammonia and alcohol emissions from fresh slurry.

Acknowledgments

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Iowa Pork Industry Center
Iowa Pork Producers Association

The Effects of Acidifier Applications in Reducing Emissions from Dairy Corrals

Kim Stackhouse[1], Jeffrey McGarvey[2], Yuee Pan[1], Yongjing Zhao[1], and Frank M. Mitloehner[1]
[1]University of California, Davis, [2]USDA-ARS, Albany, CA

Species: Dairy Cows
Use Area: Animal Housing
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Methanol, Ethanol, Methane

Point of Contact:
Frank Mitloehner
University of California, Davis
One Shields Ave., Davis, CA 95618
USA
(530) 752-3936
fmmitloehner@ucdavis.edu

System Summary:

Acidifier (SBS, sodium bisulfate) application may provide an effective management practice for the reduction of alcohols emissions from dairy housing. Application of sodium bisulfate has been demonstrated to be effective in the mitigation of alcohols (methanol and ethanol) emissions from dairy drylot corrals that are used to house dry cows and growing heifers. Methanol and ethanol emissions decrease with an increase in the amount of SBS applied.
SBS has also shown to have the potential for reducing pathogens and fly larvae.

Product should be applied to dairy drylots with a fertilizer spreader twice per week at a rate of 50 - 75 lb/1000 ft^2 for control of methanol and ethanol emissions. However, SBS should not be spread evenly but rather topical around highly frequented cow areas (feed bunk, water troughs). Application to enclosed drylots at the University of California, Davis showed reductions of methanol and ethanol of 15-30%. The 75 lb SBS treatment reduced methane emissions from waste as well.

Applicability and Mitigating Mechanism:

- Emission of gaseous alcohols from fresh manure and urine is dependent on pH, temperature, microbial activity and etc.
- Application of SBS lowers pH of slurry and as a result reduces methanol, and ethanol fluxes
- Reduction in pH reduces bacterial populations
- Reduction of pathogens and fly larvae due to the acidic environment induced by SBS application

Limitations:

- Sodium bisulfate must be applied consistently to manure to maintain constant emission reduction as the substance looses its effectiveness over time
- In locations that are sensitive to salt or areas with existing high salt loading in soils, applications of SBS should be considered with care because sodium is one of its components
- SBS is a mineral acid. Appropriate measures, as defined by the chemical supplier, should be used during the handling of SBS

Cost:

Bulk cost of product delivered to the farm is $660.00/ ton. Application at 50 – 75 lb / 1000 ft^2 2X / week equates to costs of between $33.00 – $49.50 / 1000 ft^2 / week. Treatment of heavy use areas, approximately 30% of the total pen area, reduces total pen cost by 70%. Cost / cow assuming 4 cows / 1000 ft^2 of pen area would be $2.48 - $3.71 / week treating only the heavy use areas.

Fax: (202) 690-0644 or (OS) 690-4727
E-Mail: cbailey@wdc.usda.gov

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Iowa Egg Council
Iowa Pork Industry Center
Iowa Pork Producers Association

Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing

Trisha Marsh Johnson[1], Bernard Murphy[2]
Veterinary & Environmental Technical Solutions, PC[1]; Jones-Hamilton Co.[2]

Species: Poultry (Broiler, layer & turkey), cattle & horses
Use Area: Animal Housing
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Ammonia, Volatile Organic Compounds

Point of Contact:
Dr. Bernard Murphy
Jones-Hamilton Co.
30354 Tracy Road
Walbridge, OH
800.379.2243
bmurphy@jones-hamilton.com

System Summary:

The application of Sodium bisulfate (SBS) has been shown to effectively reduce ammonia emissions from poultry housing, horse stalls, and dairy facilities. In addition, VOC emissions from fresh cattle manure are also greatly reduced (Marsh Johnson, et al. 2006, Ullman, et al., 2004; Blake and Hess, 2001; Sweeney, et al., 1996; Harper, 2002, Sun et al, 2008). Currently, 40-50% of all broilers produced in the United States are raised on SBS treated litter (PLT® litter acidifier, Jones-Hamilton Co., Walbridge, OH) for the purpose of controlling interior ammonia levels below 20 PPM and reducing litter bacterial levels for bird welfare and performance reasons. In addition to reducing ammonia emissions by 60% from fresh dairy manure, ethanol and methanol emissions were also reduced 61% and 58%, respectively (Sun, et al. 2008). Sodium bisulfate is broadcast over the surface of the bedding material and can be applied in the presence of poultry and livestock.

Sodium bisulfate is a dry, granular acid salt. Current application rates are dependent on litter age, animal density, and other factors and range from 0.32-1.95 kg/m^2 (50-300 lbs/1000 sqft) of animal housing space. Decreasing interior ammonia concentrations in poultry housing allow for a reduced ventilation rate leading to substantial fuel savings of up to 43% with sodium bisulfate application (Terzich, 1997). In addition, sodium bisulfate usage improves bird performance, reduces pathogens on poultry carcasses, and decreases poultry respiratory lesions and ascites (Pope and Cherry, 2000; Terzich et al, 1998 a & b).

Applicability and Mitigating Mechanism:

- SBS reduces litter and bedding pH reducing ammonia flux
- SBS reacts with ammonia to form ammonium sulfate preventing release of ammonia as pH increases over time
- The combination of sodium and hydrogen reduce manure bacterial populations thereby reducing VOC emissions and pathogens
- SBS can be safely applied in the presence of animals or prior to animal placement

Limitations:

- SBS application rates need to be increased as ammonia demand in the litter increases

Cost:

Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial additional return on investment.

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Acidifier Dosage Impacts on Ammonia Concentrations and Emissions from Heavy-Broiler Houses

Sanjay B. Shah, assistant professor

North Carolina State University (NCSU), Biological and Agricultural Engineering (BAE) Dept., sanjay_shah@ncsu.edu

Craig Baird, research engineer

NCSU, BAE Dept.

Trapier K. Marshall, post-baccalaureate student

NCSU, BAE Dept.

Philip W. Westerman, professor

NCSU, BAE Dept.

E. Philip Harris, electronics technician

NCSU, BAE Dept.

Edgar Oviedo, assistant professor

NCSU, Poultry Science Dept.

Jesse Grimes, professor

NCSU, Poultry Science Dept.

Trisha Marsh-Johnson

Veterinary and Environmental Technical Solutions

Dan Campeau, area specialized poultry agent

NCSU, NC Cooperative Extension Service

Michael Adcock, research technician

NCSU, BAE Dept.

Roberto Munilla, research engineer