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Preface

Initiated in 1988, the National Poultry Waste Management Symposium has maintained a biennial tradition of meeting the needs of industry by showcasing economically viable options for dealing with these dynamic problems and opportunities in an environmentally sound manner. The National Poultry Waste Management Symposium communicates the latest technology and research regarding by-products from the production and processing of poultry. This year's symposium featured top scientists, and industry personnel on topics that included: air monitoring and strategies for emission reduction, developing value added products, water quality trading programs, litter trading programs, role of diet in nutrient reduction, land use issues and future direction of the poultry industry as well as immersion and air chilling, processing water conservation. The information provided helps mid-level managers and decision makers to understand and manage the challenges associated with concentrated animal production facilities as well as provide opportunities to hear "success" stories. The Symposium also featured a poster section showcasing current research in the area of waste management. Exhibits of waste processing equipment, environmental services and educational topics were displayed during the symposium.

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WASHINGTON UPDATE/OVERVIEW OF THE NPWMS PROGRAM

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BACKGROUND

Introductions are to be upbeat, uplifting and inspiring to set a proper tone for the meeting. Hearing discussions of "reality" at a waste management meeting Introduction is to many people not appropriate. However, reality and a desire to improve our organization and society forces us to look beneath the facades we often construct to shelter us from the truth and on which we usually prefer to focus. Ironically, the positive "don't worry, everything will be ok" or even the less positive "let someone else do it" philosophy often leads to very negative situations. To dwell on these situations, rather than provide an objective analysis and timely corrective action for deficiencies, could lead to an unhealthy and destructive dose of depression and finger pointing. We need to be realistic in our appraisal of the National Poultry Waste Management Symposium's (NPWMS) history and future. We also need to stay positive, and focused on improving the environment through an objective analysis of our opportunities and potential responses.

This organizational team, which has shifted personnel since the 1988 symposium, has a lot for which it should be proud. The 2002 Introduction for this symposium provided a history of selected contributions from the previous symposia. The significant number of papers, posters, and pages of proceedings that this series of symposia have provided was also enumerated. Table 1 is an updated list of contributions to the poultry system by the NPWMS.

Few, if any, group of volunteers from the universities and industry can point to a sustained list of accomplishments as seen in this table. What is not fully appreciated is that the accomplishments of these volunteers, since planning began in 1987, probably has not been done before and undoubtedly will never be done again. This begs the question—"How much longer?".

The NPWMS has contributed to the training of several young professionals through presentations and committee work. Participation in the symposia has provided proof of national reputation for young faculty in their quest for promotion and tenure. Some of these young professionals are with us today and one just accepted a prestigious endowed chair position at a Land Grant University.

Table 1. Updated list of contributions of the NPWMS team. Included are proceedings pages, number of speakers, special session presentations, and attendance from each workshops. The original list is provided in the 2002 Proceedings.

Year	Pages	Number of Speakers	Special Sessions	Location	Attendance
1988:	198	36		OH	± 180
1990:	304	52		NC	± 340
1992:	453	71	Special Processing Workshop	AL	± 380
1994:	344	40	15 Poster Presentations Special Session on Spent Hen Utilization	GA	329
1996:	354	53	10 Poster Presentations	PA	213
1998:	460	44	27 Poster Presentations	AR	432
2000:	390	50	11 Poster Presentations	MD	331
2002:	380	50	14 Poster Presentations	AL	240
2004	188	38	5 Poster Presentations	TN	153
2006				AR	
Total	3071	434	Over 20 speakers at the special sessions Over 80 poster presentations		±2,598

Our goal has been to provide the poultry system with up to date information on their current concerns and to define opportunities for environmental protection. We have also attempted to create opportunities for positive dialogue and understanding between the poultry system and our regulatory counterparts at the Environmental Protection Agency (EPA) and at state offices responsible for state-wide regulations of livestock and poultry operations. Our intent was to provide objective, science based information for the promulgation of regulations. In some cases we even succeeded. At other times it was clear our efforts were not successful. The important point is that we tried to help create positive changes for the poultry system.

Our program traditionally included optional tours on the last day, but biosecurity and other concerns prevented continuation of that part of the program. To many, this has been a significant reduction in the quality of the program. Discussions have occurred regarding replacement of the tours with virtual tours, but progress has not been made in that area. A volunteer to lead this effort would be appreciated.

WASHINGTON UPDATE

The National Air Emission Monitoring Study (a.k.a., Air Quality Consent Agreement), projects are coordinated by Al Heber at Purdue University. He will manage this project of about 28 livestock and poultry operations that are to be monitored for particulate matter, H_2S, VOC's and ammonia. There are about 2,700 agreements with producers in the database, with about 900 being layers and pullet farms, 250 broilers, and 40 turkey. There are about 600 dairy producers and 5,000 swine farmers who have agreements. Hongwei Xin will be discussing the UEP portion of the study in his presentation.

The US EPA sought comments in June, 2006, on a proposed rule that would revise several parts of EPA's National Pollutant Discharge Elimination System (NPDES) and Effluent Limitation Guidelines for Concentrated Animal Feeding Operations (CAFOs). The proposed rulemaking was in response to the order issued by the Second Circuit Court of Appeals in Waterkeeper Alliance et al. V. EPA, 399 F.3d 486 (2nd Cir.2005).

The proposal would revise several aspects of EPA's current regulations governing discharges from CAFOs. Poultry is included in the new and revised CAFO rule. EPA proposes:

1. To require only CAFOs that land apply manure, litter or processed wastewater to apply for a permit. CAFOs that land apply manure litter or processed wastewater would Not need NPDES permits if the only discharge from those facilities is agricultural stormwater.
2. To require greater public participation in the issuance of an NPDES permit by requiring CAFOs seeking a permit to submit a facility-specific nutrient management plan (NMP) with their permit application or notice of intent. The public would be allowed meaningful review, and to comment. Permitting authorities would also be required to incorporate terms of the NMP into the permits as enforceable elements.
3. To remove the 100-year, 24-hour storm containment structure standard for new large swine, poultry and veal facilities and replace it with a zero discharge requirement.
4. To clarify its selection of Brac (Base Realignment and Closure) Cleanup Team (BCT) for pathogens (fecal coliform) and reaffirm its decision to set the BCT limitations for fecal coliform to be equal to the Best Practicable Technology (BPT) limits established in the 2003 CAFO rule.

Newly defined CAFOs must apply for a permit by July 31, 2007, and all existing CAFOs must develop and implement NMPs by July 31, 2007.

SESSIONS

The General Session contains presentations that overlap the interests and concerns of both production and processing personnel. Concurrent sessions will cover topics germane to production and to processing areas in the poultry system's on-going efforts to protect the environment.

General Session speakers will discuss the "State of the Environment" today, beginning with an overview of events of the last 20 years. The reasons nitrogen continues to be an area of major concern will be addressed, as well as results from the United Egg Producers air monitoring project. A panel will provide their views on our progress to date in the various environmental protection areas including litter management and mass depopulation or mortality options. Of particular interest will be the comments on water quality trading programs. Environmental change is constant, and through the efforts of the poultry system personnel, we believe the changes are positive. Different views as to our progress, and the status of this progress in relation to where we need to be to allow future generations the same or better opportunities we have enjoyed, will be provided for international, national, and state levels. The final comments will be a discussion of our future challenges and opportunities.

The Production Session focuses on unfinished business such as litter amendments, dust control, and air emissions. The scientific basis of odors is an important area of study, which will be critical in interactions with neighbors of CAFOs. The phosphorus issues continue to be of concern, with the P-indices and dietary impact on manure soluble phosphorus being important topics of discussion. The final paper before lunch will provide important information on fecal source tracking, which is a critical concept due to the historical propensity to blame food animals for contamination regardless of the potential for other sources also being a culprit. Papers on feed management options include reduced nutrient diets, and will provide important insight into the tools the poultry system can use to improve the environment. Land issues are critical to the long term survival of food animal production, with this situation becoming ever more important to the poultry system. Today, citizens in rural areas are banding together to prevent the construction of new facilities, which is due to several related factors that will be discussed in detail by two speakers. Related to this situation is the image we present to the public (voters and consumers) and other decision makers (county commissioners, state and federal legislators) and how we respond to the media impacts this image.

Beginning with the first symposium, the Processing Session has been an essential part of a holistic approach to environmental protection for the poultry system and thus this program. Carcass microbiology and wastewater discharge are basic concerns to the processing portion of the industry, as is the decision of whether to use immersion versus air chilling of poultry carcasses. Speakers will discuss options available to the industry in these important areas, and will be followed by presentations on various aspects of water conservation, reuse and recycling. Cutting edge technologies are the use of waste products as a fuel source, as are robotics and imaging technology for poultry and egg processing and evaluation. Presentations will provide insight as to the advantages and limitations of this technology.

Of great significance to our program are the papers presented as part of the Poster Session. A summary of this information is included in the Proceedings, but for more details please be certain to visit with the authors.

We are also proud of the extensive commercial exhibit section, which is located in the reception and break area. New concepts and proven technologies are presented for your consideration.

We are grateful to the Arkansas Cooperative Extension Service for providing sponsorship of Dr. K. H. Nahm, Taegu University, South Korea, as our special guest speaker. Dr. Nahm will discuss a World View of environmental issues. Likewise, the organizing committee is indebted to Wanda Linker and the Alabama Poultry and Egg Association. Wanda continues to be an essential part of the team by coordinating the registration and handling travel arrangements for speakers.

GENERAL COMMENTS

As in the past, the primary purpose of this meeting is to address current and projected educational, research and other requirements of the poultry system in the area of poultry waste management. Therefore, it is very important that each participant fill out the **evaluation form** and provide feedback to the organizing committee regarding each aspect of the program. If at a later time you discover a topic or speaker you would like to see for the 2008 meeting, please contact the coordinator or any committee member.

If you would like to **volunteer** as a committee member for future programs, we welcome your participation. Contact Casey Ritz, University of Georgia, to assist on the 2008 planning committee. We will meet at the US Poultry and Egg Association International Exposition in January 2007 to discuss the 2006 program and start planning for the 2008 symposium.

Participants at the symposium have been provided a copy of the proceedings. Additional hard copies are currently available for $30.00, while the CD-ROM version is available for $15.00. Add $5.00 each for postage and handling, and send the request to:

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Please make the check payable to: **National Poultry Waste Management Symposium**

We appreciate your interest in pollution prevention and environmental management. We hope the next few days will add to your capacity to understand current problem areas, and your ability to successfully address future environmental challenges.

I am proud to have been a part of this important symposia series, and to have had a chance to work with these outstanding groups of professionals.

ACKNOWLEDGMENTS: The author thanks Basil Eastwood, Casey Ritz, Russell Reynnells, and Samuel Reynnells for their review of the paper, and Richard Hegg for his review and the material he provided for the Washington Update section.

Environmental Overview
Past 20 Years

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Good Morning! It certainly is a pleasure and an honor to be back in front of this symposium. It is through my friend, the sweet talking Dr. Susan Watkins that I am with you this morning. Yet, I am not sure why they chose me to give an environmental overview of the past 20 years, hopefully it was for my broad-based understanding of the environmental issues not because I am old enough to have been through and hopefully remember the past 20 years. Environmental Overview, Past 20 Years can be a very boring topic, full of statistics, a history of the new laws and regulations, etc. etc. Well that type of presentation is not what we need to start off a symposium. So....

Wow, the environmental picture for the poultry industry has certainly changed much in the past 20 years and has unquestionably been on a fast track for the last 10 years. The landscape and climate has, without a doubt, changed and continues to change, almost on a daily basis. Poultry, once considered a component of agriculture, as American as apple pie, the flag and motherhood now has become, according to some, one of the major contributors to the environmental degradation of the planet Earth. The industry has been accused of polluting the air, the water and the soil. It has been the subject of new regulations, new interpretations and applications of existing laws and regulations and the favorite target for litigation. What once were considered standard and acceptable practices, sanctioned by land grant universities, are now verboten. I have only been in the poultry industry for the last 11 years, but from the first day I walked through the door, I have felt like I have had a bull's-eye on my back.

Just a note from my days as a regulator - you must keep in mind that regulators never put themselves out-of-business. You will never see a sign on the front door of EPA that says, "We have remediated the problems of the environment and no additional work is needed, therefore we will be closing and going out-of-business." A regulator will always find a new target or a reinterpretation of an existing regulation or just write a new one.

Today, environmental issues are on the agendas of company boards of directors, stockholders meetings, industry trade groups, educational seminars and training programs. Environmental management, environmental stewardship, environmental affairs, call it what you may, was once considered a cost of doing business has now become the manner in which we ***must*** conduct our business. Our customers, our consumers, the government and the general public expect no less. The times have changed. This is not the same chicken business your daddy was use to.

We in the poultry industry are now facing what the "smokestack" industries faced during the mid 70's and early 80's. They too thought they were being singled out as the sole source of the environmental evils society was facing. They too said environmental regulations would be cost prohibitive, that they would go out of business, they too had their past and current practices questioned and they too asked questions about and pointed fingers at the other sources of pollution.

Significant, also like the smokestack industries did, is the manner in which the poultry industry has come together to speak with a more unified voice on environmental issues. We have started to act in the interest of the whole not as individual companies. We have developed and continue

to develop industry wide practices and BMPs. We have become more legislative and regulatory wise. We have been able to assert our positions, with some substantial success, on a broad range of environmental issues. We have become an entity to be consulted during regulatory development.

Today's poultry industry, and we *are* considered an industry, and the general public are victims of our own successes. The industry can produce protein faster and cheaper than ever before, enough to feed the world and us. Our advances in technology have allowed us to measure to levels that are incomprehensible for most of us. When I first started in the environmental business, which *was* longer than 20 years ago, laboratory results came back in the parts per thousand ranges. Boy, we thought it couldn't get any better. But, today we are routinely getting results from the laboratory in the part per billion and part per trillion ranges. We even talk about parts per quadrillion. I thought I was fairly smart, but my mind cannot comprehend 1 part per quadrillion. At that level, we are talking about one postage stamp on a letter the size of California and Oregon, one human hair out of all the hair on all the heads of the people in the world or 1 mile on a journey of 170 light years. Yet, if the results say 1 part per quadrillion or less than 1 part per quadrillion, it is bad, it cannot be allowed, it will most likely kill you.

I feel I must warn you to be careful because there is nitrogen in the air and in waste water, phosphorous in manure and phosphorous compounds in our sodas, aluminum in soils and aluminum compounds in our deodorants. And all can be found here in this room, within our own bodies.

We have embarked on the regulation of elemental matter as a pollutant, elemental matter that we cannot create nor destroy; yet, according to some, certain types of that elemental matter we cannot tolerate at almost any level no matter how small. An example, regulators, and others, want phosphorous taken out of the wastewater streams because it can cause eutrophication. Forgetting that phosphorous is an essential building block of life, including their own being. Forgetting that they are also part of the problem. Forgetting that if phosphorous is taken out of the wastewater stream, it can only go into two other environmental media, the air or the soil. Now that the traditional methods of utilization of phosphorous as a fertilizer on the soil is being restricted or eliminated, that only leaves one environmental media, the air. I am pretty certain; they don't want it in that environmental media either. So where do you want me to put it?

Mother Nature does not respond well to legislative mandates, bureaucratic regulations, court orders or other artificial criteria. I can see it now, an EPA demand letter to God informing her that her design for nature is in violation of the Clean Air Act, the Water Pollution Control Act, CERCLA or EPCRA and she needs to immediately come into compliance. Failure to comply with these statues will subject you to severe penalties and the possibility of jail time. Please submit your written plan for compliance within 15 days of receipt of this notice. What is a Creator to do?

While the industry has been and continues to be challenged on the environmental front, we have not sat idly by. We have explored, evaluated, developed and implemented new technologies to address and resolve those challenges. Examples such as the use of feed additives to better utilize the phosphorous from corn; we have promoted the development and the use of nutrient management planning; we are developing technology for the management of ammonia emissions; we are implementing environmental management programs for ourselves and growers; we are implementing alterative uses for litter/manure; we are managing the business with new approaches; and I am sure we will continue to search for answers to all of the environmental issues that are facing the poultry industry.

Today, our customers in the retail, food service, protein conversion and feed formulation sectors are questioning how we conduct our business in the light of environmental sustainability. This is

beyond compliance. We have costumers that want to drive environmental sustainability down through their supply chains. This is the next step in environmental management. Who knows what will come next but you can bet your next paycheck there will other environmental challenges.

The last time I spoke to this symposium, which was 10 years ago, I outlined the four things that the American public wants of their food supply – that is be safe, abundant, cheap and produced in an environmentally sound fashion. At that time, I said to pick three. Today, I can stand before you and say that we are fast approaching the expectations of the American public so that they can have all four. We are meeting today's environmental challenges. We will need to be prepared to meet the challenges of the future. We need to stay the course.

WHY IS REACTIVE NITROGEN IN THE ENVIRONMENT AN ISSUE?

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Summary

Animal agriculture is a major contributor of N emissions to air, particularly with respect to ammonia and to a lesser extent with respect to nitrous oxide and nitric oxide. These emissions can occur immediately after excretion when urine N is hydrolyzed, or more slowly when fecal N is decomposed and hydrolyzed during storage and field application. As chemically fixed N has become an inexpensive input to agriculture, we have come to consume greater quantities of animal products and fruits and vegetables that use a great deal of fertilizer per unit of N in those products. The result has been increased amounts of N going into air and water, with animal production contributing large amounts of N to air via animal manure. Improved animal nutrition and feeding should aim to reduce manure N output, especially in urine, to proportionally reduce air emissions. In addition, feeding programs may eventually consider their effects on crop selection in order to further reduce environmental impact. The historical trends in animal production have resulted in reduced output of manure N per unit of animal product. Nonetheless, increased use of N fertilizer for greater output of animal products and fruits and vegetables, has resulted in an increased loss of N to the environment.

Introduction

Agricultural practices have become more intensive to provide for the nutritional needs of an increasing human population and as a response to economic pressures on individual farms. Higher production levels are possible on farms through the use of chemically fixed fertilizer and feeds imported to farms from other regions (Smil, 2001). However, such practices also may increase the potential for losses of reactive nitrogen to air and water. Losses of reactive nitrogen to the environment include nitrate leaching and nitrogen runoff from feedlots and crop fields, as well as volatilization of ammonia (NH_3), nitrous oxide (N_2O), and nitric oxide (NO) to air. This paper will focus specifically on the volatile emissions to air, and in a general way, address the problem of losses of reactive nitrogen (N) to the natural environment.

Although virtually no N is volatilized directly from animals, the N in animal manure can be converted to ammonium (NH_4^+) by hydrolysis of urea or uric acid or deamination of amino acids after hydrolysis of proteins. This ammonium equilibrates with ammonia (NH_3) which can be readily lost to air in a gaseous form. The urea (mammals) and uric acid (birds) in urine is rapidly hydrolyzed by enzymes present in the animal's feces (Oenema et al., 2001). Thus, a substantial amount of ammonium can be formed within hours of urination, and this can be readily emitted to air from animal housing. Nitrous oxide (N_2O) is formed from microbial processes of nitrification and denitrification that may occur when manure is stored or applied to land for crop production. Nitric oxide (NO) is released during nitrification in aerobic soils when manure or other fertilizer is applied.

Once emitted, the NH_3 can be converted back to NH_4^+ in the atmosphere, and this NH_4^+ reacts with acids (e.g. nitric acid, sulfuric acid) to form aerosols with a diameter of less than 2.5 micometers (PM 2.5). These small particles are considered a health concern for humans and a contributor to smog formation. Removal of ammonium by deposition contributes to soil and water acidity and ecosystem overfertilization or eutrophication. Nitric oxide and N_2O are rapidly interconvereted in the atmosphere and are referred to jointly as NO_x. Nitrous oxide diffuses from the troposphere into the stratosphere, where it can remain for hundreds of years contributing to global warming and stratospheric ozone depletion. A molecule of nitrous oxide has a global warming potential that is 296 times that of a molecule of CO_2 (IPCC, 2001).

A single molecule of ammonia or nitrous oxide once emitted to the environment can alter a wide array of biogeochemical processes as it is passed through various environmental reservoirs in a process known as the nitrogen cascade (Galloway et al., 2003). A single molecule of nitric oxide can continue regenerating in the stratosphere while sequentially destroying one ozone molecule after another. Likewise, as reactive nitrogen is

passed through various environmental reservoirs a single atom can participate in a number of destructive processes before being converted back to N_2. For example, a single molecule of reactive nitrogen can contribute sequentially to decrease atmospheric visibility (increase smog), increase global warming, decrease stratospheric ozone, contribute to soil and water acidity, and increase hypoxia in fresh and subsequently coastal waters.

World wide, more than half of the anthropogenic losses of reactive nitrogen to the air, and more than 70% of the ammonia losses, are estimated to derive from agricultural production (van Aardenne et al. 2001). About 50% of the anthropogenic ammonia losses to the environment derive directly from animal feedlots, manure storage, or grazing systems, with additional losses occurring indirectly from cropping systems used to feed domestic animals as well as feed humans directly. In addition, animals contribute 25% of the anthropogenic N_2O production with an additional 25% coming from cropping systems. Only about 10% of the anthropogenic NO production derives from agriculture, most of it coming from crop-soil systems.

The environmental problems caused by reactive nitrogen release into the environment are profound and ever increasing, and agriculture is the biggest source of reactive nitrogen losses to air and water (van Aardenne et al. 2001). Thus, it has become necessary to develop control strategies to reduce losses of reactive nitrogen to the environment.

NRC Recommendations

The importance of nitrogen emissions from agriculture was recently addressed in two reports from the National Research Council (2002, 2003). While these reports dealt with several different substances emitted to air from animal feeding operations, NH_3 emissions from animal agriculture were identified as a major global concern, and N_2O and NO were considered significant concerns. By "global" concern, the NRC indicated that the emissions were not only important around the world, but that it is the aggregate of these emissions throughout the world that matters more than their distribution in any specific locality. Thus, the NRC recommended: "the aim is to control emissions per unit of production (kg of food produced) rather than emissions per farm". This specific recommendation may directly contradict often-recommended control strategies aimed at decreasing the intensity of agriculture rather than improving the efficiency. It is important to emphasize the need to use nitrogen more efficiently for animal production rather than to simply use less per farm or per unit area of land.

The NRC also emphasized the need to consider a systems approach, which integrates animal and crop production systems both on and off (imported feeds and exported manure) the animal feeding operation, and considers emissions from water as well as air. It is certainly possible to reduce N emissions to air by transferring them to ground or surface water, but such "solutions" are not acceptable. It is also possible to reduce emissions from an animal feeding operation by exporting manure or importing crops, but the emissions will still occur, albeit on a different farm. One of the greatest opportunities to improve efficiency of N utilization for animal production is to select crops that use N more efficiently, especially by using whole-crop legumes to fix N near crop roots rather than non-legumes that require additional N fertilizers. Of course, selection of such crops would require the aid of an animal nutritionist to consider various options for diet formulation with different types of feeds.

The NRC committee also recommended against using emission factors to estimate emissions on individual farms, and recommended use of a process-based model to estimate emissions. Currently, the Environmental Protection Agency (EPA) calculates the expected emissions on farms by multiplying the number of animal units on the farm by the expected emissions per animal. When the estimated emissions exceed defined limits, reporting or regulatory requirements go into effect. The NRC recommended against using these emission factors for a number of reasons: data are not available to define average emissions per animal; animals are not uniform within discrete classifications; and management to decrease emissions is not rewarded with this approach. Thus, the NRC recommended a process-based modeling approach to estimate emissions from individual animal feeding operations. The process-based approach involves analysis of the farm system through study of its component

parts. It uses mathematical modeling and experimental data to simulate conversion and transfer of reactants and products through the farm enterprise.

For N emissions, the process-based approach involves calculation of the N in manure as the difference between what is fed and what is transferred to animal products. The amount of N lost from manure is the difference between N excreted and that removed from storage, and this manure N loss can be divided between various forms of N lost to air and water. Additional losses can be estimated as fractions of the manure N applied to crops.

The NRC committee recognized that reactive N losses to the environment may occur as NH_3, N_2O, or NO lost to air, as soluble nitrogen running off into surface water, or as nitrate leaching into groundwater. They recommended that control strategies be aimed at decreasing emissions of total reactive N from animal production systems. These strategies can include both performance standards based on process-based model estimates of N losses, or technology standards to decrease total system emissions of reactive N compounds by quantifiable amounts.

The role of the animal nutritionist was not lost on the NRC committee as evidenced in their reports. Calculation of N emissions using a process-based model uses feed and production information to calculate manure output, and this estimate drives the subsequent predictions of volatile losses. Furthermore, improvements in animal nutrition that decrease manure output would be reflected immediately in the process-based model estimates. Furthermore, diet formulation can affect what crops are used, and these decisions further affect the total losses of nitrogen, and the forms of losses, from the total animal production system. In essence, the NRC calls for an improvement in the efficiency of N utilization for animal production; animal nutrition is a key element in orchestrating this improvement.

The Role of Animal Feeding and Management

Within the animal production system, there are a number of ways to conserve nitrogen rather than let it be released to the environment in either air or water. Broad categories of improvement might include manure handling and management, crop selection and management or improved feeding and nutrition.

A mathematical model of nitrogen flows on a dairy farm (Kohn et al., 1997) was used to identify the critical control points for conserving nitrogen on a dairy farm system; however, the results are applicable to any animal production system. In this model, the efficiencies of N utilization (i.e. units of N used constructively per unit of N imported) were set to high and low extremes for each of these major subsystems (manure, crop, feed). For example, the efficiency of feed N utilization was calculated as the grams of N in animal products (milk and meat in this case) divided by the feed N consumed by the herd, and this was allowed to vary from 16 to 24%. The grams of feed N produced per g of N available at the root zone of crops ranged from 50 to 75% or would be as high as 95% for forage legumes. The amount of N available to crops in soil is likely to be 25 to 50% of the manure N produced.

When all three efficiencies were set at lower limits 5 units of N would be lost from the system for every 6 units of N fixed by legume crops, and 10 units of N would be lost for every 11 units applied as commercial fertilizer. Only the remaining unit would be converted to animal products. How much of the loss goes to air and in what forms depends on choices made regarding various management options. For example, incorporating manure or fertilizer immediately after application may decrease ammonia volatilization considerably, but increase leaching. It is still a recommended practice because it is a means of conserving N. Improving the utilization of N by the herd through better feeding and management programs, decreased these losses by 40%. Selecting more legumes, selecting highly efficient crops, and managing crops better also reduced N losses by to similar levels. However, improving manure management had little impact on conserving N in the system. Most manure N is still lost to the environment before being recycled back to the feed, even under the best of conditions. Thus, it is best not to produce it in the first place.

In the past several years, regulators and other developers of pollution control strategies (e.g. NRCS) have become interested in the feeding and animal management option to reduce N and P losses to the environment. Nonetheless, they have been struggling with how to translate their interest into policies to improve nutrition or feeding. Cropping systems are the other vital half of the equation; but optimizing cropping has still not received much attention. The agronomists may consider this their domain, and to a large extent it is. However, nutritionist again need to be involved when it comes to optimizing selection of crops that are needed for nutritional reasons. Ultimately, diet formulation may some day consider the environmental impact of feed selection, as it is a means to use byproducts safely and drive production of environmentally friendly crops.

Historical Trends

Over the past 50 years there have been two simultaneous trends in N use for animal production. First, following World War II, the development and use of chemically fixed nitrogen has increased tremendously. This means that non-legume crops have replaced the leguminous crops that were previously the source of N input to agriculture. When chemical fertilizer is applied to crops, only 25 to 50% of that N is taken up by the crop while the remainder is lost to air and water, and a small amount is returned to the atmosphere as harmless, N_2 gas. In contrast, most N fixed by legumes ends up in harvested grains or crop residues. Thus, the increased use of N fertilizer generally represents a trend that has put a great deal more N into the environment.

The increased use of fertilizer and other aspects of agricultural intensification have made foods more available to humans in the US and around the world. As a result, we have the option to eat more meat, vegetable crops and fruits, all of which require greater N inputs per unit of N output than traditional diets of beans and rice. Today, many people eat much more protein than they actually need. In the US, we appear to throw away about half the food N we purchase at the retail level (Smil, 2001). The human body needs about 2 kg person^{-1} yr^{-1} nitrogen but human beings (collectively) create 20 kg person^{-1} yr^{-1} nitrogen during food production processes. All of the reactive nitrogen is distributed to the environment representing a biogeochemically active element that, in large excess, has detrimental consequences on environmental ecosystems (Galloway, et al 2003).

We need to reduce our dependence on N fixation if we are to reduce the losses of N to the environment. It is unlikely that consumers will choose to eat less of the foods they like and which are good for them (e.g. animal products, vegetables and fruits). But would it impact our standard of living to decrease how much food we waste? Otherwise, we need to produce food with fewer N inputs. In this regard, there has been positive trend for the past 50 years regarding animal production.

Figure 1 shows estimates of the amount of N and P that were excreted per kg live weight of broiler in 1957 and 1991. The data of Havenstein et al. (1994) were used to calculate excretion for the 1957 strain of broiler raised on the diets from that period, vs. the 1991 strain raised on diets fed at that time. There was a 51% reduction in the amount of N excreted per kg of live weight produced. It is not enough to offset the added inefficiencies, of the entire agricultural system, but it does show the positive effect that animal management has had.

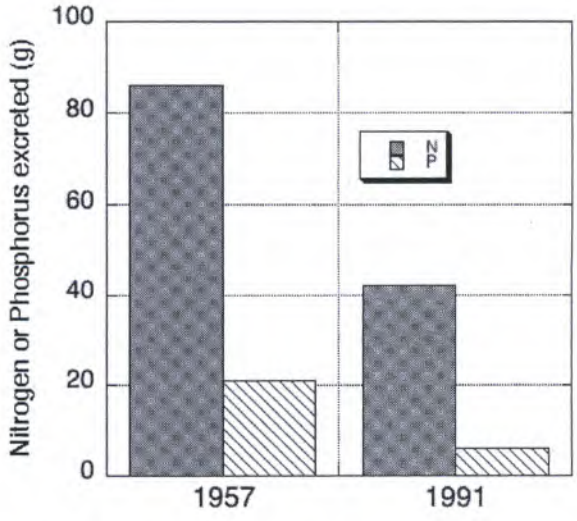

Figure 1. Excretion of nitrogen and phosphorus (g) per kg live weight of broiler produced in 1957 or 1991 (Data from Havenstein et al, 1994).

Table 1 shows a similar example for milk production. Production data were obtained from historical surveys, and assumed feeding levels were calculated using historical feeding recommendations. Excreted N was calculated as the difference between N intake and N in animal products (milk and growth). The total US dairy herd peaked in 1944 with 25 million cows, although today we produce 40% more milk with only 9 million cows. Although N excretion per cow per year has increased by about 12%, the total N excreted by all dairy cows in the US has decreased by 60%.

Table 1. Production and nitrogen excretion for the US dairy herd in 1944 and 2001.

	1944	2001
Milk per cow (kg/d)	7	27
N intake per cow (g/d)	360	490
N excreted per cow (g/d)	326	364
N excreted / N in milk (g/g)	10	3
N in milk / N intake (g/g)	0.09	0.26
Number of cows (10^6)	25	9
Milk per cow (kg/yr)	2073	8152
Total milk (10^9 kg/yr)	52	73
N Excretion per cow (kg/yr)	119	133
Total N excretion (10^9 kg/yr)	3.0	1.2

Calculated from agricultural statistics and historic animal feeding recommendations.
Sources: USDA 2003; NRC 2001; Morrison, 1950.

Conclusions

Reactive nitrogen from agriculture is an increasing environmental concern that results from feeding an ever-increasing world population with an improved quality of food. Improving animal nutrition is a means to reduce urinary and fecal N so as to proportionally reduce N emissions to air. In addition, feeding choices will affect crop selection and cropping practices that will have an additional impact on air as well as water loading of nitrogen. The challenge is to improve the efficiency of agricultural production at using fixed nitrogen and carbon fast enough to compensate for the impact of the expanding world human population and its demand for higher quality food.

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UEP INITIATIVE TOWARD MITIGATING AIR EMISSIONS

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Background

Appreciable progress has been made toward collection of air emissions data under U.S. animal production conditions since the release of the 2002 National Academy of Science Report on air emissions from animal feeding operations. For laying hen operations, ammonia emissions from some representative commercial high-rise houses and manure-belt houses have been quantified over one year in Iowa and Pennsylvania (Liang et al., 2005). The recently acquired U.S. data are compared with those in the literature that mostly originate from European studies (Table 1). As expected, the magnitude of house-level emissions is largely affected by the manure management practices. For instance, ammonia emissions from high-rise layer houses with in-house manure storage (typically for a year) are markedly higher (10 to 17 times) than those from manure-belt layer houses with daily to semi-weekly manure removal. Manure removal frequency also has a profound impact on the house-level emission quantity (Table 1).

Despite the progress, collection of more baseline emissions data for both house levels and manure storage is justifiable because of the wide range of production schemes used throughout the United States in terms of housing style (cross ventilation vs. tunnel ventilation; high-rise vs. manure-belt, etc.), manure handling practices (extended period of in-house storage vs. frequent removal at various intervals; naturally drying vs. forced drying of manure on belt, etc.). All these factors can have notable impacts on emission quantities and thus emission factors. A distribution of egg production facilities being used in the United States is given in Table 2 (Lippi, 2006; Personal Communication). To improve the national air emission inventory, an Air Compliance Agreement (ACA) between the EPA and certain sectors of the animal industries (broilers, dairy, layers and swine) has been reached, through which more baseline data on aerial emissions will be collected. The United Egg Producers (UEP), representing about 90% of the national egg production and about 70% of its individual members, are participating in the ACA study. The American Egg Board has committed $2.8M in funding support to the study.

While baseline emission data are important, seeking practical solutions to mitigate air emissions remains the ultimate goal of the industry in addressing air quality-related environmental issues. For instance, as shown by the data in Table 3, most high-rise houses (typically housing over 100,000 hens) will emit more than 100 lb NH_3 per day, the reportable quantity under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The situation would become more severe if the entire farm is treated as one emitting source.

UEP Environmental Scientific Panel

To this end, a 13-member UEP environmental scientific panel (ESP) on air emissions has been created and functional since 2004. The missions of UEP ESP are: a) to serve as a clearinghouse for the U.S. egg industry on air quality research and findings pertaining to the egg industry, and b) to identify current and emerging areas in air quality that warrant long-term or short-term scientific research, with the emphasis on exploration of practical solutions to mitigate air emissions from egg operations. The ESP consists of representatives from land-grant universities, U.S. government agencies, egg production and allied industries, as listed below:

Dr. James Arthur, geneticist, Hy-Line International, IA
Dr. Richard Gates, agricultural & biological engineer, University of Kentucky, KY
Mr. Chad Gregory, Vice President, United Egg Producers, GA

Mr. Carroll Hale, environmental specialist, Rose Acre Farms, IN
Mr. Rich Hall, egg producer, Southwest Iowa Egg, IA
Dr. Albert Heber, agricultural & biological engineer, Purdue University, IN
Dr. Richard Hegg, national program leader, USDA-CSREES, Washington, D.C.
Mr. Tom Lippi, equipment engineer, Chore-Time Brock, Inc., IN
Dr. Philip Moore, soil scientist, USDA-ARS, Fayetteville, AR
Dr. Paul Patterson, poultry nutritionist, Pennsylvania State University, PA
Mr. Bob Pike, egg producer, Braswell Foods, NC
Dr. Eileen Wheeler, agricultural & biological engineer, Pennsylvania State University, PA
Dr. Hongwei Xin (Chair), agricultural & biological engineer, Iowa State University, IA

Research Priorities Identified by UEP ESP

The ESP has identified the following research priorities/areas concerning air emissions from egg production facilities (** = very high priority, * = high priority):

I. **Source reductions (pre-excretion)**
   a) Feed and water additives **
   b) Nutritional manipulation **
   c) Genetic and strain differences *

II. **Treatment technologies (post-excretion)**
   a) Manure management/treatment **
      Physical, chemical, microbiological
   b) Manure storage **
      Physical, chemical, microbiological
   c) Facilities design *
      Building & equipment design *
      Site design/layout **

III. **Measurement/Methods/Characterizations**
   a) Alternative measurement instruments *
   b) PM size distribution (PM2.5, PM10, TSP) *

ESP Actions Toward Implementation of Its Missions

The ESP members have been working to seek funding for the identified mitigation research areas from federal, state, regional and industrial sources. Differing from most reported studies, the ESP-initiated mitigation research will place more emphasis on field-scale verification tests while devoting some energy and resources to exploring new potential mitigation techniques in the laboratories. The research will be multi-disciplinary and multi-institutional in nature. At the time of this writing, the prospects of funding look reasonably favorable.

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Table 1. Summary of ammonia emission rates (ER, g NH_3 $AU^{-1}d^{-1}$) of laying hen houses with different housing and management schemes in different countries (1 AU = 500 kg live weight) (*Liang et al., 2005)*

Country	House Type (season)	Manure Removal	NH_3 ER	Reference (year)
England	Deep pit (winter)	INA	192	Wathes et al. (1997)
England	Deep pit (summer)	INA	290	Wathes et al. (1997)
England	Deep pit (N/A)	INA	239	Nicholsen et al. (2004)
U.S.A (Ohio)	High-rise (March)	Annual	523	Keener et al. (2002)
U.S.A (Ohio)	High-rise (July)	Annual	417	Keener et al. (2002)
U.S.A (Iowa)	High-rise (all year) – *standard diet*	Annual	299	Yang et al. (2002)
U.S.A (Iowa & Pennsylvania)	High-rise (all year) – *standard diet*	Annual	298	Liang et al. (2005)
U.S.A (Iowa)	High-rise (all year) – *1% lower CP diet*	Annual	268	Liang et al. (2005)
The Netherlands	Manure Belt (N/A)	Twice a week with no manure drying	31	Kroodsma et al. (1988)
The Netherlands	Manure Belt (N/A)	Once a week with manure drying	28	Kroodsma et al. (1988)
Denmark	Manure Belt (all year)	INA	52	Groot Koerkamp et al. (1998)
Germany	Manure Belt (all year)	INA	14	Groot Koerkamp et al. (1998)
The Netherlands	Manure Belt (all year)	INA	39	Groot Koerkamp et al. (1998)
England	Manure Belt (all year)	Weekly	96	Nicholsen et al. (2004)
England	Manure Belt (all year)	Daily	38	Nicholsen et al. (2004)
U.S.A (Iowa)	Manure Belt (all year)	Daily with no manure drying	17.5	Liang et al. (2005)
U.S.A (Pennsylvania)	Manure Belt (all year)	Twice a week with manure drying	30.8	Liang et al. (2005)

INA = information not available

Table 2. Approximate distribution of U.S. cage layer housing styles (number of houses and % total), based on an accepted figure 2900 layer houses currently in operation (Lippi, 2006; Personal Communication)

House Type	Tunnel Ventilation	Cross Ventilation	Negative Pressure Turbo	Positive Pressure Turbo	Total
High-rise with curtain-back cages	500 (17.2%)	300 (10.3%)	500 (17.2%)	0 (0%)	1300 (44.8%)
High-rise with dropping board cages	300 (10.3%)	200 (6.9%)	300 (10.3%)	0 (0%)	800 (27.6%)
Manure belt	300 (10.3%)	100 (3.4%)	400 (13.8%)	0 (0%)	800 (27.6%)
Total	1100 (37.9%)	600 (20.7%)	1200 (41.4%)	0 (0%)	2900 (100.0%)

Note: All estimates are rounded off to the nearest hundred houses, which is why the dozen or so positive pressure turbo houses show up as zero here.

Table 3. Estimated number of laying hens taken to emit 100 lb of NH_3 per day for different housing and manure handling systems, based on one-year field measurement in Iowa and Pennsylvania (Liang et al, 2005)

Housing & Manure Handling Schemes	Emission Rate, g NH_3/bird-d	# hens to emit 100 lb NH_3/d
Mean of high-rise houses	0.90	50,444
Hi of high-rise houses	1.61	28,199
Mean of belt houses – 1d removal	0.054	840,741
Hi of belt houses – 1d removal	0.132	343,939
Mean of belt houses – 3-4d removal	0.094	482,979
Hi of belt houses – 3-4d removal	0.28	162,143

A FRAMEWORK FOR TRADING PHOSPHORUS CREDITS IN THE LAKE ALLATOONA WATERSHED

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Abstract: This paper presents preliminary results from a project, funded by USDA 406 Water Quality Program, that integrates research, education and extension activities to develop a framework for trading phosphorus (P) credits between point and nonpoint sources in the Lake Allatoona watershed in north Georgia. It shall describe the process being used to monitor 12 first order streams in forested and poultry watersheds to determine P loading based on land use and to model the entire watershed. After presenting some results from these efforts, it will briefly discuss planned efforts to establish a trading program in the watershed.

Introduction

Controlling non-point source pollutants requires a change in the tools we use to control pollutants. The permit process, which works well for point source pollutants, is difficult to apply to diffuse, dispersed non-point source pollutants. Instead, a mix of pollution prevention techniques, best management practices (BMPs), land use controls, and incentives for land preservation are necessary for the control of non-point source water pollution. Emissions trading has become a widely accepted tool of cost-effective environmental protection over the past two decades. The best known examples are the Acid Rain Trading Program created by Title IV of the 1990 Clean Air Act Amendments and the architecture for international burden sharing under the Kyoto Protocol. Emissions trading programs designed to meet water quality standards bring additional complexities compared to these better-knows programs that regulate atmospheric emissions. US EPA's recently-finalized policy on water quality trading (US EPA, 2003) sets forth the Agency's current framework for trading to meet water quality objectives.

A primary objective of water quality trading is to meet or exceed environmental objectives at lower cost than alternative regulatory structures. Those entities that face high costs of nutrient emission reductions can transfer their obligation to those that have lower costs, and do so in a way that makes both parties better off from the exchange. This central advantage of emissions trading has been thoroughly demonstrated in practice and in theory, and is vitally important in strategies to achieve the best possible combination of environmental and economic objectives. In the case of water quality trading, an additional advantage is the ability to engage non-point sources of nutrients in solving watershed problems. If point sources (such as waste water treatment facilities, WWTFs) are willing to pay non-point sources (for example, farmers instituting BMPs) to engage in pollution-reducing activities, it would be an important step forward in engaging non-point sources as part of a strategy to meet watershed objectives.

Effluent trading programs were first developed in the early 1980s. A review of effluent trading and offset programs completed in 1999 found 37 programs in various stages of operation (Sessions and Leifman, 1999). The scale of the trading programs range from an individual facility, a localized group of facilities affecting the same water body, a watershed, or an entire state. Although there are a number of trading programs in existence, a program has not been developed to date that has resulted in a significant number of trades between point and non-point sources.

Our goal is to develop a scientifically-based framework for water quality trading between point and non-point sources. We will use watershed-scale modeling and monitoring of first order streams to develop loading estimates for different agricultural practices that have been identified as contributing to non-point source pollution in the watershed. These loading estimates along with load estimates from other land use categories will be used to scale and route loads through the stream system. Load estimates for other land use types will be taken from previous studies in the region and the literature. Uncertainty analysis of the model will be used to develop scientifically-based P trading ratios for point and agricultural non-point sources. We also intend to create an advisory council of stakeholders to assist in identifying potential trading opportunities, evaluating trading frameworks, and determining the best method for communicating to a larger, more diverse audience.

The Lake Allatoona Watershed

This watershed is an ideal site for applied research for several reasons. First, according to the EPA Allatoona Phase 1 Clean Lakes Diagnostic Feasibility Study, unless measures are taken to control nonpoint sources of sediment and P in the watershed, Lake Allatoona will ultimately be unfit for drinking or recreational purposes. Second, P loading restrictions are now in place for Lake Allatoona and EPA and Georgia EPD have committed to developing a nutrient TMDL for the lake. Finally, we have in place a strong partnership between the University of Georgia and the governmental bodies and major stakeholders within the watershed. The Lake Allatoona watershed drains an area of 1,050 square miles. The Etowah River is the major tributary and Canton Creek, Shoal Creek, Little River, and Noonday Creek are minor tributaries (Fig. 1). The average volume of Lake Allatoona is 367,000 acre-ft, mean annual flow is 1,939 cfs, and the average residence time is 95 days. Most of the watershed is in forest (67%), with significant areas in pasture/hay (13%), and residential (18%) land use. There are significant areas of agricultural land use in the more rural northern part of the watershed. Broiler production is the main agricultural activity and a typical farm combines this with beef cattle production on pastures. Lake Allatoona is on the northwestern outskirts of the Atlanta metropolitan area and rapid development is occurring along the southern shore of the lake. A 1999 study projected that population in these counties would double by 2010 (Rose, 1999).

A Clean Lakes Study classified the Lake Allatoona as being in transition between mesotrophic and eutrophic, with P being the primary limiting nutrient for algal growth (Rose, 1999). The authors concluded that unless measures were taken to control P inputs to the lake, it would be unfit for drinking or recreational purposes within ten years. As a result, the Georgia EPD has imposed a P load restriction of not more than 1.3 lb/acre-ft of lake volume per year (GAEPD, 2002). This was developed using the estimated total load for the year (May 1992 to April 1993) in which the Clean Lakes study was conducted. At that time, 84% of the P load to the lake was thought to come from non-point sources. The Lake Allatoona Watershed is an ideal area for trading between point and non-point sources since most of the current P load to the lake appears to come from non-point sources.

Monitoring

While the overall project will look at trading with all potential sources, our initial funding is focused on agricultural non-point sources. To estimate the P loads and the impacts of BMPs, we are monitoring nine poultry operations in first order watersheds and three forested watersheds as reference conditions. Since these farms are in first order watersheds (where the streams originate on the farm), we can monitor one point and assume that all the impact is from the farm. The monitoring data will also be used to calibrate the models. In addition to existing and monitored data, we are also conducting a survey of growers to supply data for the modeling efforts.

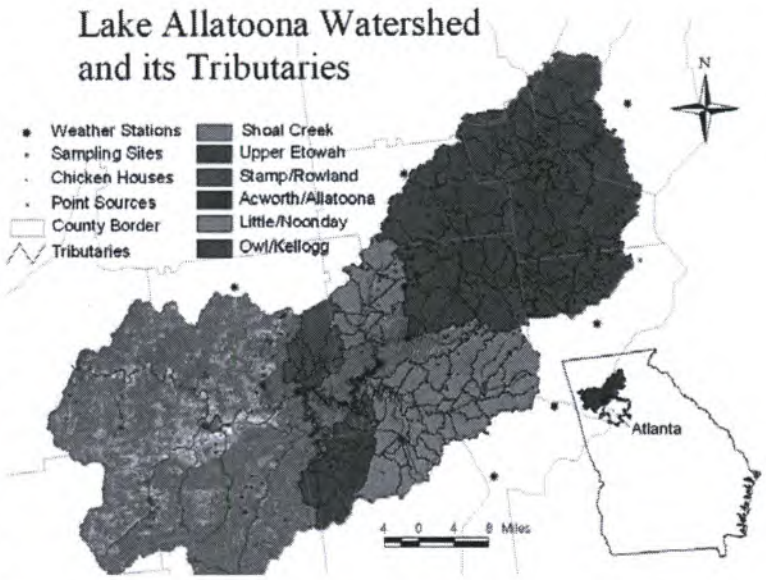

Figure 1 Lake Allatoona Watershed

Field monitoring of 12 streams was initiated in January of 2005. Nine of the streams are in first order watersheds predominated by poultry and/or cattle operations. These 9 watersheds differ in terms of land use history, manure management, and other factors. The remaining 3 streams are on the Chattahoochee National Forest and are assumed to represent reference conditions. Drainage area and characteristics of the watersheds are presented in Table 1.

From January 2005 to June 2005, each stream was instrumented with a 2 foot H-flume with a pressure transducer connected to a datalogger and an ISCO sampler. Flows are monitored at a 15 minute time interval. Stream water is sampled bi-weekly and during storm events. Robertson and Roerish (1999) found this to be an optimal sampling strategy for determining average annual loads. Samples are analyzed for suspended sediment concentration (SSC), dissolved reactive P, and total P. Dissolved reactive P is quantified using colorimetric techniques and total Kjeldhal P will be analyzed using a micro-Kjeldhal, automated ascorbic acid reduction method. Both techniques are adapted from EPA approved methods (Greenberg et al. 1992). SSC will be analyzed using the evaporation method (Guy, 1969). Soil test P levels were also measured in each field within the watersheds as well as in several other land uses within the watershed using the Melich 1 method. Average field values are reported in Table 1.

Figures 2 and 3 show some of the preliminary results graphically. Median TP concentrations for grab and storm samples from forested watersheds range 3.4 to 7.6 and 3.8 to 10 ug-P/L, respectively. For agricultural watersheds, median TP concentrations for grab and storm samples range 3 to 298 and 30 to 1,970 ug-P/L, respectively. Highest P concentrations, loads, and unit-area loads are associated with agricultural watersheds #5, 6, and #12. These three watersheds are the smallest agricultural watersheds being monitored and have some of the highest soil test P. The agricultural sites displayed substantial variability. We are currently conducting detailed surveys of the farmers, developing a database of BMP parameters, and developing field scale models in an attempt to better explain much of this variability.

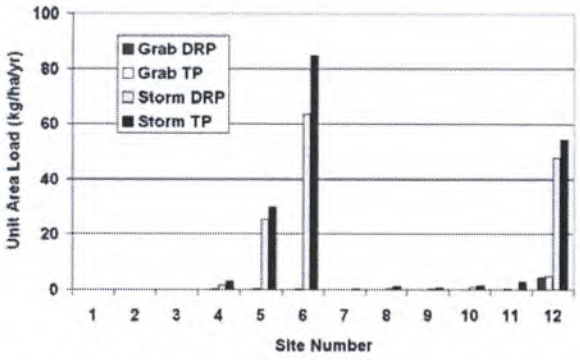

Figure 2 Median unit area P load by site and sample type.

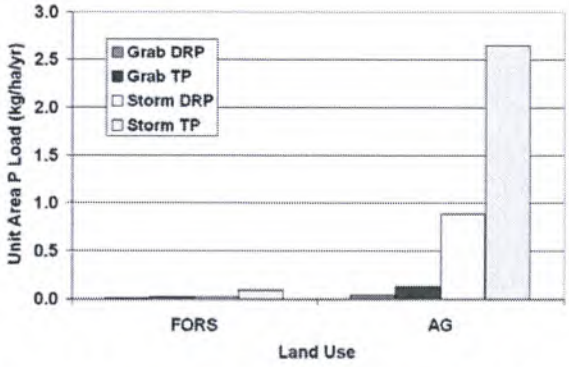

Figure 3 Unit area P load by land use and type.

Table 1 Drainage area and characteristics of the selected watersheds.

Site	Area (ac)	Land Use	Soil Test P	Highlights
1	109	Forest	7	Reservoir
2	69	Forest	6	Heavy sediment
3	76	Forest	7	
4	69	Ag	191	Cattle; reservoir, add'l land use
5	7.0	Ag	458	Cattle, no buildings
6	6.0	Ag	441	Cattle, manure pile
7	24	Ag	138	No cattle
8	18	Ag	178	No cattle
9	26	Ag	166	Reservoir; add'l land use
10	47	Ag	118	Cattle; no buildings
11	39	Ag	394	Cattle, reservoir
12	8.0	Ag	279	Ephemeral drainage, sheep

Modeling The main purposes of this SWAT (Arnold et al., 1990) modeling exercise are to derive initial estimates for model parameters governing phosphorus generating and transport processes in SWAT model and to estimate sediment and phosphorus loadings to Lake Allatoona from its twelve primary tributaries. In order to make reasonable predictions, we first calibrated SWAT model against the Clean Lake Study data collected during the period of 1992-1996. In the calibration stage, we used NLCD (National Land Cover Data (NLCD) 1992. Streamflow observations from three well documented USGS monitoring sites in HUC 03150104 have been retrieved from USGS website (http://waterdata.usgs.gov/nwis/) were used in the calibration process. A program called PEST (Model independent Parameter Testing, Doherty, 2002) was used in the calibration process. The calibrated SWAT

model parameters were used to make predictions of the sediment and phosphorus loadings to Lake Allatoona using more recent landuse data, NLCD 2001 (Homer et al. 2004).

The modeling efforts included both point and non-point source P loads. About thirty point source dischargers were identified located within the Lake Allatoona watershed. Discharge records for 21 of these were obtained from the EPA Envirofact database or through GA EPD Cartersville Regional Office and were incorporated into SWAT as constant values that were averages of available monthly measurements of the past five years. Non-point sources included poultry litter application, cattle, and urban lawn fertilization. The fertilizer database in SWAT was modified to include dry broiler manure containing 1.5-1.7% phosphorus, 90% of which is inorganic phosphorus. All pasture received 8,000 lb/ac (8965 kg/ha) broiler fresh manure each year, in split applications. Animal grazing on pasture was assumed to be 0.5 animal units per acre so that the grazing animals would consume 45 kg/ha grass per day while they add 27 kg /ha beef fresh manure to pasture each day. Pastures were determined from land use using aerial photographs to identify poultry houses and delineating a 0.5-km radius buffer. If the land use in the NLCD was pasture and it was within this radius, then it was assumed to have cattle on it. Home lawns in the watershed were assumed to be tall Fescue lawns fertilized twice per year at the rate of 530 kg/ha (or 11 lb/1000 ft^2) of fertilizer (25-3-0). Soil test P levels for both the urban and agricultural land uses were determined using a database of analysis from the University of Georgia Cooperative Extension Soil Test Lab.

In general, SWAT did fairly well in simulating the flow and loads of sediment and P from Etowah River (except for sediment), Shoal Creek, Noonday Creek, Little River, Kellogg Creek, Allatoona Creek and Rowland Spring, which contribute 91.6% of total discharge, 97.1% of total sediment and 89.5% of total phosphorus loads (Table 2). Overall, the model underestimated the flow volume by 7.4%, sediment loading by 96.9%, but overestimated the total phosphorus loadings by 16.0%. From Table 2, it is evident that Etowah River is the biggest contributor with about 65% of the discharge, 80% of sediment, and 70 % of total P loadings to Lake Allatoona, respectively. Calibrated results were also used to compare P loading rates to those listed in the literature for various land uses and compared favorably.

Calibrated SWAT model parameters were then used to make predictions of the sediment and phosphorus loadings to Lake Allatoona using more recent land use data, NLCD 2001 (Homer et al. 2004). From the calibration period to the most recent land cover database, land use changes included a 15% increase in urban area, a 3% increase in pasture, and a 18% reduction in forest. Since these results are still preliminary, they are not presented here. These results and future modeling efforts will be used to 1) quantify point and non-point source loadings, 2) evaluate future loading scenarios under different trading frameworks, 3) assess the uncertainty associated with the non-point source contributions, and 4) develop scientifically sound trading ratios.

Future Directions and Conclusions

In this time of constraint on resources available for watershed protection, funding must be directed to the most cost effective applications. Trading, as a market-based mechanism that directs funding to the lowest cost controls, offers an opportunity to get the "best bang for the buck" in restoring and protecting our critical water resources. Using the results of our field and modeling efforts, we will establish an advisory council in the basin. The advisory council will help us identify potential trading opportunities and limitations. Focusing our data collection on P loading from agricultural practices provides the advisory council the opportunity to identify and discuss fundamental policy issues specific to the agricultural community. The council will help us establish the agricultural baseline from which a trading credit may be generated. Accountability is necessary for ensuring that reductions are indeed real and surplus. The advisory council will work on identifying a mechanism that will work for the agricultural community and the other stakeholders in the basin. The advisory council will also review our analysis of trading frameworks and help determine the most effective framework for the Lake Allatoona watershed. This

research provides the poultry industry with numerous benefits. If a nutrient trading framework can be established, growers could gain greater access to funding to address non-point source water quality problems and point sources (such as processing plants) may be able to meet NPDES permitting requirements in the most economic matter possible. While this grant is focused on poultry, others on this research team are pursuing funds to do work looking at other sources such as septic tanks, development, golf courses, and residential areas. Poultry was not targeted as the primary problem, but as the most significant opportunity related to the funding sources available.

Initial results are showing that there is tremendous variability between the farms with some having P concentrations similar to forested watersheds and others having concentrations 20-30 times higher. Modeling results are showing that NPS contributions within the watershed are quite high. Preliminary economic analysis is indicating that the low costs of P removal at the point sources could hinder establishment of trading programs but that as the P limits become stricter, trading scenarios may offer a legitimate alternative to additional treatment.

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Table 1. Budget of flow, sediment and phosphorus for Lake Allatoona

Source	Discharge			Sediment			Total P		
	Estimated (Mm^3/yr)	Modeled (Mm^3/yr)	Rel. Diff. (%)	Estimated (ton/yr)	Modeled (ton/yr)	Rel. Diff. (%)	Estimated (kg/yr)	Modeled (kg/yr)	Rel. Diff. (%)
Etowah River	1,511.3[a]	1,407.5	-7.1	209,702	60,292	-110.7	158,752	122,229	-26.0
Shoal Creek	107.6	126.4	16.1	4,612	3,390	-30.5	4,153	3,403	-19.9
Noonday Creek	93.6	93.1	-0.5	6,988	6,434	-8.3	12,669	10,577	-18.0
Little River	317.5	223.8	-34.6	16,944	10,575	-46.3	21,685	15,808	-31.3
Owl Creek	0.86	0.84	-2.4	14	22	44.4	217	77	-95.2
Kellogg Creek	2.03	1.4	-36.7	66	40	-49.1	160	155	-3.2
Lake Acworth	7.61	10.8	34.7	338	366	8.0	247	503	68.3
Allatoona Creek	23.1	25.5	9.9	1,211	1,076	-11.8	1,474	1,259	-15.7
Tanyard Creek	9.24	4.5	-69.0	414	76	-138.0	930	130	-150.9
Clark Creek	10.9	10.9	0.0	217	217	0.0	868	306	0.0
Stamp Creek	24.8	20.7	-18.0	830	355	-80.2	834	505	-49.1
Rowland Spring	1.34	1.5	11.3	35	19	-59.3	43	35	-20.5
Secondary Tributaries[b]	8.12	8.12	0.0	1,190	1190	0.0	3,145	3,145	0.0
Point Sources	3.69	6.2/26.9[c]		345	243/345		1,758	9805/17183	
Precipitation	109.6	109.6		0	0		3,399	3,399	
Total In	**2,231.3**	**2,050.9**	**-7.4**	**242,804**	**84295**	**-96.9**	**209,772**	**171,336**	**-16.0**
Evaporation[b]	-54.7	-54.7		0	0		0	0	
Drinking[b]	-48.2	-48.2		0	0		-1,795	-1,795	
Etowah Out	-2,281.1[a]	-2281.1		-51,378	-51,378		-166,107	-166,107	
Total Out	**2,384.0**	**2,384.0**		**51,378**	**51,378**		**167,902**	**167,902**	
(In-Out)/In (%)	***-6.6***	***-15.0***		***130.1***	***48.5***		***22.2***	***2.0***	

(a) Estimated from daily streamflow recorded in USGS gage stations (#02392000 and #0239400). They are more accurate than those estimated using bi-weekly instantaneous flow recordings. The corresponding estimates of these two numbers based on the instantaneous flow recordings (adopted by the Clean Lake Study) are 1683.2 and 2212.6 million m^3/yr, respectively. All other estimation from observed data was using mid-interval method, which is essentially a flow-weighted method (for sediment and phosphorus).

(b) Adopted directly from the Clean Lake Study report except the sediment load from the secondary tributaries.

(c) Estimated by averaging the measurements in the DMR's (Discharge Monitoring Report) obtained through USEPA Environfact Database and GAEPD Cartersville Regional Office. They are more accurate than the reported values in the Clean Lake Study report (Rose 1999). The numbers to the left of the slash (/) represent the point sources discharging to the downstream of the monitoring points, while those to the right are the total quantities from point source dischargers. Therefore, only the numerators were added in the budget calculation since the differences between the numerators and denominators have already been counted in the receiving streams in SWAT models.

MASS MORTALITY COMPOSTING PROGRAMS

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Introduction

Every poultry farm should have a plan to deal with a catastrophic mortality event! This plan should include mass disposal options and procedures, list of materials and contact people. Basic knowledge of the procedure(s) and all necessary approvals that will allow a swift response is essential. Local, state and federal regulations will dictate the disposal option(s). Furthermore, the disposal method must be economical, environmentally and socially acceptable. Although the poultry industry makes every effort to circumvent catastrophic losses, there are numerous situations that pose risk, many of which are unavoidable. A catastrophic loss can be a few thousand birds in a house or farm, or can represent millions of birds in an entire region of the country that requires mass disposal. There have been several recent examples in which there was uncertainty and lack of knowledge on methods of mass disposal, lack of preparation to deal with a catastrophic event and perhaps more important, not having procedures pre-approved by local and state regulatory authorities. The consequence of these situations has been conflict, delays in responding to the emergency at the most critical time period and added overall cost to deal with the crisis.

Situations that lead to catastrophic mortality events are numerous. With a shift toward windowless housing and greater dependency on electronics and power ventilation, electrical outages less than half-hour duration can results in partial or whole houses "heat" losses. The losses can be limited to one or more houses on a farm or can be widespread in a region such as recently seen with Hurricane Katrina. Although back-up generators are required for most farms to deal with power outages, past experience have found they are not fail-proof in all situations. To farther complicate mortality disposal issues are natural disasters which cause additional structural damage to the houses. Examples of natural disasters causing structure damages include wind from hurricanes and tornados, and collapsed roofs from heavy snow or ice loads. As seen with Hurricane Floyd in North Carolina, flooding can cause yet another significant disposal challenge. When the decision is made to depopulate a farm for disease control purposes, selection of the disposal method should focus on minimizing disease spread. Recent Avian Influenza events suggest every effort should be made to inactive the virus prior to carcass (and litter) removal from the house. Finally, flocks identified with and depopulated due to chemical residues must use a disposal method that avoids further environmental contamination.

Every catastrophic loss on each farm needs to be assessed to determine the appropriate disposal option(s). The following are some of the questions that need to be asked when analyzing potential options. What caused the catastrophic event? How many and what size birds are involved? Is it a partial, whole house or entire farm loss and are these losses widespread in the region? What resources and disposal options are available on the farm, from the poultry company or agency(s) overseeing this matter? What is the state of carcass decomposition? What local, state and/or federal regulations apply to this situation? How will the public "perceive" the disposal option being recommended?

MASS CARCASS DISPOSAL OPTIONS

Burial. For many catastrophic mortality events on-farm burial has historically been the predominant disposal option. This practice is one of the simplest and most cost-effective ways to deal with many types of mass mortality losses. Although some states relax environmental standards for burial when dealing with an emergency, this situation is changing due to increasing water quality and public perception concerns. Following the unearthing of intact ~15 year old carcasses at a trench burial site from an Avian Influenza event in Virginia in the late 1990s, environmental standards have become so stringent in this state the requirements have essentially eliminated on-farm burial as a mass disposal option. In locations having high seasonal water table such as the Delmarva Peninsula, burial above the water table may not be an option. Finding an elevated site that is not in close proximity to the water table can be a major challenge following a flooding catastrophe. Furthermore, burial may not be an option for some types of chemical residue depopulation situations and when the ground is frozen. When houses are damaged beyond repair due to natural disasters, separation of house debris from carcasses and litter is not possible and burial of the entire mass may be one of the few viable options.

Sanitary Landfill. The use of sanitary landfills has been used extensively for mass disposal of Avian Influenza flocks in the last few decades. It may also be one of the few options for disposal of some types of chemical residue contamination in poultry carcasses. Since all landfills do not accept carcasses, pre-approval is required and there can be logistical challenges when coordinating the transportation and deposition of large volumes of carcasses to these sites. Costs associated with transportation and tipping fees can be significant. During several recent Avian Influenza outbreaks there are indications that any disposal option that removes infectious carcasses from farms poses a potential biosecurity risk of spreading the virus to other farms.

Rendering. For some geographic areas that have plants capable of processing mortalities, rendering may be a viable and cost-effective option for non-disease and residue-free carcasses. The coordination of known tonnage of non-deteriorated carcasses is a requirement and can be a logistical challenge.

Incineration. Portable incineration units (e.g. Air Curtain®) have been used during recent Avian Influenza outbreaks in Virginia and British Columbia. Although the end product is very biosecure there are some logistical and environmental issues with this procedure. The units need to be transported to the region of the country having the catastrophic losses. Carcasses are then transported to a central and preferably remote receiving site. The incineration process is very slow, loading decomposed carcass poses a problem and it will require disposal of 0.3 tons of ash per ton of carcass. Without the proper fuel source and supervision of the process, smoke and odor can create nuisance complaints. With special permitting, collapsed and severely damaged houses from a natural disaster along with the litter and birds have been burned on-site.

Composting. There has been increasing acceptance of composting as a practical, economical and environmentally sound method for disposal of many types of catastrophic mortality events. Implemented properly, this method avoids many of the water and air quality issues that may be associated with burial and incineration, respectively. On farm mass mortality composting eliminates costs related to transportation (landfill, rendering, incineration) and tipping fees (landfill). For a disease outbreak such as Avian Influenza, in-house composting of meat birds may be one of the most biosecure methods since the virus is eliminated in the carcass and litter prior to removal from the house. However, composting must be implemented correctly and knowledge of the procedures is essential! Windrow composting inside poultry houses can be a challenge in facilities that have post or low ceilings. Depending on the cause and extent of the catastrophic loss, resources available, production schedule, and applicable regulations, mass mortality composting can be implemented in the poultry house or manure storage structures or outside windrows (Figure 1).

Mass Mortality Composting Programs

Disease Control

During the low pathogenecity H7N2 Avian Influenza outbreak on Delmarva in 2004, in-house composting was used successfully to contain and inactivate the virus in the carcasses and litter (Malone *et al.*, 2004). A *mix and pile* procedure was used on the infected three farms (nine houses total). This procedure requires mixing the litter and carcasses uniformly into a windrow and covering all exposed carcasses with litter or carbon materials (e.g. sawdust). A single windrow is formed in the center of the house and typically is 10 to 12 foot wide and 3 to 5 foot high. This procedure requires a *minimum* of 0.8 inches of litter or carbon material per pound of carcass per square foot floor space. Temperatures during the one-month in-house composting procedure averaged 130° F, enough to inactive this heat sensitive. Virus isolation tests of the compost at ~14 and ~21 days were negative on all farms. After ~2 weeks the windrows were turned inside the house, capped to cover any exposed tissue, and allowed to continue composting for an additional 2 weeks prior to removal. An alternative procedure is to remove the compost after the first 2 weeks and place in a covered windrow outside the house. Crushing or shredding carcasses prior to windrowing reduces the additional carbon requirement to compost large carcasses such as roasters and turkeys (Bendfeldt *et al.*, 2005). Although whole market-age turkey carcasses (up to 40 pound toms) did compost in the demonstration by Bendfeldt, *et al.*, (2005), shredding carcasses speeds up the composting process (e.g. temperatures). These *mix and pile* and *shred and pile* procedures tend to work best with a mass depopulation method is used that distributes the mortality somewhat evenly over the floor of the house. If the carcasses are concentrated to a small portion of the house, a *layering* method may be appropriate. Detailed procedures for these in-house composting methods are described by Tablante and Malone (2005).

An Ag-Bag® composting system was employed during recent Avian Influenza events in Virginia (2002) and British Columbia (2004). This system requires specialized equipment to mix carcasses with the carbon source, load the mixture into the bags and maintain proper aeration. Due to logistical considerations it may be more appropriate to transport the carcasses to a central site for composting with this system. The Ag Bag® system was used successfully to compost over 1 million Avian Influenza *negative* birds during the 2004 British Columbia outbreak. Since broiler breeder and caged layer farms may have limited on-farm carbon sources and these types of carcasses tend to be more difficult to compost, transporting theses mortalities to a centralized and professionally operated Ag-Bag® site may be appropriate.

Heat Losses

Following a major heat loss event on the Delmarva Peninsula in 1995, the local universities conducted a demonstration and developed guidelines (Carr *et al.*, 1996) for outside windrow composting of catastrophic mortalities. This procedure involves placing a 12 inch layer of carbon material (e.g. sawdust, wood chips, litter, etc.) on a well drained site. Starting with a 12 foot wide base, the windrow is constructed in alternate layers of carcass (3 to 6 layers of carcass, each carcass layer not exceeding 10 inches depth) and carbon (6 to 8 inch thick layers). The final windrow is capped with a carbon material to cover exposed carcasses and should not exceed 7 feet in height. Windrows constructed in this manner will accommodate ~300 pounds of mortality per linear foot. Ideally, the windrow should be turned to aerate the mixture when the temperatures decline below 115° F or in about two weeks after pile formation. In recent years when litter from the farm has been used as the carbon source, the windrows have been covered with polyethylene, tarpaulin or compost fleece. These covered piles have been allowed to "age" for various durations of time before turning. Although the tarpaulin and compost fleece are more expense, they are reusable and allow moisture and gases to escape from the pile yet shed rainfall. A wet condensate layer will often form under windrows covered with polyethylene or other impervious vapor barriers. If available and there are no mortality use restrictions, the *layering* procedure has been implemented inside manure or dry stack sheds when mortality losses are less severe (e.g. 5000

birds). Limitations of the loaders used for material handling may dictate the height and dimensions of the windrows inside sheds. The piles do not need to be covered with a tarpaulin or fleece since they are under roof, however, as with any procedure, the carcasses on the surface of the pile need to be covered with litter or a carbon source. Since the layering procedure can be more labor and material intensive and less likely to be implemented properly, the *mix and pile* procedure is becoming a more acceptable mass composting method. If the layout time between flocks is not a production issue, the in-house *mix and pile* windrow composting procedure can be used for heat losses. To avoid taking a house out of production for a prolonged period of time, the compost can be removed from the house at the first turn (~2 weeks).

Flood Losses

Carcass disposal of a flooded house is a *very unpleasant task*! Decomposition of carcasses and litter are often advanced since it may require days, even weeks before gaining access to a poultry house. As with any catastrophic mortality event, each house and farm will need to be assessed to determine viable option(s). A number of procedures have been used to compost carcasses from flooded houses. If decomposition is not advanced, in some situations the carcasses have been skimmed-off the litter surface and layered in outside windrows as described previously or placed in layers inside manure sheds. Most situations however have required blending of large amounts of dry carbon or litter in these flooded houses to facilitate material handling and removal of the "soupy" litter/carcass mixture. This blended mixture has been placed on a sawdust base in outside windrows or in manure sheds using a *layering* method with dry carbon materials or using the *mix and pile* procedure. After capping to cover exposed carcasses (both inside or outside windrows), the outside windrows have been covered with tarpaulin or compost fleece or left uncovered to facilitate evaporation of water. One state has required a 3 foot berm of dry shavings around these uncovered windrows to contain runoff. Additional requirements and considerations for composting flooded houses include; using track-type skid loaders, the use of all-weather roadway to an approved windrow site, having an adequate quantity of trucks and equipment to load and transport carbon materials and compost mixtures, increasing the frequency of turning piles to facilitate drying, and it may require using chemicals for odor and fly control. Since downtime was not an issue on one farm, and environmental and neighbor relations were a concern, the in-house *mix and pile* composting procedure with added carbon was recently used successfully on Delmarva.

Chemical Residues

Occasionally there have been flocks requiring depopulation and disposal due to chemical residues (*i.e.*, pesticides). Composting the carcasses and litter may be an option if there are environmentally safe and approved options for disposal of the compost. One of the first documented applications of in-house composting was by Murphy (1992). A four-house farm with 86,000 4 ½ pound broilers contaminated with a herbicide were windrow composed in-house using the *layering* technique. After 10 days the compost with only a few boney bird residues was removed from the house, land applied and incorporated as a fertilizer.

Summary

Composting is becoming one of the more accepted methods for disposal of catastrophic poultry mortality events. Compare to alternative disposal methods, composting it is often the more environmentally and socially acceptable, biosecure, cost-effective, and flexible implementation options. However, it is essential to have the knowledge and properly execute certain fundamental procedures for composting to be a successful mass mortality disposal option.

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Figure 1. Mass mortality composting options include in-house (left) and outside (top right) windrows or inside manure storage structures (bottom right).

OKLAHOMA'S POULTRY LITTER MARKET

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Introduction

Over the past 50 years, much of the animal production in the United States has successfully transitioned from small-scale family run farms to large-scale feeding operations. This movement has resulted in a substantial increase in production, efficiency, and geographic concentration, providing job opportunities, economic revenue and an affordable source of protein for humans worldwide. The economic success of the poultry industry has been attributed to its evolution into a vertically integrated business having the capacity to raise large numbers of birds in confinement. This production practice ultimately generates large amounts of waste in the form of poultry litter over a limited geographic area.

Poultry litter consists of a manure carrier, which is used as bedding material for absorption, and other components such as feathers and soil (Kelley et al., 1994). Wood shavings, sawdust, and soybean, peanut, or rice hulls are all common manure carriers added to the poultry house floor and utilized for raising four to eight flocks on a single placement (generally caked-out and top-dressed with new bedding between flocks) prior to complete cleanout. After removal from the house, the litter can be utilized as a fertilizer for pastureland, cropland and hay production. Poultry litter is recognized as an excellent source of the plant nutrients nitrogen, phosphorus and potassium. In addition, litter returns organic matter and other nutrients such as calcium, magnesium and sulphur to the soil, building soil fertility and quality. However, due to the concentration of poultry and litter production in areas such as Northwest Arkansas and Eastern Oklahoma, environmental concerns have arisen because of the over-application of litter to farmland.

In many areas of intensive livestock and poultry production, manure or litter has been applied at rates to meet crop nitrogen recommendations causing a build-up of soil test phosphorus, often well above that recommended for optimal crop yields. This practice can lead to increased runoff or leaching of phosphorus into surrounding surface and ground water resources. Depending on application rate and timing, soil type, and crop condition, there may be an additional problem of nitrate leaching into groundwater. Both nitrogen and phosphorus transport into waterways contribute to eutrophication (Williams et al., 1999).

Eutrophication, caused by nutrient enrichment of a water body, is characterized by excess plant growth and oxygen depletion in the water. This excessive biological activity can degrade fisheries as well as recreational, industrial, and drinking water uses. Such impacts have caused public outcry leading to regulations and legal action including EPA CAFO Rules, and in Oklahoma, the Oklahoma Registered Poultry Feeding Operations Act, the Eucha-Spavinaw court settlement and current litigation against the poultry industry in the Illinois River Basin (Edmondson vs. poultry industry). Due to increasing environmental pressure and the high replacement cost of bedding materials, producers are often extending the period of time between cleanouts. This practice may not always be the most beneficial strategy for optimizing bird performance, however, because of the increased moisture content, ammonia emissions, and the potential for microbial pathogen build-up in older recycled litter. Extending the time between full litter cleanouts could have a negative environmental impact, too. The crust of manure, called cake, which is screened from the litter between flocks may be used or stored on the farm. As the quantity is small and the moisture is relatively high, it usually is not easy to sell, resulting in local application to the land.

Marketing poultry litter to more distant nutrient-deficient areas or for further processing offers one solution to the litter surplus problem associated with high production areas. Nutrient deficient soils suitable for litter application are abundant in farmland at a distance of 50 to 100 miles from the heavy production areas of Northwest Arkansas and Eastern Oklahoma. This proximity coupled with recent increases in commercial fertilizer prices has created increased demand for poultry litter as a fertilizer source. If transport distance is not too great, poultry litter may be a cheaper source of nutrients than commercial fertilizer. A self-sustaining poultry litter market would benefit sellers, buyers, and service providers of poultry litter increasing the amount of poultry litter transported out of the nutrient surplus areas and nutrient sensitive watersheds to areas with nutrient needs and fewer environmental restrictions.

Oklahoma Litter Market

Oklahoma Cooperative Extension Service (OCES) initiated a project in 1997 with the ultimate goal of developing a self-sustaining poultry litter market. Funding was provided by a grant from U.S. EPA 319(h) administered by the Oklahoma Conservation Commission as part of the Oklahoma Nonpoint Source Program. One specific project task was to establish an internet website to promote communication between litter buyers, sellers and service providers. At the beginning of the project, only two efforts had been made to develop a litter market in the surrounding poultry production area and both were based on toll-free hotlines. The first, developed by Winrock International for Arkansas, was passed to Arkansas Farm Bureau while the second was established and operated by the Oklahoma Department of Agriculture, Food and Forestry (ODAFF). Both hotlines were initially well received, but slowed dramatically after the first year.

In 2001, OCES established the Oklahoma Litter Market website which includes a self-listing service for litter buyers, sellers and service providers. The current website has very clear advantages over a hotline. Instead of providing just a list of individuals with contact information, it serves as a communication system in which users have direct control. Users can sort listings by geographic area, last name or by date of litter availability. Sellers and service providers can list a product with its analysis, price, and amount as well as any services offered or needed. Likewise, buyers can list the amount of litter requested and services needed such as spreading. Perhaps the biggest advantage of a website, however, is the ability to provide educational material along with timely market information. In this case, the market information is linked with supporting

educational material such as fact sheets, regulatory information, market subsidy programs, maps of restricted watersheds, and litter fertilizer value calculators which all help the user determine the suitability and value of the product.

Individuals have gained access and membership to the Oklahoma Litter Market by directly visiting the website (www.ok-littermarket.org), by calling the ODAFF hotline (1 800 583 7131), or by visiting their local county Cooperative Extension office. Membership in the market is free, although market information and educational material can be accessed without becoming a member. New members can join simply by accessing the website and creating their own accounts with passwords. Members are then asked to provide contact information along with transaction details such as product description, price, amount, date available or needed, services available or requested, etc.

The Litter Market website has been advertised through newsletters, flyers, local newspapers, County Extension, presentations at various meetings and the Oklahoma Poultry Waste Management Educational Training Program conducted by OCES. The Training Program, in particular, is very effective at exposing producers to the litter market because the Oklahoma Registered Poultry Feeding Operations Act mandates that all poultry producers and litter applicators must attend 9 hours of initial poultry waste management training and 3 hours of annual updates. At these producer education meetings, subject matter includes marketing litter, proper use of litter, soil and litter testing, determining the value of litter, calibrating application equipment, recordkeeping and many additional topics.

As of August 10, 2006, there are 23 sellers, 91 buyers and 26 service providers represented on the Oklahoma Litter Market database. Sellers have listed over 6,000 tons of litter for sale and buyers have requested over 39,000 tons (some buyers and sellers list the amount as variable or not applicable). The number of buyers typically exceeds the number of sellers and the amount requested generally exceeds the amount for sale. The number of service providers has been increasing recently and is currently at an all-time high. Visits to the website as of August 10, 2006, have reached 40,811, 35,672 and 22,942 to the sellers, buyers and service providers lists, respectively. As staff time permits, we make phone calls to members to update their listed information, removing members from the website at their request.

Market Barriers

Obstacles to the market include high transportation costs, lack of litter hauling equipment, regulatory recordkeeping requirements, timing of house cleanout and litter availability (Eaton, 1999). Of these market barriers, transportation costs may be the most significant. There is much demand for poultry litter in central and western Oklahoma where many soils are considered phosphorus deficient; however, when current transportation and application costs are factored in, the value of litter is comparable to or more expensive than commercial fertilizer. In addition, spreading poultry litter requires specialized equipment, increased hassle and it is not always available at the right time.

Poultry litter is odorous, dusty, and land application in Oklahoma requires that recent soil and litter tests be obtained. Only certified applicators that have received Poultry Waste Management Training and a state license can apply poultry litter to Oklahoma land. Moreover, land application rates must follow current Natural Resources Conservation Service Waste Utilization Standards. Commercial fertilizer, on the other hand, can be spread easily without soil tests, land application restrictions, specialized equipment, or any educational requirement. To ease

transportation costs, several subsidy programs are available in Oklahoma and Arkansas for litter movement from the nutrient sensitive watersheds to areas without restriction. Qualified applicants can help reduce transportation costs by utilizing any of these incentive programs, thus increasing litter value and suitability.

Summary

The Oklahoma Litter Market website serves as a communication link for buyers, sellers and service providers of poultry litter to help facilitate the movement and extend the current use pattern of poultry litter across the state. In addition, the website is a source for educational material to those interested in properly applying litter to farmland.
Personal communication with market members supports the fact that litter is being transferred through the Litter Market. The foundation that has been laid provides a solid basis on which to continually build the poultry litter market in Oklahoma and Arkansas while promoting a better understanding of the movement and application of poultry litter.

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WORLD VIEW – METHODS FOR PREVENTING GREENHOUSE GAS EMISSIONS FROM POULTRY MANURE AND CHEMICAL ADDITIVES FOR MANURE

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Abstract

The main greenhouse gases are water vapor, carbon dioxide, methane and ozone. Because of greenhouse gases, climatic changes will affect poultry production due to loss of poultry facilities and poultry from flooding, heat stress, snow damage, increased disease transmission, reduced water quality and increases in mosquito and fly population. Emissions of methane gas from livestock manure occur at the greatest level under anaerobic conditions (fermentation or digestion). Methane production from manure varies according to the organic matter content, degree of anaerobic conditions, manure storage conditions, quantity of manure produced and the conditions for dispersal of methane from the manure.

The use of chemical additives for litter or manure reduces ammonia emissions, odors, and phosphorus (P) contamination of water. In the poultry industry, aluminum sulfate {$Al(SO_4)_3 \cdot 14$ H_2O or $Al(SO_4)_3 \cdot 18$ H_2O or alum} has been studied extensively. There have been promising studies conducted on the use of aluminum chloride ($AlCl_3$) in swine manure and broiler litter to reduce odors and ammonia volatilization. The levels of soluble P are reduced with aluminum chloride with and this protects drinking water from P contamination. Fe (II) and Fe (III) compounds used as manure additives have shown promise in basic research for the possibility of their use in ammonia and odor reduction. The low cost of calcium-containing compounds makes their utilization attractive. Use of potassium permanganate and zinc-containing compounds holds promise for the future. Long-term studies are needed to determine the effects of these compounds when used as fertilizers on soil quality and plant absorption.

Introduction

Greenhouse gases are the gaseous components of the atmosphere that hinder wavelengths of sunlight from being re-emitted in to atmosphere and result in warming of the earth. The major greenhouse gases are water vapor (36 – 70 % of the greenhouse effect), carbon dioxide (9 – 26 %), methane (4 - 9 %) and ozone (3 – 7 %). Other greenhouse gases include nitrous oxide, sulfur hexafluoride and chlorofluorocarbons (Kiehl et al., 1997; Comnoley et al., 2005).

Since the beginning of the Industrial Revolution, atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased sharply. This has resulted in global increases in environmental disasters such as abnormal temperature fluctuations, increases in sea levels, floods and snow storms. If these trends continue, it has been predicted that by the year 2100, the average atmospheric temperature will be raised by 1.4 to 5.8 C, resulting in elevations in sea levels, flooding of coastal cities, and loss of up to 1/3 of agricultural lands (Ray et al., 2001; Rahm et al., 2004).

Climatic changes will affect poultry production due to loss of poultry facilities and poultry from flooding, heat stress, snow damage, increased disease transmission, reduced water quality and increases in mosquito and fly populations (Eric et al., 2005).

Raising broilers on aluminum sulfate [$Al_2 (SO_4)_3.14 H_2O$ or alum] treated litter resulted in significantly heavier birds than those raised on untreated litter (1.73 vs 1.66 kg) and they also showed better feed conversion than the control birds (1.98 vs 2.04) (Moore et al., 1999, 2000). Lower atmospheric ammonia and/or lower pathogen numbers in the litter are thought to be responsible for these improvements in production. Alum has been shown to significantly reduce pathogens in the litter (Scantling et al., 1995), while also reducing *Salmonella* and *Campylobacter* populations in chicken manure and completely eliminating *Campylobacter* on poultry carcasses (Line, 1998, 2002).

There are two major nutrients and toxic materials (zinc and copper) in poultry manure. The two nutrients are nitrogen (N) and phosphorus (P). A substantial amount of N losses occur due to inefficiencies in digestion or absorption. Protein turnover is one of the major sources of N loss. Amino acid catabolism is another. Eutrophication of lakes and streams is a major concern for surface water quality. The process of eutorphication occurs when mineral and organic nutrients reduced dissolved oxygen to levels that favor plants over animal life. P is limiting nutrient for algae and other aquatic plant growth (Sharpley et al., 1992). Blue green algae overgrowth is of concern since they produce toxins. Repeated land applications of poultry litter and manures may lead to excessive Cu and Zn accumulating. These minerals can be toxin to some plants and foraging animals. Unlike excessive land application of N and P, these elements do not migrate into water supplies except during soil erosion.

No single method has been found to reduce the pollutants released from poultry and improve the air and water quality in these areas. Addition of chemical amendments such as aluminum, calcium and iron has greatly reduced both ammonia volatilization and P runoff from poultry litter (Moore and Miller, 1994; Moore et al., 1995a; Shreve et al., 1995, 1996; Burgess et al., 1998; Moore et al., 2000). Two studies (Moore et al., 1995b, 1997) conducted on broiler farms showed that alum application to poultry litter resulted in increased weight gains and improved feed conversion but another study (Do et al., 2005) did not show any increases in weight gain or feed conversion (Table 1). These chemical treatments of poultry manure may be one of the few cost-effective management practices that reduce pollution. The objective of this article is to give an overview of the research that has been done on greenhouse gas emissions and the use of chemical additives for poultry litter.

1. Agriculture and greenhouse gas emissions

The Kyoto Protocol was initiated in 1997 and entered into force in 2005, with goals of reducing the major greenhouse gases world wide by 2008. In Korea, the goal was set to reduce emissions from agriculture by 66 % and from animal production specifically by 34 % by 2013. Of this 34 % reduction from animal production, 16.3 % is to be reduced from the gastrointestinal gas production, and 17.7 % from livestock manure (Chung, 2005). Specific reduction in gas emissions from poultry manure are planned by proper storage and treatment of the manure. In Figure 1, goals for certain nations in reductions of greenhouse gas emission by 2008, compared to 1990 levels of emission. The United States and Australia did not ratify the Kyoto Protocol (Korea Energy Research Center, 2001).

2. Methane gas emissions from livestock manure

Table 2 shows the increases in concentrations of greenhouse gases. Methane gas was the highest percentage increase since 1945 (Smith et al., 1997). Emissions of methane gas from livestock manure occur at the greatest level under anaerobic conditions. Anaerobic fermentation or digestion is the most promising process for converting organic materials to methane and other gases. It is highly explosive and difficult to detect. At lower temperatures, anaerobic conditions favor methane production while thermophilic bacteria produce methane under aerobic conditions. Under both aerobic and anaerobic conditions, methane gas production was proportional to the organic matter content of the manure. A good example of this is that methane production from poultry and swine manure is higher than that of cattle manure due to the higher organic matter content. Methane production from manure varies according to the organic matter content, degree of anaerobic conditions, manure storage conditions, quantity of manure produced and the conditions for dispersal of methane from the manure.

When livestock manure was stored for long periods of time naturally, methane production was as high as 39 %, but when it forcibly fermented with aerobic conditions, methane production was reduced to 0.5 %. Methane gas production from poultry manure was reduced through aerobic forced fermentation (Chung, 2005).

3. Basic digestion process of methane

Dr. Hansen published his article (2005) for the extension service of the State of Colorado outlining methane production. Bacteria producing methane are anaerobes which only operate in anaerobic environments. Maximum methane production is promoted by constant temperature, pH and fresh organic matter. Temperatures of approximately 95° F are ideally maintained, but other temperatures can be used if held constant. Methane gas production will be reduced by approximately one half or it will take twice as long for each 20° F decrease in temperature. It is critical that constant temperatures are maintained with temperature variations of as little as 5° F inhibiting the methane forming bacteria enough to cause acid accumulation and possible digester failure.

Anaerobic digestion takes place in two processes and each process is performed by a specific group of organisms. The first process involves acid-forming bacteria breaking down complex organic matter (manure) into simple organic compounds. The second group of bacteria, the methane-formers, breaks the acids down into methane and carbon dioxide. When the digester is functioning properly, the two groups of bacteria are balanced so the methane-formers use just the acids produced by the acid-formers.

Bio-gas (about 60-70 percent methane, 30-49 percent carbon dioxide, and other gases, including ammonia, hydrogen sulfide, mercaptans and other noxious gases.) can be produced in a simple apparatus. The cost and complexity of the system are greatly influenced by the amount of gas and reliability desired. A simple bath-loaded digester requires an oxygen-free container, relatively constant temperature, a means of collecting gas and some mixing. Appropriate safety precautions are needed since methane gas is explosive.

The number, size and type of animals served, dilution water added, and detention time control the tank size required. Detention time is the factor that can be most easily changed with regard to tank size. The minimum time is ten days, but longer periods can be used. More complete decomposition of the wastes occurs with longer detention times. A frequently used detention time is fifteen days.

In anaerobic digesters, there is little volume reduction. About 90-95 % of the waste fed into the digester will be water. A portion of the solids (about 50-60 %) is the only part that can be reduced. Even though the processed material has odor, it still contains most of the original nitrogen, phosphorus and potassium so it is highly polluted and cannot enter a stream after leaving the digester. The waste is commonly held in lagoons until it can be disposed of by hauling or pumping onto agricultural land.

The organic material digested, the digester loading rate and the environmental conditions in the digester affect the total methane production. It is possible to produce about 45 cubic feed of gas at atmospheric pressure from one day's manure from a 1,000 pound cow under ideal conditions (95 F and proper pH). Not all of the bio-gas energy is available for use, since energy is required to heat and mix the digester, pump the efficient and compress the gas.

A concentration of 6 to 15 percent methane in air is an explosive mixture. Methane is lighter than air so it collects in rooftops or other enclosed areas. Detection may be difficult since it is relatively odorless. The digester design and storage tank require extreme caution and safety features, especially when the gas is compressed.

4. Poultry production and ammonia gas emissions

As a result of protein metabolism, nitrogen is excreted into poultry manure. Nitrogen is released into the environment in the form of ammonia gas and is also responsible for soil acidification when applied to farm land. Chickens excrete a higher level of nitrogen in their feces when compared to swine or cattle on the basis of live weight (Table 3). Reductions in ammonia emissions from poultry facilities involve cleaning the areas surrounding poultry facilities, and daily collection of poultry manure from these facilities.

5. Reducing harmful emissions from poultry production

In Korea reductions in harmful emissions from poultry manure has focused on proper manure storage, use of sawdust as poultry litter, mechanical agitation of poultry manure to improve aerobic storage conditions and chemical additions for poultry litter. Daily collection of poultry manure from the facilities is important, along with storage of the manure under aerobic conditions which will not only reduce methane gas production, but will also reduce odor and the number of flies.

After manure is placed in the first fermentation area during a 15 to 25 day period of time, it is important that it is properly oxygenated to improve aerobic conditions and reduce methane production. The second fermentation area or storage area where the manure is kept for approximately 45 days should also be will oxygenated to minimize methane production (Chung, 2005).

Chemical additives for poultry litter are still not widely used in Korea. Alteration of the ratio of N excreted in urine or feces by the addition of fermentable carbohydrates holds a strong possibility to reduce the emission of NH_3. Reductions in NH_3 volatilization have been achieved by reducing the N excretion in urine as urea and shifting the N excretion in feces in the form of bacterial protein (Sutton et al., 1999). Various scientists have been involved in the use of fermentable carbohydrates and methane reduction but no clear results have been obtained.

A major aerial pollutant from poultry manure is atmospheric ammonia (Kristensen and Wathes, 2000). There is no single method to reduce the pollutants released from poultry farms and improve air and water quality in these areas. Research has concentrated on use of additives

(chemicals, enzymes, ash and vitamin D), dietary manipulation, different types of litter, storage covers for manure, filter systems for removing dust and odor from poultry barns, ozone utilization and different manure land application techniques.

Additives are chemicals that are mixed with livestock waste to alleviate one or more of the problems. Chemical additives are simple and farmers do not have any complaints about their use in Korea. Several types of additives have been investigated in the past three decades, but their effectives, especially those available as commercial products, has been debated (Ritter, 1989; Zhu et al., 1997). Unfortunately information on the composition of commercial products, or their mode of action is not available because of confidentiality and is limited to the marketing literature supplied. $AlSO_4$ and $AlCl_3$ showed the most promise for practical use to reduce ammonia gas production and available phosphorus, although methane gas production was not measured.

6. Chemicals as additives

Aluminum sulfate [$Al_2 (SO_4)_3 \cdot 14\ H_2O$ or $Al_2 (SO_4)_3 \cdot 18\ H_2O$, Alum]

Aluminum Chloride ($AlCl_3$).

Fe (II) and/or Fe (III) salt as additives and their effects

Potassium permanganate ($KMnO_4$) and Zinc (Zn) compounds

Conclusion

Amendment of poultry litter with various aluminum, calcium iron, potassium permanganate, and zinc compounds reduces ammonia volatilization and water soluble P levels.
(References are available upon request from the author.)

Table 1. Goals for certain nations in reductions of greenhouse gas emissions by 2008 (Compared to 1990 levels of emissions, %).(Korea Energy and Economics Research Center, 2001)

-6	Japan
-6	Canada
-10	United Kingdom
-25	Germany
0	France
5	Sweden
-7	United States
1	Australia

**The United States and Austrailia withdrew from the Kyoto Protocol.

Table 2. Increases in concentrations of greenhouse gases since the industrial revolution (most of which has been since 1945). (Smith et al., 1997)

Gas	1998 amount by volume	Increase over pre-industrial (1750)	Percentage increase
Carbon Dioxide	365 ppm	87 ppm	31%
Methane	1745 ppb	1045 ppb	150%
Nitrous Oxide	314 ppb	44 ppb	16%

Table 3. Comparison of ammonia excretion from poultry, swine and dairy cattle (2004 Report from the Korean Economic Research Center)

Type of Livestock	Ammonia Production mg/hour/animal	Ammonia Production mg/hour/500kg live body weight
Chicken	2 - 39	602 - 10,892
Swine	22 - 1298	649 - 3751
Dairy Cattle	80 - 2001	315 - 1798

Table 4. Bio-gas production (60% methane and 40% carbon dioxide) from animal wastes per 1,000 pounds body weight. (Hansen, 2005)

Animal	Volatile solids (lb per animal per day)	Probable volatile solids destruction (percent)[1]	Gas (cu ft per day)
Beef	5.9	45	30
Dairy	8.6	48	44
Poultry, layers	9.4	60	72
Poultry, broilers	12	60	92
Swine, growing-finishing	4.8	50	29

[1] Percent destruction of volatile solid varies depending on detention time and digester temperature.

*To convert to metrics use the following equivalents: 1 lb = 0.45 kg; 1 cu ft = 0.03 cu m; 1 gal = 3.8 l

STRATEGIES TO REDUCE AIR EMISSION IN LAYER FACILITIES

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Summary

Ammonia (NH_3) emissions from laying hen facilities may be reduced via pre-excretion (e.g., dietary manipulation) and/or post-excretion (treatment of manure or exhaust air) pathways. A one-year field test involving four high-rise laying hen houses in Iowa showed approximately 10% reduction in NH_3 emissions for the HR layer houses with a nutritionally balanced 1% lower CP diet. An experimental layer diet (EcoCal) has also been shown, in lab-scale tests, to yield a 41% reduction in NH_3 emission during 14-d manure storage. Addition of fiber sources of soy hulls, wheat middlings, or DDGS to laying hen diets was shown to reduce NH_3 emission by up to 50%. Lowering surface-to-volume ratio of manure storage stacks leads to reduced NH_3 emission. Finally, topical application of chemical agents onto hen manure showed appreciable reduction of NH_3 emission. The treatment agents tested include zeolite [$(Na_4K_4)(Al_8Si_{40})O_{96}{\cdot}24H_2O$], alum [$Al_2(SO_4)_3{\cdot}14H_2O$] of both liquid and powder forms, Ferix-3 [$Fe_2(SO_4)_3{\cdot}9H_2O$], and PLT [$NaHSO_4$]. The reduction of NH_3 emission over a 7-d manure storage period, as compared to control, was as following: a) 38%, 68% and 91%, respectively, for zeolite applied at 2.5%, 5% and 10% of the manure weight (0.64, 1.28, 2.56 lb/ft^2 manure surface area); b) 63%, 89%, and 94%, respectively, for liquid alum applied at 1, 2, and 4 kg/m^2 (0.2, 0.4 and 0.8 lb/ft^2) of manure surface area; c) 81%, 93%, and 94%, respectively, for powder alum applied at 0.5, 1.0, and 1.5 kg/m^2 (0.1, 0.2 and 0.3 lb/ft^2); d) 82%, 86%, and 87%, respectively, for Ferix-3 applied at 0.5, 1.0, and 1.5 kg/m^2 (0.1, 0.2 and 0.3 lb/ft^2); and e) 74%, 90%, and 92%, respectively, for PLT applied at 0.5, 1.0, and 1.5 kg/m^2 (0.1, 0.2 and 0.3 lb/ft^2). Practicality and economic feasibility of the potential mitigation strategies remain assessed under commercial production conditions.

Introduction

Seeking practical means to reduce air emissions from animal feeding operations is an important issue facing the U.S. farm animal industries. For poultry production, ammonia (NH_3) is the main noxious gas of concern. Based on the recent NH_3 emission data for U.S. layer houses (Liang et al., 2005a), the numbers of hens taken to emit 100 lb NH_3 per day, the reportable quantity under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), for various housing and manure handling schemes are given in Table 1.

We have been conducting emission mitigation (as well as quantification) studies through both laboratory and field-scale tests. The field-scale tests involved commercial laying hen houses with either high-rise or manure belt housing and manure handling schemes. One of our lab facilities consists of four environmentally controlled air emission chambers and the measurement system (fig. 1a,b). Another lab facility involves eight emission vessels and a measurement system located in an environmentally controlled room (fig. 2a,b). The potential mitigation strategies we have been examining include a) dietary manipulation, b) physical configuration of manure storage stacks, and c) topical application of mineral/chemical agents, including zeolite (grade 14×40), alum of both liquid and powder forms, Ferix-3, and PLT (Table 3).

The purpose of this paper is to present the research findings about the efficacy of some pre-excretion (e.g., dietary manipulation) and post-excretion (handling and treatment of manure) mitigation of NH_3 emissions for laying hen facilities.

Potential Emission Reduction Strategies

Housing and Manure Handling Schemes

Data in Table 3 on NH_3 emission rates from laying hen houses in various parts of the world clearly show that NH_3 emissions at the house level are much higher for high-rise (HR) houses (featuring in-house manure storage for about a year) than those for manure-belt (MB) houses (featuring frequent removal of manure from the houses). In the case of HR and MB houses in Iowa and Pennsylvania, the MB houses emit less than 10% of NH_3 than the HR counterparts. Moreover, the frequency of manure removal affects house-level emissions, as can be seen from the emission data for daily vs. semi-weekly or weekly manure removal. It should be noted that house-level emissions are just one part of the total emissions at the farm level since manure in separate storage facilities also generates emissions. This is why we need to quantify and mitigate air emissions from manure storage as well as from the houses, as described below.

Stacking Profile of Laying Hen Manure in Storage

The effects of hen manure stacking profile on NH_3 emission were evaluated with five levels of surface-area-to-volume ratio (SVR, m^{-1}) at 1.23, 2.5, 5, 10, or 20. The experiments were conducted using our air emission chamber facility (fig. 1). The five SVRs were achieved by stacking hen manure at 2, 4, 8, 16 or 31 inches high with the same base area of 30 ft^2 (5 x 6 ft) per emission chamber. The chamber was held at 77°F air temperature near the manure surface and ventilation rate was held at 20 air changes per hour (ACH). The manure storage and emission measurements lasted 40 d. A separate study had been conducted to evaluate the effect of ventilation rate (10 vs. 20 ACH) on NH_3 emission and the results revealed none.

The cumulative NH_3 emissions during the 40-d storage from the manure stacks of the same base area but different heights are shown in Figure 3. The difference in NH_3 emission per unit weight of manure over the 40-d storage period between the 2-inch stack and the 31-inch stack was more than 6 fold. This substantial difference arose from the fact that it is the top sub-layer of the manure stack that was primarily responsible for the NH_3 emission. The crust formed near the surface was speculated to provide a physical barrier to NH_3 escape from the stack. Table 4 shows the manure properties before and after the 40-d ventilated storage. Hence, the results indicate when stocking manure, reducing surface to volume ratio will lead to reduction in NH_3 emission. Details of the experimental procedure and results were given in Li et al. (2005).

Dietary Manipulation

As shown by the data in Table 3, NH_3 emission from high-rise layer houses was reduced by 10% (298 vs. 268 g NH_3/d-AU) with a nutritionally balanced 1% lower CP diet. Results of the field study further showed no difference in hen production performance between the two diets. More lab-scale studies on effects of dietary manipulation on NH_3 emission were conducted using the emission vessel system (fig. 2). Nearly fresh manure samples from hens fed either the industry standard (i.e., control or Ctrl diet) or an experimental diet (Ecocal.[1].) were collected and shipped frozen to our lab where the manure samples were thawed and randomly allotted to eight emission vessels. Each 2.5 kg manure sample was placed in a 1-gallon (3.8 L) container that was placed inside a 5-gallon (19 L) emission vessel. The manure storage and emission measurements lasted 14 d. Four replicates were tested per dietary regimen. In another experiment (Roberts et al., 2005) that involved 256 W-36 laying hens for 12 weeks, soy hulls, wheat middlings, or corn distillers dried grains with solubles (DDGS) were added to the hen diets to determine the effect of dietary fiber on manure NH_3 emissions. Ammonia emissions from the stored manure were measured with the emission vessels system (fig. 2).

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[1]Ecocal is a custom-formulated diet by the cooperative producer, consisting of gypsum (calcium sulfate, to partially replace limestone) and zeolite.

Daily NH_3 emissions from the manure samples in either the Ctrl diet or the experimental Ecocal (Trt) diet regimen, along with the manure and air temperatures, are shown in Figure 4. The mean daily NH_3 emission over the 14-d storage period was 0.29 $g \cdot kg^{-1} \cdot d^{-1}$ for the Ctrl diet and 0.17 $g \cdot kg^{-1} \cdot d^{-1}$ for Trt diet, a reduction of 41%. Daily NH_3 emission of the Trt manure after day 2 was significantly lower than that of the Ctrl manure ($P<0.01$). The emission reduction for the Trt regimen presumably resulted from a combination of acidogenic (gypsum) and NH_3 adsorbing (zeolite) effects. Details of the experimental procedures and results were given in Liang et al. (2005b).

As shown by the data in Figure 5, addition of fiber sources of soy hulls, wheat middlings, or DDGS to the diets of laying hens led to NH_3 emission reduction by up to 50%. The reduction was realized partly through a reduction in the amount of manure uric acid and partly through a lowered manure pH. Egg production and egg mass were not affected by the dietary fiber additions, although feed consumption increased slightly (by 2%, Robert et al., 2005).

Topical Application of Manure Treatment Agents

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 (0.2, 0.4 or 0.8 lb/ft^2) of manure surface area for liquid alum; and 0.5, 1.0, or 1.5 kg/m^2 (0.1, 0.2 or 0.3 lb/ft^2) for granulate alum, Ferix-3, and PLT. 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 NH_3 emissions over a 14-d 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 NH_3 emission during a 14-d test. The efficacy of NH_3 reduction was further tested using the large emission chambers system (1.5 x 1.8 m or 5 x 6 ft, fig. 1) with 0.6 m (2 ft) high manure stacks.

Topical application of zeolite on laying hen manure reduced NH_3 emission and the magnitude of emission reduction was generally proportional to the application rate (fig. 6). Adsorption of NH_3 seemed to take effect right after the application, resulting in the largest emission reduction on day 1, 66%, 91% and 96% for the application rate of 2.5%, 5% and 10%, respectively. Daily NH_3 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 ($P<0.01$). Table 5 summarizes the effects of single or multiple topical applications of zeolite at the three dosages on NH_3 emission reduction.

Addition of two or more layers of manure did not seem to increase NH_3 emission on a per vessel basis ($g \cdot dP^{-1}$ or $g \cdot m^{-2}d^{-1}$), 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. 7). The result confirmed that the exposed surface layer mainly contributed to NH_3 emissions from stacked poultry (hen) manure as described earlier and by Li et al. (2005).

The NH_3 emission profiles of the manure with or without the chemical treatments are shown in Figure 8. Ammonia emissions for each regimen, emission reduction by the treatment as compared to the control, and manure properties are summarized in Table 6. Ammonia emission from each of the three application rates (denoted as low, medium and high) was significantly lower than that of the control ($P<0.001$). However, there was no additional emission reduction between the medium application rate and the high application rate in all cases. The cumulative 7-d NH_3 emission reductions were 64-93% for liquid alum, 81-94% for powder alum, 82-87% for Ferix-3, and 74-92% for PLT. Results of the manure properties showed that manure samples receiving the higher application rates had lower pH and lower ammoniacal N.

The practicality and economic feasibility of field-scale application of the treatment agents remain to be assessed under commercial production conditions.

Conclusions

- Dietary manipulation show promise in reducing ammonia emissions from laying hen manure. A nutritionally balance 1% lower CP diet leads to 10% reduction in NH_3 emission from high-rise layer houses without adversely affecting hen production performance. Several experimental diets showed appreciable reduction in NH_3 emissions from stored hen manure in lab-scale emission tests.
- Reducing surface to volume ratio of manure stacks can significantly reduce NH_3 emission.
- Lab-scale studies show that topical application of manure treatment agents (zeolite, alum, Ferix-3, and PLT) to hen manure stacks leads to considerable reduction in NH_3 emissions. However, the practicality and economic feasibility of field-scale application of the treatment agents remain to be assessed under commercial production conditions.

Future Work

- Conduct field verification tests on dietary manipulation that has undergone lab-scale tests with regards to hen production performance and costs as well as NH_3 emission reduction.
- Explore and assess practicality of field application of manure treatment agents.

Acknowledgements

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Table 1. Estimated number of laying hens taken to emit 100 lb of NH_3 per day for different housing and manure handling systems, based on one-year field measurement in Iowa and Pennsylvania (Liang et al, 2005)

Housing & Manure Handling Schemes	Emission Rate, g NH_3/bird-d	# Hens to Emit 100 lb NH_3/d
Mean of high-rise houses	0.90	50,444
Hi of high-rise houses	1.61	28,199
Mean of belt houses-1d removal	0.054	840,741
Hi of belt houses-1d removal	0.132	343,939
Mean of belt houses -3-4d removal	0.094	482,979
Hi of belt houses -3-4d removal	0.28	162,143

Table 2. Physical and chemical properties of alum, Ferix-3 and PLT

	Liquid Alum	Granular Alum	Ferix-3	PLT
Molecular	$Al_2(SO_4)_3 \cdot 14H_2O$	$Al_2(SO_4)_3 \cdot 14H_2O$	$Fe_2(SO4)_3$	$NaHSO_4$
Molecular	594	594	562	120
pH	2.0 (approx)	3.5 (1% solution)	1.02 (10%	<1 (5%
Appearance		White granules	Yellowish	Off-white
Physical state	48.5% in water	Dry solid	Dry solid	Dry solid
Odor	Odorless	Odorless	Slight	Odorless

Table 3. Summary of ammonia emission rates (ER, g NH_3 $AU^{-1}d^{-1}$) of laying hen houses with different housing and management schemes in different countries (1 AU = 500 kg live weight) (*Liang et al., 2005a)*

Country	House Type (season)	Manure Removal	NH_3 ER	Reference (year)
England	Deep pit (winter)	info not available	192	Wathes et al. (1997)
England	Deep pit (summer)	info not available	290	Wathes et al. (1997)
England	Deep pit (N/A)	info not available	239	Nicholsen et al. (2004)
U.S.A (Ohio)	High-rise (March)	Annual	523	Keener et al. (2002)
U.S.A (Ohio)	High-rise (July)	Annual	417	Keener et al. (2002)
U.S.A (Iowa)	High-rise (all year)	Annual	299	Yang et al. (2002)
U.S.A (Iowa & Pennsylvania)	High-rise (all year) – *standard diet*	Annual	298	Liang et al. (2005)
U.S.A (Iowa)	High-rise (all year) – *1% lower CP diet*	Annual	268	Liang et al. (2005)
The Netherlands	Manure Belt (N/A)	Twice a week with no manure drying	31	Kroodsma et al. (1988)
The Netherlands	Manure Belt (N/A)	Once a week with manure drying	28	Kroodsma et al. (1988)
Denmark	Manure Belt (all year)	info not available	52	Groot Koerkamp et al. (1998)
Germany	Manure Belt (all year)	info not available	14	Groot Koerkamp et al. (1998)
The Netherlands	Manure Belt (all year)	info not available	39	Groot Koerkamp et al. (1998)
England	Manure Belt (all year)	Weekly	96	Nicholsen et al. (2004)
England	Manure Belt (all year)	Daily	38	Nicholsen et al. (2004)
U.S.A (Iowa)	Manure Belt (all year)	Daily with no manure drying	17.5	Liang et al. (2005)
U.S.A (Pennsylvania)	Manure Belt (all year)	Twice a week with manure drying	30.8	Liang et al. (2005)

Table 4. Initial and post (40-d) storage properties of laying hen manure stacked at a surface to volume ratio (SVR) of 20, 10, 5 or 2.5 (base area of 30 ft^2 at stack height of 2, 4, 8 or 16 inch). Top layer refers to top 2 inch of stack and bottom layer to sub layer of stack (mean and standard deviation, n=2)

	Manure Property	Nearly Fresh Hen Manure	Hen Manure After 40-day Ventilated Storage			
			SVR20	SVR10	SVR5	SVR2.5
Top Layer	Dry matter (%)	28.1 (1.7)	68.4 (13.4)	54.1 (4.6)	54.9 (1.8)	56.6(11.7)
	Total N, g/kg (as-is)	16.2 (0.3)	19.9 (5.1)	19.9 (3.1)	15.5 (4.1)	20.1 (3.9)
	Total N, g/kg (dry base)	57.7 (2.5)	28.9 (1.8)	37.2 (8.9)	28.4 (8.4)	37.0(14.5)
	Total Ammoniacal N, g/kg (as-is)	8.8 (1.0)	4.6 (1.5)	6.0 (1.0)	6.0 (0.1)	5.9 (2.6)
	Total Ammoniacal N, g/kg (dry base)	31.3 (1.6)	7.1 (3.6)	11.3 (2.7)	10.9 (0.5)	11.2 (7.0)
	pH	7.4 (0.4)	8.6 (0.0)	8.6 (0.1)	8.5 (0.2)	8.6 (0.2)
Bottom Layer	Dry matter (%)	28.1 (1.7)	68.4 (13.4)	32.5 (3.0)	23.7 (1.6)	23.3 (2.4)
	Total N, g/kg (as-is)	16.2 (0.3)	19.9 (5.1)	12.2 (3.0)	16.7 (0.4)	15.9 (1.0)
	Total N, g/kg (dry base)	57.7 (2.5)	28.9 (1.8)	38.1(12.6)	70.8 (6.7)	64.6 (0.7)
	Total Ammoniacal N, g/kg (as-is)	8.8 (1.0)	4.6 (1.5)	8.2 (2.2)	10.5 (1.6)	10.8 (0.2)
	Total Ammoniacal N, g/kg (dry base)	31.3 (1.6)	7.1 (3.6)	25.5 (9.1)	44.3 (3.5)	44.2 (3.6)
	pH	7.4 (0.4)	8.6 (0.0)	8.5 (0.1)	8.0 (0.0)	8.0 (0.2)

Table 5. Effects of topical application of zeolite at different rates on reduction of NH_3 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)		Single Application (in chambers)	
		Ctrl	Trt2.5	Trt5	Trt10	Ctrl	Trt5	Ctrl	Trt5
Amount of manure, kg		2.5				2.5 kg x 4 = 10		136 kg x 7 = 952	
Surface area of the manure, m^2 (ft^2)		0.02 (0.22)				0.05 (0.54)		2.8 (30)	
Application rate	kg·m^{-2}	0	3.125	6.25	12.5	0	2.55	0	2.55
	lb·ft^{-2}	0	0.639	1.277	2.555	0	0.52	0	0.52
Number of zeolite application		Once - at the beginning				4 - once per layer		Once - after 3 weeks of manure loading & storage	
Trial/treatment duration, day		14				14		14 (w/o) + 4 (with trt)	
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	0.086	0.052
	g·m^{-2}d^{-1}	29.9	24.0	15.0	6.9	16.1	9.7	25.9	15.6
7-d cumulative emission, g·kg^{-1}		1.6	1.0	0.62	0.14	-	-	-	-
7-d cumulative emission reduction		-	38%	61%	91%	-	33% [b]	-	-
Total cumulative emission, g·kg^{-1} [a]		3.0	2.5	1.4	0.7	1.7	1.0	0.34	0.21
Total cumulative emission reduction		-	17%	53%	77%	-	41%	-	38%

[a] comparison tests lasted 14 days for vessel trials, but four days for the chamber trial (last 4 days of an 18-d trial)
[b] represents cumulative emission reduction over 7 days following the last-layer addition of hen manure

Table 6. Effects of topical application of Liquid alum, powder alum, Ferix-3 or PLT at various rates on reduction of ammonia emission from laying hen manure storage (each regimen had 4-6 replicates)

Parameter		Liquid Alum, $kg \cdot m^{-2}$				Powder Alum, $kg \cdot m^{-2}$				Ferix-3, $kg \cdot m^{-2}$				PLT, $kg \cdot m^{-2}$			
		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 (lb)		2.5 (5.5)															
Surface area, m^2 (ft^2)		0.02 (0.22)															
Application rate	$kg \cdot m^{-2}$	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
	$lb \cdot ft^{-2}$	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	$g \cdot kg^{-1} d^{-1}$	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
	$g \cdot m^{-2} d^{-1}$	21.10	7.87	2.30	1.271	16.95	3.23	1.23	1.07	8.41	1.56	1.19	1.09	16.28	4.18	1.57	1.38
Cumulative emission [€]	$g \cdot kg^{-1}$	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
	$g \cdot m^{-2}$	147.7	55.1	16.1	8.90	118.7	22.61	8.62	7.48	58.8	10.88	8.33	7.6	113.95	29.24	10.95	9.64
Emission 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, $g \cdot kg^{-1}$ (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, $g \cdot kg^{-1}$ (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
Total Ammoniacal N, $g \cdot kg^{-1}$ (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
Total Ammoniacal N, $g \cdot kg^{-1}$ (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

[€] Over 7-day storage testing period

[Φ] Represents reduction in 7-day cumulative emission ($g \cdot kg^{-1}$)

[Φ] Values of emission reduction rate for each agent followed by different superscript letters are significantly different ($P<0.05$)

Figure 1. Photographical views of the air emission chambers and data acquisition system used in our air emission measurement and mitigation studies.

Figure 2. Photographical views of the lab-scale setup for evaluating efficacy of air emission mitigation strategies. Pictured (right) is topical application of zeolite on laying hen manure at various dosages.

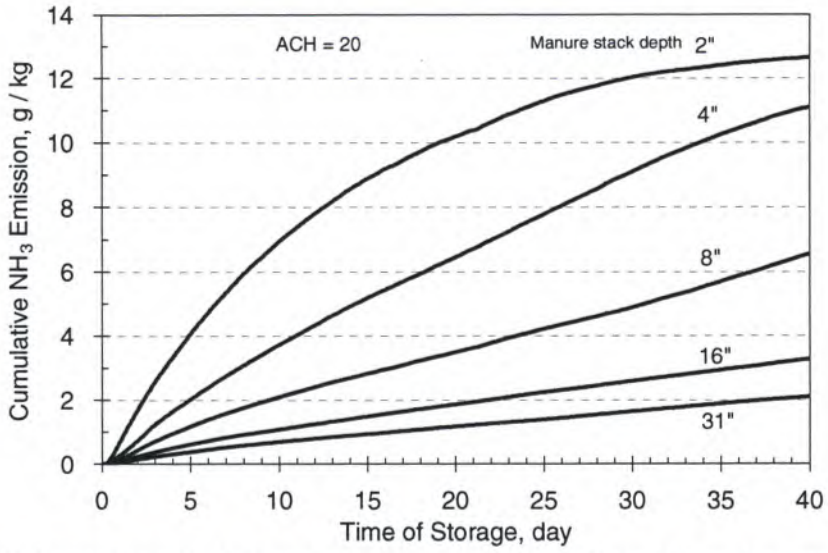

Figure 3. Specific NH_3 emission rate of stored laying hen manure as affected by surface area to volume ratio of the manure stack. All manure stacks had the same base area of 30 ft^2 but different heights of 2 to 31 inch. Air temperature in all chambers was held at 77°F, with a ventilation rate of 20 air changes per hour (ACH).

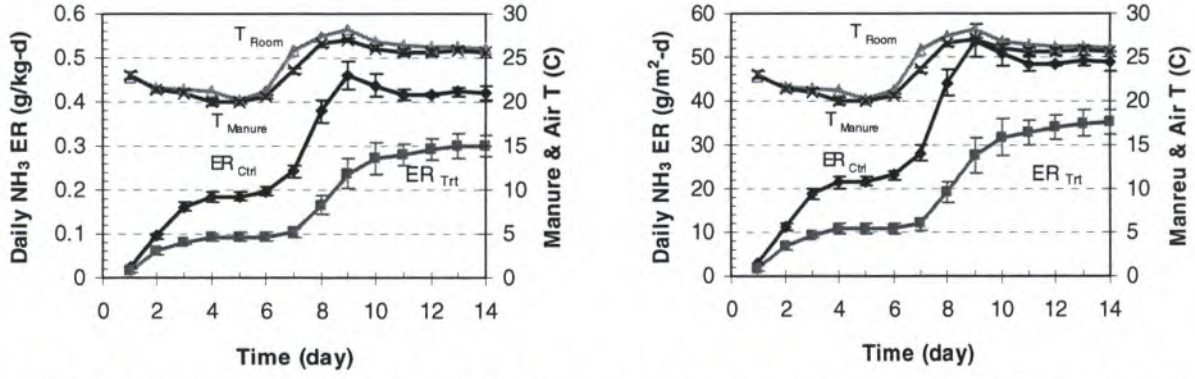

Figure 4. Daily ammonia emission rate (ER) and manure or air temperatures of stored laying hen manure using either standard (Ctrl) ration or the experimental Ecocal (Trt) ration.

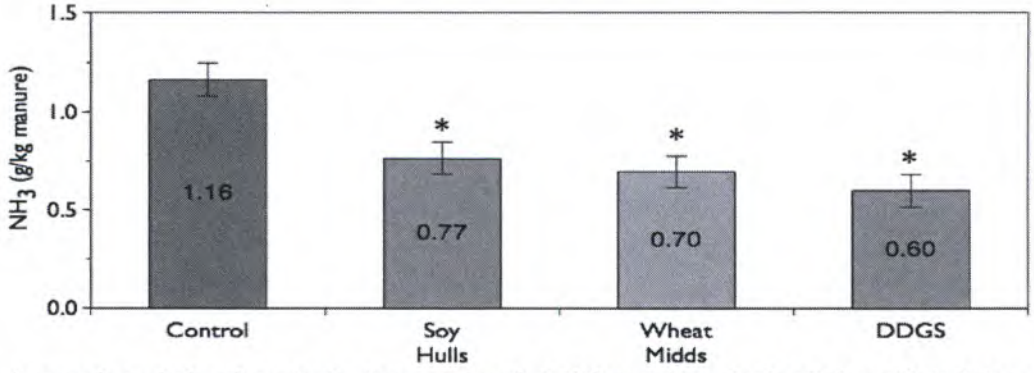

Figure 5. Ammonia emission from laying hen manure fed different diets during 7-d ventilated storage. Data are means ± pooled SEM, n=6. *Different from control (P<0.05) (Roberts et al., 2005).

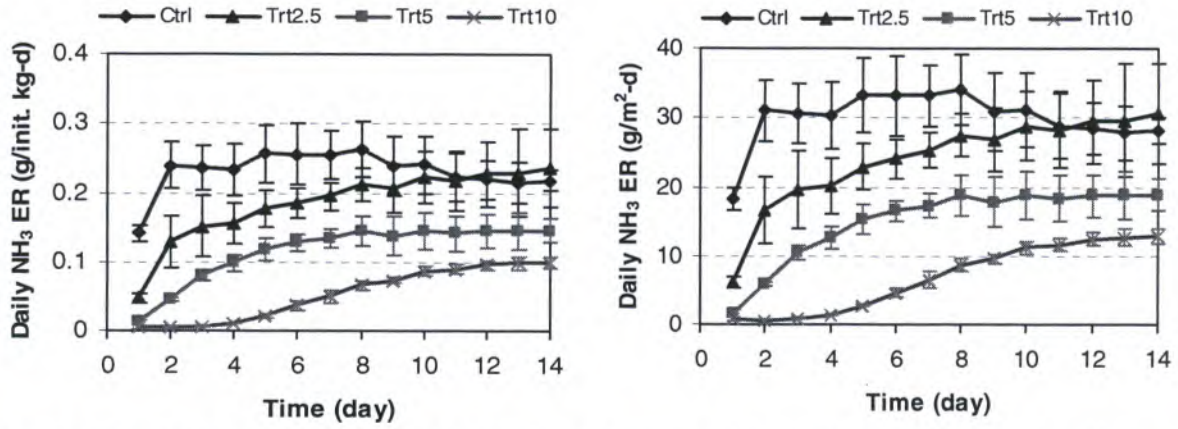

Figure 6. Daily NH_3 emissions of ventilated laying hen manure storage with various rates of *single* surface application of zeolite (Ctrl – no zeolite; Trt2.5 – 2.5% zeolite by weight; Trt5 = zeolite 5% by weight; Trt10 – 10% zeolite by weight).

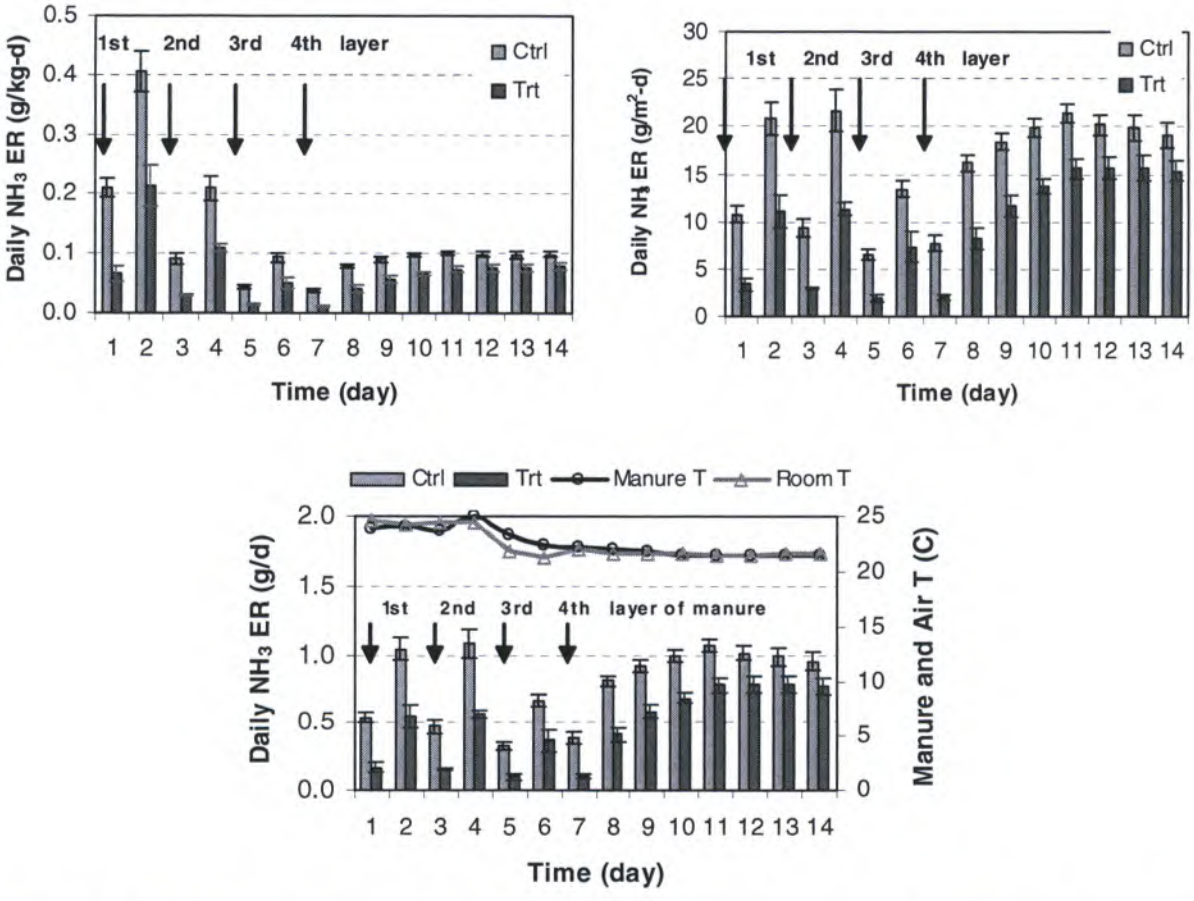

Figure 7. Daily NHB_{3B} emissions of ventilate hen manure storage, expressed in different units. Fresh manure was added and zeolite topically applied on day 0, 2, 4, and 6 (Ctrl = no zeolite; Trt = 5% zeolite by weight).

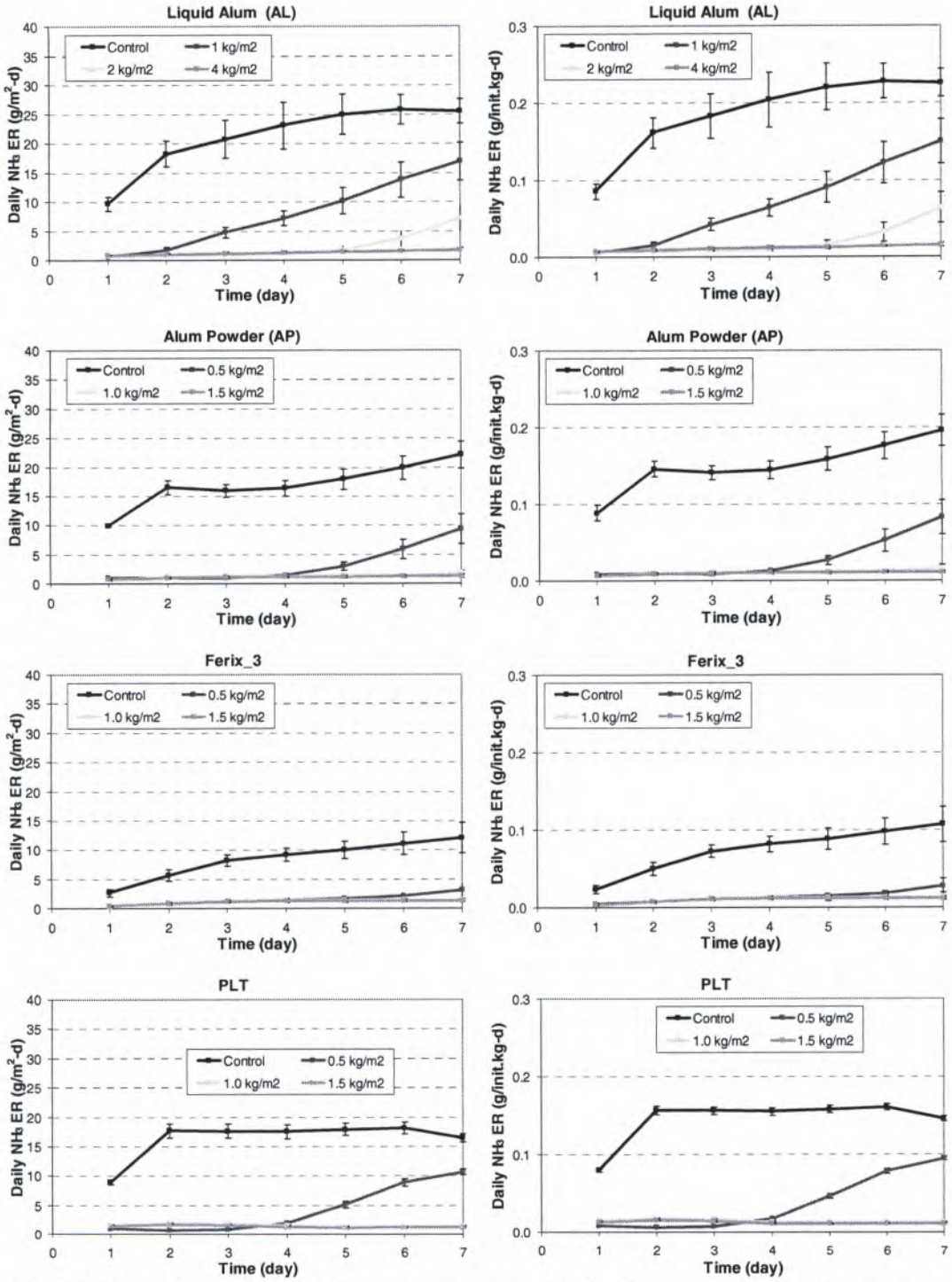

Figure 8. Daily NH_3 emission rate (ER) of ventilated storage of laying hen manure with different rates of topical application of liquid alum, powder alum, Ferix-3 and PLT.

METHODS TO REDUCE DUST IN BROILER HOUSES

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Introduction

Air quality relating to poultry production housing has been a major concern for years, particularly with regard to poultry health. Environmental concerns and nuisance issues related to poultry house air emissions are now issues affecting the poultry industry. Of specific concern are ammonia, particulate matter, and odor. While there is considerable research directed at defining the problem and scope of emissions, it is equally important that practical and economical control measures be examined.

Dust concentrations in poultry houses have been reported to vary from 0.02 to 81.33 mg/m^3 for inhalable dust and from 0.01 to 6.5 mg/m^3 for respirable dust [1]. Sources of dust in broiler houses include feed, down feathers, excrement, microorganisms, and crystalline urine [2]. There are a number of factors that affect dust levels in poultry houses, including animal activity, animal density and moisture conditions [1].

Several approaches can be used to reduce dust concentration in animal housing areas. These include adding fat to feed, fogging with water, fogging with an oil-based spray, ionization, electrostatic filtration, vacuum cleaning, filtration and recirculation, cleaning with wet scrubbers, purge ventilation, deep litter, and optimization of air inlet position. Reductions reported with these approaches ranged from 15 percent for weekly washing of pigs and floors, 23 percent with ionizers, to 76 percent with a rapeseed oil spray [3]. Other reports of ionizer efficiency have ranged from 31 percent [4] and 67 percent [5], to 92 percent [6]. Furthermore, studies have shown that reducing airborne dust levels by 50 percent can reduce airborne bacteria by 100 fold or more [7, 8].

The Electrostatic Space Charge System (ESCS) described by Mitchell and Stone [9] has been shown to significantly improve air quality by reducing airborne pathogens and disease transmission in poultry. The principle behind the ESCS is to transfer a strong negative electrostatic charge to airborne dust particles within an enclosed space. The negatively charged particles will then precipitate out of the air as they are attracted to grounded surfaces. Nitrogen compounds attached to the dust should also precipitate out of the air. In broiler breeder studies completed within a controlled research facility, ESCS technology showed reductions in airborne pathogens and bird-to-bird or bird-to-egg transmission by reducing airborne dust, ammonia, and total aerobic bacteria by an average of 60, 56, and 76 percent, respectively [10, 11, 12]. Airborne *Salmonella enteritidis* (SE) experiments conducted in controlled environment transmission cabinets with and without an ESCS showed chicks exposed to a naturally generated aerosol of SE beginning at one day of age had no cecal contamination 8 d later [13, 14]. Electrostatic fields have not been shown to produce adverse health effects in animals or humans [15, 16].

Field Study

A field study was conducted at the University of Georgia to determine whether a practical ESCS can be developed and operated in a commercial broiler production house for improving air in-house quality and subsequent reductions in emissions of dust and ammonia.

A custom-made ESCS system was designed and installed in a 500 ft x 40 ft tunnel ventilated commercial broiler house with drop ceiling. The treatment house (TH) system consisted of four rows of in-line, negative air ionization units; with two 200 ft rows on each side of the house in the brood end and two 200 ft rows in the growout end, as shown in FIGURE 1. Separate high voltage (-30 kVdc, 2 mA) power supplies were used to supply -25 kVdc to the ion generators in each half of the house. The in-line generators were installed on each end of the house such that it was centered between the center curtain (used for half-house brooding) and the evaporative cooling pads on one end and between the center curtain and the tunnel ventilating fans on the other end. Winches were used to raise the ESCS to a height of 7 ft above the litter (sufficiently high to walk under, but as low as possible to concentrate the charge near the birds where dust is being generated). A broiler house adjacent and essentially identical to the TH was instrumented for airborne dust and ammonia monitoring but operated as the control house (CH) without ionization. Both the TH and CH were operated simultaneously. The houses were set up to be as identical as possible and special efforts were taken to assure that treatment and control houses were operated at the same temperature and ventilation rate. Both houses were stocked at a density of 0.75 cu. ft per bird. Each house was initially bedded with pine shavings and the caked litter material around the feeders and drinkers was removed between each flock followed by a thin top dressing of new shavings.

Dust and ammonia concentrations, temperature and relative humidity readings were each measured at two sites within the house and approximately 4 ft above the litter in the center of the house. Dust concentrations were measured with a TSI DustTrak [17], a laser-based instrument with a range of 0.001 to 100 mg/m^3. Aerial ammonia was measured with a Draeger Polytron I [18] electrochemical sensor with a sensitivity range of 0 to 100 ppm. Data were collected for three sampling periods during each of seven flocks; during the first, third, and fifth weeks of production. Air samples were collected continuously for approximately 5 d during each period. Sampling frequency was once every 15 min for dust and every min for ammonia. The three sampling period means were then used to generate a flock mean concentration for dust and ammonia.

Bird performance (body weights and feed efficiencies), immune response, and microbial load of the house were not evaluated in this study.

Field Study Results

TABLE 1 contains the mean dust and ammonia concentrations and reduction efficiencies for aerial dust and ammonia for each of the seven consecutive flocks. The results of this study show that the use of the ESCS produced an overall airborne dust reduction of 43 percent in the TH. Aerial dust concentrations within the broiler houses were low and ranged from 0.2 to 1.9 mg/m^3. Charged dust could often be seen extending from the grounded water and feeder support cables in the treatment house. Besides reducing airborne dust, the ESCS likely inhibited aerosolization of dust by keeping surface dust near its source due to the negative space charge. Loose dust on the floor of a treated area will tend not to become airborne because as soon as it leaves the floor it would be charged and re-attracted to the floor. Long term exposure to airborne dust and pathogens in poultry houses has been associated with chronic respiratory problems for workers [19, 20], therefore, an additional benefit of reducing airborne dust and pathogens in poultry houses would be the improvement of air quality for workers.

Ammonia levels in the study houses ranged from an average of 11 ppm to 54 ppm with concentrations reduced by 13 percent with the ESCS (TABLE 1).

Examples of recorded data profiles of dust and ammonia concentrations for the fifth flock during the third week of the brooding period are shown in FIGURES 2 and 3. Aerial dust levels in the TH were consistently lower than in the CH.

While it is known that some ammonia and odors are sorbed to poultry house dust, it is not known what percentage of total ammonia production the sorbed fraction represents. Previous studies indicate that a significant portion of airborne ammonia in animal rearing facilities is associated with dust particles [21, 22]. An assumption in the present study was that reduction of airborne dust by the ESCS would result in a similar reduction in airborne ammonia, based on previous work with broiler breeders. In the present study with built-up litter over a period of one year, the ESCS did not appreciably reduce ammonia concentrations. The reasons for this discrepancy are not clear. It is likely that the amount of gaseous ammonia compared to that which is sorbed into the dust is much greater, resulting in less opportunity for overall ammonia reduction by a dust reduction system.

No differences in bird activity were observed in the form of decreased water consumption or increased mortality, and no adverse effects of the continuous charge were observed in the form of stray voltage or static discharge at the feeder and water lines. The incidences of static discharge to workers were minimal. The intensity of a discharge from direct contact with an ESCS ionizer was similar to touching a spark plug wire on a gasoline engine.

Dust collection on the ESCS and the subsequent need for cleaning was not a major issue. Brushing the dust from the equipment every 7 to 10 d was sufficient to maintain desired high charge levels from each unit.

The cost of materials and installation of the experimental ESCS unit was approximately $4,000. Power consumption of the entire system was less than 100 watts during operation.

Summary

Reducing airborne dust in enclosed animal housing has been shown to result in corresponding reductions in airborne bacteria, ammonia and odor. The search for strategies to reduce particulate matter and ammonia emissions from animal housing has led to considerable interest in the poultry industry for practical systems to reduce these air emissions. Results of this study indicate the ESCS significantly reduced airborne dust by an average of 43 percent. Commercial application of this technology within the production house has the potential to improve in-house air quality and reduce particulate emissions.

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TABLE 1. Efficiency of electrostatic space charge system (ESCS) for reduction of broiler house dust and ammonia concentrations.

Flock	Period	Dust Concentration Mean (mg/m^3)			NH_3 Concentration Mean (ppm)		
		CH[a]	TH[b]	Reduction %	CH[a]	TH[b]	Reduction %
1	Jan-Feb	1.13	0.60	46.9	44	38	13.6
2	Mar-Apr	0.48	0.27	43.7	54	46	14.8
3	May-Jun	0.14	0.09	35.7	24	19	20.8
4	Jun-Jul	0.49	0.36	26.5	20	17	15.0
5	Aug-Sept	0.47	0.23	51.1	12	11	8.3
6	Oct-Nov	0.63	0.38	39.7	31	27	12.9
7	Nov-Dec	1.10	0.44	60.0	51	47	7.8
Mean ± SEM		0.63 ± 0.030	0.34 ± 0.014	43.4 ± 0.913	34 ± 1.369	29 ± 1.187	13.3 ± 4.086

[a]Control House

[b]Treatment House

FIGURE 1. Electrostatic space charge system (ESCS) in-line ionization units hanging from the ceiling of the Treatment House (TH). Four units, two in the brood end and two in the growout end were hung on either side from the center of the house.

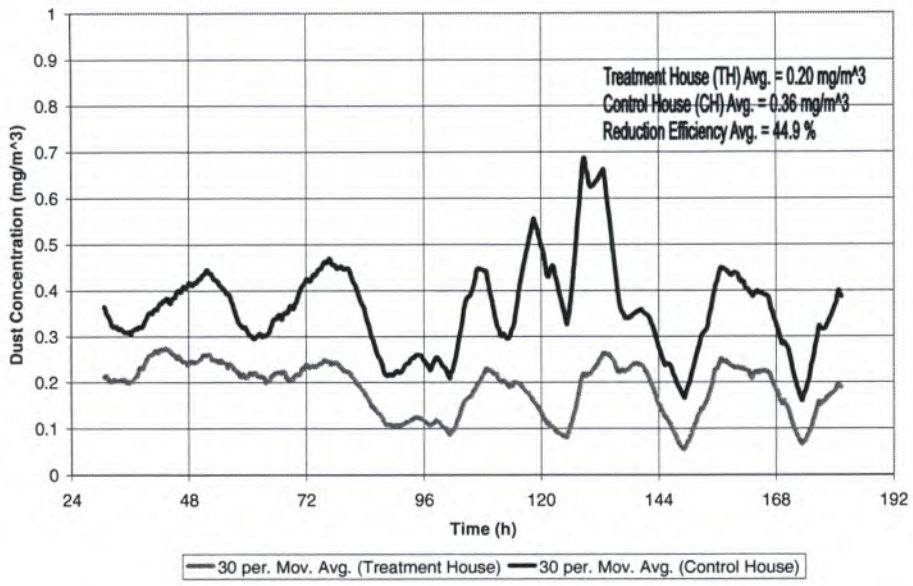

FIGURE 2. Data profile showing dust concentration comparison between Treatment House (TH) and Control House (CH) during brooding. Data are displayed as a 30-period moving average.

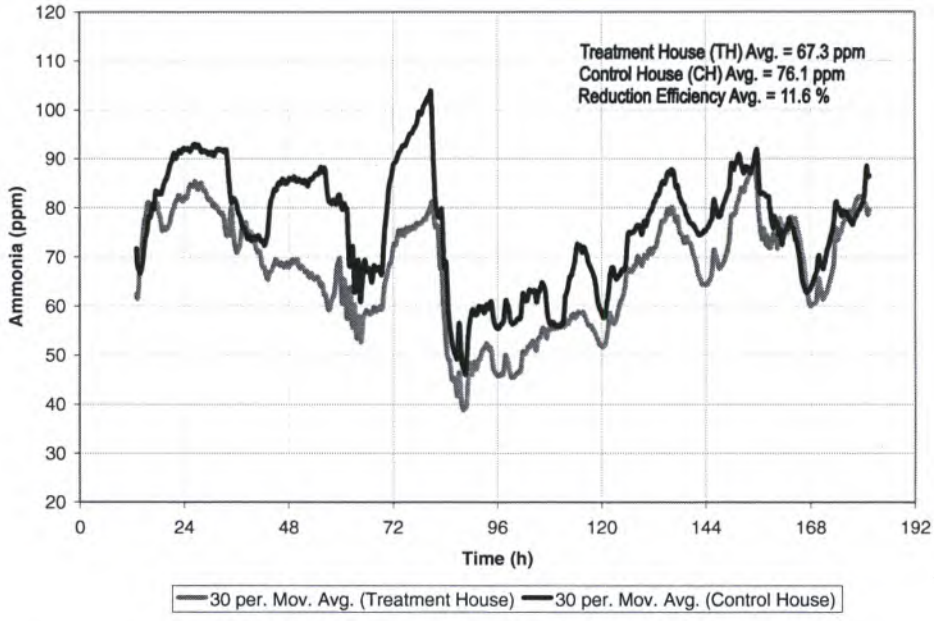

FIGURE 3. Data profile showing ammonia concentration comparison between Treatment House (TH) and Control House (CH) during brooding. Data are displayed as a 30-period moving average.

Animal Odor Assessment – Chickens, Cats, Pigs or Bats; it is Still Analytical Chemistry

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Abstract

Solving odor problems related to poultry operations can be achieved with analytical tools available to the food, beverage and consumer products industry. Past experience from crisis-driven odor investigations has shown that there is an odor impact priority ranking which is definable for virtually every odor emission source; natural or synthetic. An accurate definition of odorant priority rankings relative to a particular odor source is, in turn, critical to the development of accurate and objective instrument-based methods of odor analysis. Past and recent odorant prioritization efforts relative to a number of different animal sources has pointed up the importance of this understanding. As illustration of this importance, select case studies are presented relative to four of the animal species which have been the focus of odorant emission prioritization efforts by these authors. These efforts suggest, for example, that contrary to popular belief, downwind-at-distance odor impact is often led by a few high impact semi-volatiles; odorants of extreme odor potency but relatively low volatility. This situation, where shown to exist, has a direct bearing upon selection and optimization of sampling and analytical odor assessment protocols. Identification of these few target odorants responsible for the characteristic offensive odor is also critical for the development of effective odor control methods. We believe that these results serve to emphasize that odor assessment, whether sensory or instrument based, is still chemical analysis; subject to the same constraints and considerations of any other analytical procedure. Problems and advantages relative to various sampling strategies are presented with respect to these considerations.

P-INDICES: A SOUTHERN COMPARISON

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Introduction

Over the past thirty years, there have been trends in agricultural management practices that increase potential delivery of phosphorus (P) to water resources. In response to increases in P application, particularly from animal waste, the USDA-NRCS developed the P Index – a strategy to determine potential P loss from agricultural fields. Twenty-three states have adopted the P Index, either directly or with modifications from the original concept, 25 states use a combination of the P Index and/or environmental P threshold, and two states (California, and Connecticut) use STP crop response (Sharpley et al., 2003). The NRCS 590 practice standard, which includes the P-index option, allowed individual states to modify the original P-Index, and, thus, very few P Indices are exactly the same. The objective of this work was to compare the P-Index ratings from the 12 southern states for cropland (upland and drained) and pasture land scenarios.

Methods and Materials

All of the 37 factors used in the P Indices of the 12 southern states were compiled (Table 1). No state uses all factors. Scenarios were developed for pastures, cropped uplands, and "drained" or cropped or pasture bottomland mineral soils. Even though any number of variables could have been changed, we focused on four primary variables that we believed to be the most likely to affect P-Index ratings: soil test P (STP) (75 and 150 ppm Mehlich-3 P (M3-P)), poultry litter application rates (1, 2, 4, 6, and 8 ton ac^{-1}), the presence or absence of riparian buffers, and soil erosion rates (0.5, 1, 4, 8 ton ac^{-1}) as affected by tillage (pasture, conservation, minimum, or conventional). Broiler litter was selected due to the representation of the poultry industry in the South. Soil test P levels of 75 ppm M3-P are considered High for crop response and would not require additional P for optimum crop production; soil test P levels of 150 ppm M3-P are Very High. Not all states use M3-P soil test extractant, thus these states, such as FL, had to use conversion equations that they have developed (Mylavarapu et al., 2002.) Phosphorus-Index ratings were generated by each state for the three scenarios where possible.

Table 1. A general comparison of properties and factors associated with southern P Indices

FACTOR OR CONDITION	SOUTHERN STATES											
	AL	AR	FL	GA	KY	LA	MS	NC	OK	SC	TN	TX
	GENERAL PROPERTIES OF P TOOL											
Quantitative Index		x		x				x				
Qualitative Index	x		x		x	x	x		x	x	x	x
Factors added	x	x	x	x	x	x	x	x		x	x	x
Factors multiplied		x	x	x		x	x	x		x	x	
STP trigger					x							
Pasture only		x										
Crop, tillage, groundcover		x	x		x			x			x	x
County			x	x				x				
MLRA					x							
P SOURCE FACTORS												
Soil test P	x	x	x	x	x	x	x	x	x	x	x	x
Total P added	x		x	x						x	x	x
Source type			x	x		x	x	x			x	x
Source content		x				x	x	x			x	
Source soluble P		x		x				x				
Source moisture %								x				
Application method	x	x	x	x	x	x	x	x	x	x	x	x
Time of application		x		x	x	x	x		x		x	x
Amount of waste water applied			x									
Animals present	x	x										
P TRANSPORT FACTORS												
	AL	AR	FL	GA	KY	LA	MS	NC	OK	SC	TN	TX
Soil erosion	x	x	x	x		x	x	x	x*	x*	x*	x
Slope	x	x	x		x	x				x		x
Slope length										x		x
Distance to water resource	x		x		x	x	x	x	x		x	x
Buffer width	x			x	x			x		x	x	x
Buffer present		x										
Depth to water table			x	x		x						
Drain spacing								x				
Drain depth								x				
Underground outlet	x		x									
Flood potential		x							x			
Soil series/map unit			x	x								
Soil hydrologic group	x	x	x	x				x		x	x	x
Soil hydrologic condition		x						x				x
Soil runoff class		x								x		x
Soil permeability						x	x					
Receiving slope								x				x
Curve number		x		x				x		x		x
Depth of Soil									x			
Rock Fragments									x			
Rocks >10-inch diameter									x			
Precipitation		x						x				x
Other practices		x						x				
Watershed/stream Factors												
Impaired/protected	x				x	x			x			x

* Soil erosion determine without using RUSLE.

Results and Discussion

Pasture Conditions

The pasture comparison was the simplest scenario developed, with only three categories varied: STP, broiler litter rates, and the existence of a buffer. For the pasture conditions, some state P Indices were always Low (NC and MS) and two states were always high (KY and TX), indicating that the P Indices of these states were insensitive to the comparison values selected (Table 2). The remaining states had P-Index ratings that varied depending on conditions.

Table 2. Southern state P-Indices ratings for pastures.

Pasture Scenario Comparisons			**P-Index Rating**			
STP (mg kg^{-1})	**Broiler Litter (t ha^{-1}/ton ac^{-1})**	**Buffer**	**Low**	**Medium**	**High**	**V. High**
75	2	No	AL, FL, GA, LA, MS, NC, SC	AR	KY, TN, TX	OK
75	4	No	GA, LA, MS, NC,	AL, FL, SC	KY, TN, TX	AR, OK
75	6	No	GA, MS, NC	FL	KY, LA, SC, TX	AL, AR, OK, TN
75	6	Yes	GA, MS, NC, LA, SC	FL	AL, KY, OK TN, TX	AR
75	8	No	GA, MS, NC		KY, LA, FL, SC,TX	AL, AR, OK, TN
75	8	Yes	GA, MS, NC, LA, SC	FL	AL, KY, OK, TN, TX	AR
150	6	No	MS, NC	GA	FL, KY, LA, SC, TX	AL, AR, OK, TN
150	6	Yes	GA, LA, MS, NC,	FL, SC	KY, OK, TX	AL, AR, TN
150	8	No	MS, NC	GA	FL, KY, SC, TX	AL, AR, LA, OK, TN
150	8	Yes	GA, MS, NC	LA	FL, KY, OK, SC, TX	AL, AR, TN

At the lowest STP value (75 ppm M3-P), 2 ton ac^{-1} broiler litter application, and no buffer, only four states (KY, OK, TN, and TX) were rated at High or Very High (Table 2). When the broiler litter application rate was increased to 4 t ac^{-1}, the AR rating increased to Very High (Table 2). As litter rate increased further to 6 and 8 t ac^{-1}, the existence or lack of a buffer impacted the

ratings more than amount of litter applied when M3-P was at 75 ppm. When buffers existed, only AR had a Very High rating; when buffers did not exist, AL, AR, OK, and TN (6 and 8 t ac^{-1}) were rated at Very High.

When the effects of STP on P Index ratings were compared, higher STP (150 M3-P) had ratings very similar to the 75 M3-P when contrasted against the same litter application rate and without a buffer (Table 2). Comparisons of ratings between STP levels at the higher litter application rates revealed that two state ratings (AL and TN) shifted from High at 75 M3-P to Very High at 150 M3-P when a buffer was present. Generally, at the 150 M3-P, buffers had less impact in lowering ratings when all other variables were considered.

The states with the greatest rating changes were AL and LA. Alabama ratings varied from Low (75 M3-P, 2 ton ac^{-1} and no buffer) to Medium (75 M3-P, 4 ton ac^{-1} and no buffer) to High (75 M3-P, 6 t ac^{-1}, and a buffer), and finally to Very High (75 M3-P, 6 ton ac^{-1}, and no buffer). If, however, the receiving water resource had not been impaired, most of the ratings for AL would have been lower and less variable. Lack of a buffer moved the LA P-Index ratings from Low or Medium to High or Very High, depending on STP and litter rate.

Upland Crop Comparison

The upland cropped (corn) scenario uses similar comparisons to the pasture conditions. The same two STP levels were used (75 and 150 M3-P), as were two of the four litter rates (2 and 4 ton ac^{-1}), and presence or absence of buffers. Only 75 M3-P, 2 ton ac^{-1} and 150 M3-P, 4 ton ac^{-1} are discussed in this section. The primary difference between the pasture and upland conditions was tillage practice and the ensuing soil loss related to each tillage type: conservation tillage (1 ton ac^{-1}), minimum tillage (4 ton ac^{-1}), and conventional tillage (8 ton ac^{-1}). It was assumed that conservation tillage maintained at least 30% crop cover, minimum tillage left some crop cover, but not as much as 30%, and conventional tillage produced a clean seedbed. In addition to differences in soil erosion rates, tillage practices affected source application since conventional and minimum tillage afforded mixing of the litter and conservation tillage did not.

For all but the M3-P of 75 and buffers, the AL P-Index rating was always Very High (Table 3). The TN rating was fairly insensitive to STP, but very sensitive to litter and the presence of buffers. Florida's P-Index was insensitive to the majority of the comparison factors for upland cropping systems since most of the ratings were Medium. Kentucky ratings were generally insensitive to changes in STP, litter application rate, or tillage, as most ratings were High.

Ratings from the GA, LA, NC, SC, and TX P-Indices were variable depending on the scenario (Table 3). For the GA P-Index, all ratings for fields with buffers were Low regardless of STP, litter rate, and tillage. When no buffers were used at a litter application rate of 4 ton ac^{-1}, conservation tillage increased the P-Index rating to High or Very High, due to litter applications on top of the soil surface. Louisiana's ratings ranged from Low (STP 75, 2 ton ac^{-1}, buffer) to Very High (STP 150, 4 ton ac^{-1}, no buffer). North Carolina ratings were Low if a buffer was present, regardless of litter application rate, STP or tillage. If, however, the buffer was absent, STP, litter application rate and conventional tillage generally increased the rating to Medium or High. At lower STP and litter levels, buffers tended to lower ratings in the SC P Index by one rating level. Also, minimum tillage treatments tended to have lower ratings than the other tillage types. The TX P-Index ratings were High or Very High at 2 ton ac^{-1} regardless of buffer or tillage and varied depending on STP, tillage system, and litter rates. As the STP and litter rate increased, ratings moved from High to Very High for all tillage systems except conservation tillage. The STP level was more sensitive in this example than the litter rate.

Table 3. Southern state P-Indices ratings for different scenario conditions in well drained upland soils.

Cropland Scenario Comparisons				P-Index Rating			
STP mg kg^{-1}	**Litter (ton ac^{-1})**	**Buffer**	**Tillage**	**Low**	**Medium**	**High**	**V. High**
75	2	No	Conserv.	MS, NC	LA	KY, GA, SC, TX	AL, OK, TN
75	2	No	Minimum	GA, MS	FL, LA, SC, NC	KY, TX	AL, OK, TN
75	2	No	Convent.	GA, MS,	FL, LA, NC	KY, TX, SC	AL, OK, TN
75	2	Yes	Conserv.	GA, LA, MS, NC	SC, TN	AL, KY, OK, TX	
75	2	Yes	Minimum	GA, LA, MS, NC,	FL, KY, TN, SC	AL, OK, TX	
75	2	Yes	Convent.	FL, GA, LA, MS, NC	SC	AL, KY, OK, TN, TX	
150	4	No	Conserv.		MS, NC	KY, LA, TX	AL,GA, OK, SC, TN
150	4	No	Minimum		FL, GA, MS, NC	KY, LA, SC	AL, OK, TN, TX
150	4	No	Convent.		FL, MS, GA	KY, NC, SC	AL, LA, OK, TN, TX
150	4	Yes	Conserv.	GA, LA, NC	MS	KY, SC, TN, TX	AL, OK
150	4	Yes	Minimum	GA, NC	FL, KY, LA, MS,	OK, SC, TN	AL, TX
150	4	Yes	Convent.	GA, NC	FL, LA, MS	KY, OK, SC	AL, TN, TX

Note: The AR P-Index is only applicable to pasture conditions and, therefore, not included.

Summary and Conclusion

All Southern states developed state-specific P Indices to meet the USDA-NRCS Code 590 Practice Standard. The year that each index was finalized, however, differed. A number of states had their P Indices developed by 2000 or 2001: AL, KY, MS, SC, TN, and TX. Other states, such as LA and NC, were later in the development of their P Indices. Differences or similarities in the P Indices, however, did not reflect their development time period.

Most of the Southern P Indices are similar to the original one developed by Lemunyon and Gilbert (1993) as represented by the indices for AL, FL, KY, LA, MS, OK, SC, TN, and TX. These qualitative P-Indices include, however, modifications to reflect state-specific features. Three states, AR, GA, and NC chose to deviate entirely from the original P-Index concept by developing quantitative P Indices. The AR, GA, and NC P-Indices calculate P runoff losses in lb ac^{-1} $year^{-1}$. When a comparison of ratings was made for similar scenarios for the qualitative southern P-Indices, few behaved similarly to each other. The quantitative P Indices (AR, NC and GA) were just as variable between each other as they were when compared to the qualitative P Indices.

The rating differences between the P Indices for the same set of conditions demonstrate the flexibility of the USDA-NRCS 590 standard. Each state committee determined the factors it believed to be most important to P loss from agricultural fields within their state. Because these factors and the weighting associated with these factors varied by state, given the same scenario conditions, state P-Index ratings differed. Although the flexibility of the P-Indices results in differences in ratings across the southern states, it also allows for indices designed to match conditions and concerns from each state.

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EFFECT OF DIET AND PEN LOCATION ON SOLUBLE PHOSPHORUS IN MANURE

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Introduction

Modern intensive animal production can lead to more nutrients entering a region in animal feeds than may be exported in animal products. The excess P is normally applied to crop land, often at rates above crop requirements leading to the buildup of soil test P. Due to concerns over P losses from agricultural activities decreasing the quality of surface waters, some recent efforts have been directed towards decreasing the P in animal feeds and therefore P excreted in manure.

In a review article, Maguire et al. (2005) reported that feeding P closer to animal requirement could decrease total P in manure by up to 33% in poultry. Combining this with other feeding strategies, such as using phytase and high available P (HAP) corn, could decrease total P in poultry and swine by approximately 40%. Decreasing total P applications to agricultural land by reducing total P in manure will help control build up of soil test P in the long term. However, dietary strategies not only change the total P concentration in the manures produced, but also the forms of P that are present. Of particular concern is WSP in manures, as this has been linked to the potential for soluble P losses in runoff immediately after land application of manures (Smith et al., 2004).

Most dietary strategies have decreased WSP in the manures produced. Studies have shown that feeding P closer to animal requirements and HAP corn have consistently led to reductions in WSP in addition to decreasing total P, although the magnitude of decreases has varied between studies (Maguire et al., 2005). For example, Smith et al. (2004) reported that changing from normal to HAP corn in broiler diets decreased WSP by 35% and total P by 18%.

Objectives

Despite the recent research efforts focusing on decreasing dietary P, there is limited research available on the impact of diet modification on P in broiler breeder manure. Breeder manure accumulates for much longer than broiler litter and in a purer form (no dilution by bedding such as wood chips), due to the longer life and management of these birds. Therefore, this study was conducted to investigate the influence on WSP in broiler breeder manure of (i) reducing dietary P and using phytase, (ii) location in pens, as moisture is much greater under the drinker, and (iii) feed spillage.

Materials And Methods

Breeder Study

Ross 308 female and male Ross 344 broiler breeders were fed diets with or without phytase and 0.1% non-phytate phosphorus (NPP; from dicalcium phosphate) was removed from the phytase amended diets. High and Low available NPP diets were also evaluated, with the High diet being equivalent to the NRC (1994) recommendations and the Low diet created in a manner such that when phytase was added no supplemental NPP from dicalcium phosphate was required. This provided the four dietary treatments described in Table 1. Calcium level was maintained at 2.7% of the diet by weight by substituting calcium carbonate for dicalcium phosphate in the reduced P diets.

Table 1. Dietary phosphorus and phytase concentrations in broiler breeder feeds.

Diet name	Non-phytate P	Phytase	Available P†	Total P
	%	FTU kg^{-1}	%	
High	0.37	0	0.40	0.63
High + phytase	0.27	500	0.40	0.53
Low	0.19	0	0.22	0.45
Low + phytase	0.09	500	0.22	0.35

†Assumes that 500 FTU kg^{-1} of phytase makes 0.1% of phytate P available.

While not always well defined in animal feeding experiments, the dietary NPP and available P (AvP) content of diets fed to poultry have been determined not to be the same and have often been erroneously interchanged (Angel and Applegate, 2001). The use of the term AvP in this experiment represents the relative bioavailable P fraction as determined using a slope ratio assay with monocalcium phosphate as the reference standard (Soares, 1995). NPP was calculated by subtracting the analyzed phytate P content of ingredients from their analyzed total P content. The importance of differentiating between AvP and NPP was emphasized in data from Van der Klis and Versteegn (1996) that showed poultry to be capable of digesting a variable portion of the phytate bound phosphorus that differed considerably between ingredients. The general industry practice of maintaining the same level of AvP by replacing 0.1% NPP from monocalcium phosphate with 500 FTU of phytase was applied (Van der Klis and Versteegn, 1996). The phytase enzyme used was Allzyme® SSF (Alltech, Inc., Nicholasville, KY) with an analyzed activity of 1,098 FTU/g.

There were 6 Male and 60 female breeders placed in each 3.96 x 3.96 m pen, with each pen having a litter scratch area of one third of the pen and raised plastic slats for the remainder. Clean pine wood shavings were placed in the scratch area to a depth of 10 cm (4 inches) while no shavings were placed under the slats. There were five female tube feeders with male exclusion grills and one automatic waterer located above the slats, and one male tube feeder located over the scratch area. Birds were introduced to the pens after the 21 wk rearing period and stayed there for the 42 wk production period, during which time all manure generated accumulated within the pens. Each treatment was replicated four times, for a total of 16 pens. All eggs laid by the birds were collected twice daily and fertility determined by incubating sets of eggs periodically throughout the production period.

Manure Collection and Analysis

Immediately following removal of the birds at the end of the production phase, manure samples were collected from four locations in each pen (i) the scratch area, (ii) under the feeder, (iii) under the drinker, and (iv) around the edge of the pen away from the feeders and drinkers to avoid spillage effects of either feed or water. These samples were called 'scratch', 'feeder', 'drinker' and 'clean,' respectively. Moisture content was measured by drying subsamples at 105°C overnight. Fresh (undried) manure samples were then extracted for WSP at an equivalent dry weight: water ratio of 1:10. The extract was centrifuged at 1000 × *g* and filtered through Whatman #40 (Whatman, Maidstone, UK) filter papers. Phosphorus in the extract was measured by Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES). To determine total P, 8 mL of concentrated nitric acid was added to 2.5 g sample, dried on a steam plate, and combusted at 500°C in a Muffle Furnace overnight. Once the samples had cooled, 4 mL of 6N HCl was added, dried on a steam plate, then rehydrated with 4 mL of 6N HCl and warmed before being transferring into a volumetric flask and diluted with deionized water. The resulting solution was filtered through Whatman #40 filter paper, and then analyzed for P by ICP-AES.

Statistical Analysis

Manure samples from breeder laying pens were analyzed using a split-plot design with breeder treatment as the main plot and sample area within each pen as the sub-plot. Variations within pens in the breeder manure analyses was not considered in the calculation of differences between dietary treatments. Data were interpreted using the mixed procedure of SAS Institute (1998). Means were partitioned using LSMEANS and statements of statistical significance were based upon $P \leq 0.05$, unless otherwise stated.

Results And Discussion

Effect of Diet and Location in a Pen on Breeder Manure Parameters

Total Phosphorus

The breeder manure was diluted by wood chips in the scratch area, but not at any of the three locations under the slats. Therefore, it was not surprising that when total P was averaged across all diets, it was lowest in the scratch area (13 983 mg kg^{-1}) compared to the feeder, clean, or drinker areas under the slats (Table 2). The total P in the manures from under the slats was of a similar magnitude, but it was significantly greater under the drinker (30 446 mg kg^{-1}) than the clean location (26 893 mg kg^{-1}), with the manure under the feeder being intermediate (27 365 mg kg^{-1}). The greater moisture in the manure under the drinker (Table 2) may have increased microbial activity, reducing carbon content by driving off carbon dioxide and concentrating the remaining P. Increased microbial activity in manures with greater moisture content has been suggested by McGrath et al. (2005). Manure under the drinkers had turned black, which may indicate anaerobic conditions due to increased oxygen use by microbes. Manure was not black in any other location.

Table 2. Effect of breeder diet and spatial location on total P in broiler breeder manures.

Manure from diet	Location				Mean across locations
	Scratch	Feeder	Clean	Drinker	
			mg kg^{-1}		
High	16011† a	39110 a	34571 a	39671 a	32341‡ a
High + phytase	16772 a	29916 b	30701 a	34233 a	27905 a
Low	11735 a	20127 c	23019 b	24032 b	19729 b
Low + phytase	11413 a	20308 c	19281 b	23848 b	18713 b
Mean across diets	13983‡ c	27365 ab	26893 b	30446 a	

†Values in the same column followed by different letters are significantly different at the 0.05 probability level.

‡Means across Locations or Diets followed by different letters are significantly different at the 0.05 probability level.

When averaged across locations, total P in the manure decreased in the order High P (32 341 mg kg^{-1}) > High P + phytase (27 905 mg kg^{-1}) > Low P (19 729 mg kg^{-1}) > Low P + phytase (18 713 mg kg^{-1}) (Table 2). This trend applied to all locations, with minor exceptions probably due to sample variability. The manures from the phytase diets on average had numerically lower total P (14% for the High P diet and 5% for the Low P diet). However, dietary phytase had no significant effect on manure total P, probably due to the variability between pen locations. Other researchers have shown that dietary phytase significantly decreased manure total P in poultry, when NPP supplements were decreased to allow for phytase increasing phytate-P digestibility. For example, Applegate et al. (2003) reported phytase decreased total P in broiler litter by 24%. For turkeys, Angel et al. (2005) showed that dietary phytase decreased total P in litter by 45% and Maguire et al. (2004) reported a drop in litter total P of 7 to 24%. The only significant differences in our study were between the High P and Low P

diets, unrelated to whether or not dietary phytase was included (Table 2). This showed the importance of feeding P closer to the birds requirement by decreasing overfeeding of supplemental inorganic dietary P.

Total P in manure is important in the long term, as it is the total manure P application rate that determines long term trends in soil test P (Sims et al., 2000). Total P is particularly important when manures are applied on N-based nutrient management rates, which is the normal practice in many areas. Therefore, decreased manure total P through diet modification will be environmentally beneficial in the long term, regardless of whether achieved through feeding phytase to replace some supplemental dietary P, or minimizing overfeeding of P.

Water Soluble Phosphorus

Water soluble P varied greatly across location and diets, from a minimum of 473 mg kg^{-1} for the Low P diet in the scratch area, to a maximum of 1899 mg kg^{-1} for the High P diet under the drinker (Table 3). Across all diets, WSP was greatest in manure from under the drinker and lowest in the litter from the scratch area, which followed the same pattern as manure moisture (Table 4). When averaged across all diets for each location, WSP in the manure significantly decreased in the following order: Drinker (1279 mg kg^{-1}) > Feeder (912 mg kg^{-1}) ≈ Clean (907 mg kg^{-1}) > Scratch (661 mg kg^{-1}). McGrath et al. (2005) reported similar results, and attributed this to elevated microbial activity resulting in the degradation of usually insoluble P forms such as phytate P. As manure under the feeder had similar WSP to the manure in the clean area, spilled feed appeared to have had no effect on manure WSP. This agrees with Maguire et al. (2006) who stored manure with and without spilled feed and found that spilled feed had little effect on WSP. As soluble P in runoff from manured soils has been linked to WSP in manures (Smith et al., 2004), this shows the potentially large impact that dietary P and bird pen management can have on controlling P losses in runoff. The elevated WSP in manure from under the drinker emphasizes the importance of reducing manure moisture levels by implementation of water restriction programs in broiler breeders combined with dietary feed formulation strategies to reduce urinary water losses.

Table 3. Effect of breeder diet and spatial location on water soluble P in broiler breeder manures.

Manure from diet	Location				Mean across locations
	Scratch	Feeder	Clean	Drinker	
	mg kg^{-1}				
High	950† a	1385 a	1030 a	1899 a	1316‡ a
High + phytase	740 ab	843 b	938 a	1237 b	940 b
Low	473 b	710 b	746 a	1045 b	743 b
Low + phytase	479 b	711 b	916 a	935 b	760 b
Mean across diets	661‡ c	912 b	907 b	1279 a	

†Values in the same column followed by different letters are significantly different across diets at the 0.05 probability level.

‡Means across Locations or Diets followed by different letters are significantly different at the 0.05 probability level.

Table 4. Effect of breeder diet and spatial location on moisture content of broiler breeder manures.

Manure from diet	Moisture†	Position	Moisture†
	%		%
High	41.4 a	Scratch	15.6 d
High + phytase	46.3 a	Feeder	38.5 c
Low	42.1 a	Clean	52.2 b
Low + phytase	45.1 a	Drinker	68.6 a

†Values in the same column followed by different letters are significantly different at the 0.05 probability level.

Most research has shown that dietary phytase either decreased or has no significant effect on WSP in manures (Maguire et al., 2005). This study had four locations and two levels of available dietary P with and without phytase, making for eight possible comparisons of equivalent manures from diets with and without phytase (Table 4). Out of these eight comparisons, dietary phytase significantly decreased WSP twice (under the Feeder and Drinker for the High P diet), and had no significant effect on the other six comparisons. When averaged across all pen locations, phytase significantly decreased WSP for the High P diet (from 1316 mg kg^{-1} to 940 mg kg^{-1}), but had no significant effect on the Low P diet. Therefore, these results suggest that dietary phytase will not increase soluble P losses in runoff following land application of broiler breeder manure, and may even decrease them for manure applied on an equivalent mass or nitrogen basis.

The four locations and two levels of available dietary P with and without phytase also make it possible to have eight comparisons where supplemental P was reduced to feed P closer to the birds requirement (High P vs. Low P and High P + phytase vs. Low P + phytase for all four locations). For all of these comparisons, the manure from the Low available P diet had numerically less WSP than the manure from the equivalent High available P diet, and these decreases were significant on three occasions. When averaged across all locations, WSP decreased in manures from the High P (1316 mg kg^{-1}) to the Low P (743 mg kg^{-1}) diets, but there were no significant differences for manures from the High P + phytase and Low P + phytase diets. These equivalent manures from High P and Low P diets were achieved by removing some supplemental dicalcium phosphate from High P diets. As this consistently decreased manure WSP, it shows the importance of minimizing supplemental dietary inorganic P to help reduce WSP losses in runoff following land application of manure. Consistent decreases in manure WSP of 21 to 52% when supplemental dietary P was removed have also been reported for broilers and turkeys (McGrath et al., 2005; Maguire et al., 2004).

Relationship Between Water Soluble P in Manures and Their Moisture Content

When the moisture for all locations within a pen was averaged by treatment, diet had no significant impact on manure moisture (Table 4). However, when the consolidated samples were collected for the storage part of this study from the total pen cleanout and moisture determined on four replicates, there was significantly ($P < 0.01$) more moisture in the manures from the phytase diets. No results for the effect of phytase on manure moisture content are available in the literature, so this observation deserves more study. The moisture content of the breeder manure for the four locations significantly decreased in the following order: drinker (69%) > clean (52%) > feeder (39%) > scratch (16%) (Table 4). The higher percentage moisture of the breeder manure collected from under the drinker can be explained by spilled water dropping onto the manure beneath it.

Despite differences in dietary P, when WSP in manure from all diets and all pen locations was plotted against manure moisture content, there was a significant ($P < 0.001$) positive relationship (Fig. 1). Therefore, increased manure moisture led to greater manure WSP. However, the regression coefficient was relatively low (0.23), almost certainly due to the different concentrations of P in the diets fed to the broiler breeders. This again demonstrates the importance of preventing water spillage from drinkers, which was the single main factor that increased manure moisture and hence WSP.

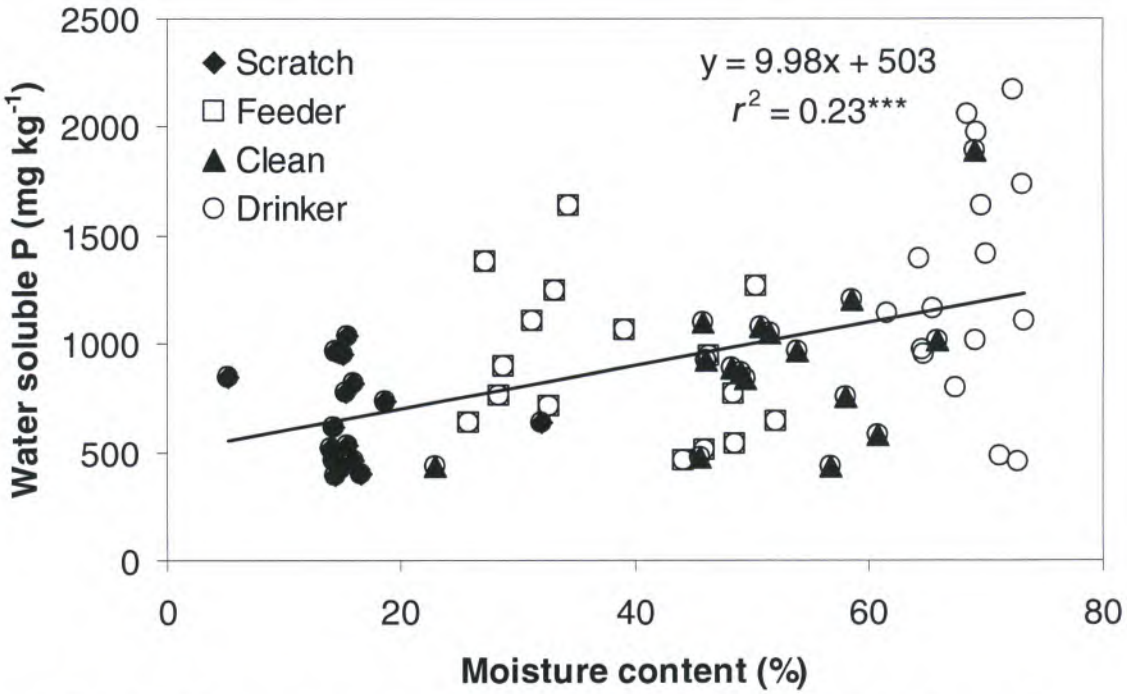

Figure 1. Relationship between water soluble P in manure samples from all locations in the pens and their moisture content.

Conclusions

With increased intensification of animal production and concerns over P losses from manured soils, reducing dietary P represents a cost-effective way to decrease excreted P. However, there are many interactions between changes in dietary P, bird management, and total and WSP in manures produced to be considered. Several studies have reported that total P in manure can be decreased through diet modification. The present study showed that combining feeding P closer to bird requirements and phytase led to a 42% decrease in total P. As the total P applied in manure controls long term changes in soil test P, diet modification can therefore address concerns over long term build up of P in soils by decreasing P excreted. However, manure WSP is an indicator for soluble P losses in runoff immediately following land application of manure. We found that water management within pens greatly affected WSP, as spilled water led to elevated moisture under the drinker and this location was where WSP was greatest. Therefore, all efforts should be made to maximize drinker efficiency to minimize spillage and hence manure WSP. Feeding to the P requirement consistently decreased WSP, and phytase either decreased or had no significant effect on manure WSP. Comparing manure from under the feeder to manure from a clean area away from the feeder, showed that spilled feed does not have a great effect on manure WSP even when the feed contained phytase. Therefore, all efforts should be made to encourage implementation of reduced P diets and improve water management to decrease concerns over the environmental impact of manure applications.

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FECAL SOURCE TRACKING FOR WATER QUALITY

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Coastal and inland waters are becoming increasingly impaired by fecal pollution (6). Water resources are constantly monitored by federal and state agencies. When routine water sampling results show unacceptable levels of sentinel indicators, indicative of fecal pollution, bacterial source tracking (BST) is often performed to predict the sources of contamination. A remediation plan can then be developed to decrease pollution and return the subject water resource to compliance with official water quality standards. EPA standard limits for recreational water are 200 fecal coliforms (FC) or 126 *E. coli* per 100 ml of fresh water and 33 *Enterococci* per 100 ml of salt water (1).

Examples of potential sources of fecal pollution are: human sewage; concentrated animal feeding operations; pastured animals; pet animals; migratory birds; and wild animals. Feces contains pathogenic (disease producing) microbes, which are normally scarce, and non-pathogenic organisms, which are much more numerous. Examples of generally non-pathogenic bacteria are fecal coliforms and *Escherichia coli* (*E. coli*) which normally inhabit the intestinal tract of humans and nonhumans. *E. coli* is a commonly used indicator.

Pollution of water with human and animal waste represents a public health risk. Since human feces are generally considered as the greater risk, an initial question is whether human waste is involved or not. Beyond that level of concern there is the need to distinguish and identify the various nonhuman sources. *E. coli* are often used to accomplish this "fecal source tracking". Particular strains of *E. coli* inhabit the various hosts - human and nonhuman. These "host-specific" strains can be distinguished by their different biochemistry (function/phenotype) or different genetic/DNA structure (genotype). BST can be performed based on phenotype (7) or genotype (5). Our laboratory routinely uses two genotypic methods to predict host sources of fecal pollution. The first is DNA fingerprinting by rep-PCR (5). There are multiple copies of the target gene, located in varying positions in the genome/chromosome of *E. coli* which come from humans and animals. The rep-PCR method generates millions of segments of DNA representing the spaces between the target genes. The final mixture of segments, of various lengths, is separated by electrophoresis in slabs of agar gel. The result is DNA fingerprints or signatures of the isolated *E.* coli strains that are represented. This method requires initial formation of a known-host database, or library of fingerprints, which resemble bar-codes. Fingerprint patterns from *E. coli* isolates, derived from environmental water samples, are then compared with a database of patterns for host-of-origin assignment by computer analysis.

The second method, used in our laboratory for BST, is a library-independent procedure based on a specific gene that occurs in a fecal bacterium that is considered to be host-specific. Our particular method targets *Bacteroides*, which are the most numerous bacteria in human feces (8). The *Bacteroides* group of bacteria has been successfully used as the source of host-specific target genes (3). We specifically target *Bacteroides thetaiotaomicron* (B. tim), which is considered to be a human–associated species (9). The PCR method is indicative of the presence or absence of human feces in a water sample (4).

The Shoal Creek watershed, in the extreme southwest corner of Missouri, is used in this presentation as an example of field application of the rep-PCR method for fecal source tracking (2). Shoal Creek is located in one of the most agriculturally productive parts of the State. The watershed consists of 91,000

acres, of which 90% is pasture land, grazed by cattle and fertilized by spreading poultry litter. We examined Shoal Creek water for evidence of pollution by cattle, domestic animals (horses and dogs), poultry, human and wildlife waste. The major source of pollution was found to be cattle in the streams. Runoff, which contained cattle manure and poultry litter, was a significant but less dominant source. Poultry litter became more evident as a source of pollution during rain events. There was also evidence of human and wildlife contributions. In our experience, there are usually multiple host-sources associated with each instance of water pollution.

Bacterial source tracking is a powerful water quality tool to resolve questions related to high bacterial counts. Results must be interpreted carefully and preferably related to serial samples collected over a period of time.

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WILL FEED MANAGEMENT OPTIONS WORK FOR THE POULTRY INDUSTRY? WHAT HOLISTIC TOOLS ARE AVAILABLE?

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Introduction

This paper and its companion presentation will provide you with an understanding of a national education project that has been funded by the USDA-Natural Resources Conservation Service. The full title of the project is "Feed Management – Resources and Livestock in Balance: A National Education Program for Technical Service Providers and Animal Nutrition Consultants". Simply stated, the primary goal is to develop a systematic approach for consultants and advisers to assist owners and managers of livestock and poultry operations in adoption of feed management practices that will be profitable and contribute to protection of the environment. A secondary goal is to provide the infrastructure where Feed Management can be financially supported by NRCS incentive programs.

A Bit of History - The US Environmental Protection Agency (EPA) released new guidelines for Concentrated Animal Feeding Operations and Animal Feeding Operations (CAFO/AFO) in 2003. Under the new guidelines, permitted CAFO/AFO's will be required to develop a Nutrient Management Plan (NMP). One form of a NMP is a Comprehensive Nutrient Management Plan (CNMP) as defined by the Natural Resources Conservation Service. There are six core elements of a CNMP: 1) Feed Management, 2) Manure and Wastewater Handling and Storage, 3) Nutrient Management, 4) Land Treatment, 5) Record Keeping, and 6) Other Manure and Wastewater Utilization Options. Livestock and poultry operations defined as permitted CAFOs are required to have a NMP by December 2006. For those that choose to develop a CNMP, there will be an immediate need for an understanding of the Feeding Management element of the CNMP.

Feed is the Major Route for Nutrient Import to the Farm - Feed represents the largest import of nutrients to the farm, followed by commercial fertilizer. Feed Management opportunities currently exist to reduce imports of nutrients, particularly nitrogen and phosphorus, to most animal livestock and poultry operations.
Feed represents the largest import of nutrients to the farm, followed by commercial fertilizer (Klopfenstein at al.,2002). Feed Management opportunities currently exist to reduce imports of nutrients, particularly nitrogen and phosphorus, to most animal and livestock operations. The technologies and approaches to achieve these reductions vary in their degree of economic

feasibility and environmental impact. It is important that agricultural professionals understand the degree of success that can be expected both from an economic and an environmental standpoint.

Whole Farm Import of Nutrients - Figure 1 depicts the concept of whole farm nutrient management. Ideally the goal is for the input to equal the output from the farm. This is rarely the case because only ~ 32 to 51 % of feed input of N are exported in meat or eggs.

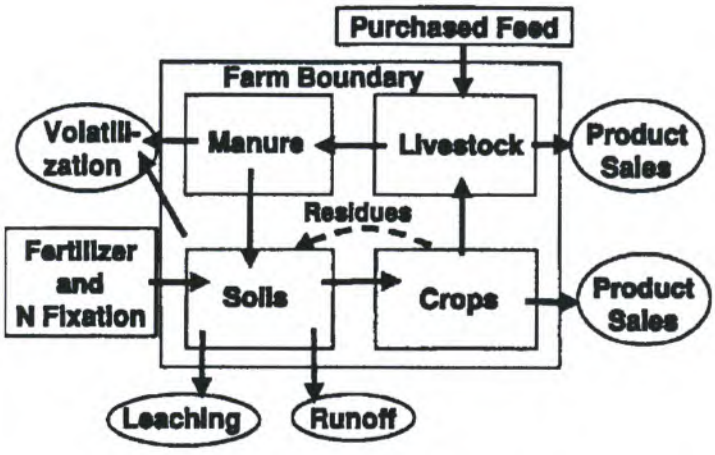

Figure 1. Schematic depicting the concept of whole farm nutrient management. Ideally, inputs = outputs.
Source: Nelson (1999).

The National Feed Management Project - In 2005, a group of Universities (Washington State University, University of Idaho, Oregon State University, Texas A&M, University of California – Davis, University of Nebraska, Purdue University, Iowa State University, Cornell University, Virginia Tech, and the University of Georgia) were funded by the NRCS for an implementation project entitled "Development and Integration of a National Feed Management Education Program and Assessment Tool into a CNMP"(short working title).

The goal of the project is to increase the understanding of agricultural professionals about the area of Feed Management, with an emphasis on Environmental and Financial Sustainability of Livestock and Poultry Operations. The primary audience for the education program will be: 1) Animal Nutritionists, and 2) NRCS staff and Technical Service Providers and advisors. The NRCS and ARPAS have established a memorandum of understanding which identifies ARPAS members as the appropriate professional to develop a feed management plan.

The national version of the NRCS 592 Feed Management Practice Code can be found at http://www.nrcs.usda.gov/. The primary purposes of the 592 Standard are: 1) supply the quantity of available nutrients required by livestock and poultry for maintenance, production, performance, and reproduction; while reducing the quantity of nutrients, especially nitrogen and phosphorus, excreted in manure by minimizing the over-feeding of these and other nutrients, and 2) improve net farm income by feeding nutrients more efficiently.

The Feed Management project team is in the process of developing species-specific tools and education materials to provide training across the US for both consulting nutritionists as well technical service providers and NRCS staff (see Feed Management 592 Implementation Decision Flow Chart). A key outcome that will be used by nutritionists will be species-specific on-farm implementation checklists which can be used to gather the information needed to develop a Feed Management Plan. We are working closely with NRCS to develop payment rates for implementation of the 592 Feed Management Standard so that there is both an incentive for the consultant as well as the livestock and poultry producer.

Educational training is planned in a format of 4-hour workshops with follow-up on-line training for specific electronic tools and spreadsheets. A flow diagram is noted at the end of this paper that indicates the 5 steps involved with making a decision about development of and implementation of a Feed Management Plan.

Consider these Feed Management Practices – There are a number of proven Feed Management practices that can reduce the amount of nutrients excreted in manure and include: controlling feed wastage, monitoring the mineral content of water, feed processing to increase digestibility, use of enzymes such as phytase, reduced protein and amino acid supplementation, split sex feeding, growth promotants, and phase feeding.

Summary - Development of Feed Management Plans is a new opportunity for the Poultry industry. We encourage you to embrace this opportunity and assist poultry producers to remain economically viable and environmentally responsible.

Contact the Project Team – The Feed Management Project Team can be contacted at the following e-mail addresses: Overall Project Director - Joe Harrison, jhharrison@wsu.edu; Project Manager, Becca White, rawhite@wsu.edu; Poultry Lead - Todd Applegate, applegt@purdue.edu; Curtis Novak, cnovak@vt.edu , Casey Ritz, critz@uga.edu.

CNMP* Activity → **Feed Management 592 Implementation Flow Chart**

Step 1) Determine purpose *(TSP and Producer)*

Step 2) Identify conditions where practice applies and assess the Opportunities *(TSP and Producer)*

Step 3) Economic evaluation *(TSP, Nutritionist Producer)*

Step 4) Feed management plan development *(Nutritionist and Producer)*

Step 5) Implement and monitor *(Nutritionist and Producer)*

Feed to minimize excess nutrients in manure while maintaining production, performance, and reproduction

Conditions where practice applies:
1) Whole farm imbalance
2) Soil nutrient build-up
3) Land base not large enough
4) Seeking to enhance nutrient efficiencies

If one or more apply, continue on to next step

Determine the FM opportunities for addressing resource concerns
Use Opportunity Checklist (NRCS, TSP may want to collaborate with nutritionists)

Little opportunity for FM to address resource concern, no FMP developed

Consider other opportunities of the CNMP:
1) Manure and waste water handling and storage
2) Nutrient management
3) Land treatment

Opportunities exist for FM to address resource concern

Feed to improve net farm income by feeding more efficiently.

Conditions where practice applies:
Seeking to enhance nutrient efficiencies

If applies, continue on to next step

Determine the FM opportunities for improving net farm income
Use Opportunity Checklist (NRCS, TSP may want to collaborate with nutritionists)

Opportunities exist for FM to improve net farm income

Little opportunity no FMP developed

Evaluate options based upon:
- Economics of feed change (*Nutritionist*)
- Economics and time requirements for manure transport (*NRCS, TSP and Nutritionist*)
- Land access requirements including costs (rent lease or purchase) (*Producer*)

Transport manure or increasing land base more profitable- no FMP

Ration change more profitable

Nutritionist utilizes the FMP Checklist to develop & complete FMP

Nutritionist communicates ration change to TSP as it relates to changes in manure excretion

Nutritionist and producer work to implement and monitor FMP

*CNMP= Comprehensive Nutrient Management Plan; FMP= Feed

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LAND USE ISSUES AND FUTURE DIRECTIONS OF THE POULTRY INDUSTRY

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Introduction

Poultry production in the United States has been one of the leading agricultural growth industries since the early 1950's. To meet the demands for more poultry products, producers and poultry companies across the country have expanded their operations by building more production and processing facilities. At the same time, states have experienced increased urbanization and loss of agricultural lands in many of our rural counties. As cities have become more crowded, many people have moved to the country to satisfy their desire for a more serene and idealistic lifestyle. Unfortunately, many of these individuals understand little about modern commercial farming practices and, as a result, tend to be intolerant and unaccepting of livestock farming practices that sometimes result in dust, odors and insect pests. This unfortunate set of circumstances is leading to increased conflict between farmers and citizens who have little prior exposure to agricultural operations. More and more often, poultry producers are finding it difficult to operate or expand their operations with new production facilities because of local opposition to animal agricultural. What is surprising is that these conflicts are occurring in some of our most rural counties as well as in more populated areas.

Nuisance Complaints

Opponents of poultry farming will often use allegations of perceived nuisance issues as a means of trying to stop construction or operation of a production facility. Individuals using nuisance issues to attack poultry operations do so because these types of allegations are often emotionally charged and are very effective in offending aesthetic sensibilities. Often these negative perceptions are due to a lack of accurate knowledge of modern poultry farming and/or a general intolerance of any inconvenience that might be caused by livestock production. In some cases individuals will deliberately distort facts by using information out of context that they believe will advance their cause. Many of the most contentious debates related to nuisance complaints revolve around what I refer to as the **three common myths of poultry farming** (Cunningham, 2006).

Myth # 1. Poultry Farms Will Ruin the Environment. Opponents of poultry farming will often contend that environmental pollution is a major problem associated with poultry farming. It is not unusual for individuals using this argument to seriously distort the truth regarding this issue. Poultry farms do produce manure nutrients as by-products of growing birds and these nutrients have the potential, like any fertilizer material, to cause water pollution problems if improperly handled. These manure nutrients, however, have substantial value as organic fertilizer and are often applied as a replacement for commercial fertilizers. The application of these manure nutrients via the use of nutrient management plans that address the appropriate application rates for both nitrogen and phosphorous utilization allows poultry producers to maximize the value of the fertilizer components while simultaneously protecting the environment. Thus, a properly managed poultry farm should not pollute or cause environmental problems for neighbors or the community.

Myth # 2. Poultry Farms Smell and Produce Flies. Poultry farms will produce some odors and flies. It is impossible to operate a livestock production farm without having some odor or fly production, however, individuals using this argument often contend that poultry farms smell so badly and produce so many flies that no one can live near them. This is not the case for the vast majority of modern well-managed poultry farms. The dry conditions created in tunnel ventilated broiler and pullet houses keeps odors and fly production to a minimum. Occasionally wet conditions occur in these types of houses, but these problems can usually be corrected with changes in management or equipment. The odors associated with poultry production are most often associated with clean out. The odor from cleanout and litter application is, however, temporary and depends a lot on weather conditions. Appropriate management practices for litter application can reduce the occurrence and impact of this annoyance, but will not eliminate it . Breeder houses represent more of a challenge with regard to odor control and fly production because of the wet conditions that occur more frequently in these facilities. Until we develop new design concepts for breeder houses or improved management programs that will reduce the wet manure conditions, these facilities will continue to be sources of complaints in the future.

Myth # 3. Air Exhausted from Poultry Houses Damages Property and Causes Health Concerns. The adoption of the tunnel ventilation system for poultry houses which places all of the exhaust fans at one end of the house and concentrates the exhausted air has led to the perception that these fans can cause problems for neighbors. The purpose of the tunnel ventilation system is to bring more fresh air into the house and move it at a faster rate to cool the birds. These systems have been very effective in reducing the negative effects of hot weather on the growth and mortality of birds, but tunnel ventilation does result in a more concentrated and noticeable exhaust from the house. The force of exhausted air from tunnel ventilation fans, however, only extends about 50 feet from the house before it can no longer be measured. Recent studies at the University of Georgia measuring particulate matter and ammonia outside of poultry houses suggest that dust concentrations and ammonia levels at 300 feet down wind of broiler facilities do not differ from the normal background concentrations upwind from these buildings (Visser *et. al.*, 2006). Data of this nature is very beneficial to growers being sued for perceived nuisance and/or health complaints from neighbors. This important research is continuing and more studies are needed to separate fact from fiction and to protect growers from lawsuits.

One issue that does suggest a potential problem with air emissions from poultry houses relates to a study of the incidence of pitch canker disease in slash pine trees (Barnard *et. al.*, 2005). This study has suggested that the incidence of pitch canker in slash pines is greater in stands of trees near poultry houses. Pitch canker is a fungal disease of slash pines that can be exacerbated by excess N fertilization. Ammonia released into the atmosphere from poultry houses seems to be dispersed during typically unstable daytime atmospheric conditions within a few hundred feet of the houses. However, during evening or night time when atmospheric conditions may be more stable, the air may be held closer to the ground resulting in higher ammonia concentrations. This possible increase in ammonia concentration during these periods of stable air conditions may be a contributing factor in the increased incidence of pitch canker in slash pine stands. As a result of this pitch canker report, legal actions against poultry operations near pitch canker affected stands of slash pine are increasing. More research in this area is needed to determine the cause(s) and effect(s) of this disease and the relative contribution, if any, of poultry house emissions. Although this disease and set of circumstances surrounding it is very specific to one particular type of pine tree, it is of great concern because of the potential for those opposed to poultry production to use the results to blame poultry house emissions for other unrelated problems.

Terrell et al v. Payne et al. (Case # S05G0238). Unfortunately, nuisance complaints related to poultry too often end with legal action. Legal action is expensive and always risky, because one never knows how a judge or jury might decide a case regardless of the facts. A recent case in Georgia demonstrates the difficulties that a lawsuit can bring in resolving an issue. In the Georgia case of **Terrell v. Payne (2005)**,

the Paynes , neighbors of the Terrells, sought an injunction by the local court in Franklin County to restrain the construction of four poultry houses by the Terrells on the grounds that the operation of the houses would constitute a nuisance. This was a very serious case because it proposed that poultry houses could be deemed a nuisance before being built and put into operation. An adverse court decision would have set a precedent that would have made it difficult to build poultry houses anywhere.

The trial judge hearing the case at the local level ruled in favor of the Terrells indicating that the evidence did not show to a **reasonable degree of certainty** that the poultry houses would be a nuisance to the Paynes. The Paynes, not satisfied with the judge's decision, appealed the case to the Georgia Court of Appeals. The Court of Appeals, a three member panel, reviewed the transcripts and reversed the trial court's decision on the basis that, in their opinion, enough evidence was presented to rule against the construction of the poultry houses. At this point, the Georgia Poultry Federation, Georgia Farm Bureau, Georgia Cattleman's Association, Georgia Agribusiness Council and others signed on as Amici to the case to support the Terrells in their appeal to the Supreme Court of Georgia. The lawyers for the Terrells and Amici argued in front of the Supreme Court that the Appellate Court had erred in reversing the trial court on the basis that the evidence in the trial case did not support a finding that **"irreparable damage**" would occur with a **"reasonable degree of certainty"** as a result of the operation of the houses. The Supreme Court of Georgia, a seven member panel, agreed with this argument and unanimously reversed the Appellate Court ruling. The Georgia Supreme Court ruling indicated that the Appellate judges relied on selected evidentiary items rather than the entirety of the evidence presented to overrule the trial court. The Georgia Supreme Court ruling is very significant in that it reinforces the legal concept of nuisance complaints meeting the **"irreparable damage"** and the **"reasonable degree of certainty"** threshold for blocking the construction of poultry houses, or any other legitimate business before it is in operation. This ruling, however, does not prevent the Paynes from taking legal action against the Terrells once their farm is in operation. Unfortunately for the Terrells, they seem to have neighbors that are inclined to take legal actions to resolve their issues.

Zoning Issues

As poultry farming has increased, there has been a trend in many counties toward developing zoning regulations to manage issues between agricultural enterprises and the non farm community. Some view development of zoning ordinances as an intrusion upon their rights as individual property owners, but **zoning ordinances that are factually based and prudently written can be beneficial to all citizens.** A carefully planned and devised zoning ordinance can be beneficial to the continued operation of the family owned farm while simultaneously providing protection for all citizens. A poorly designed ordinance can result in unfair treatment of some members of the community and can have a negative impact on the economy of that community as well. Lack of zoning regulations, or zoning ordinances that are not based on facts, can lead to unnecessary conflicts and litigation. It is not unusual, even in an agricultural community, for the individuals responsible for developing zoning ordinances to have little if any knowledge of poultry farming. These individuals will often be receiving inaccurate and misleading information regarding poultry production from a variety of sometimes uninformed and biased sources and, as a result, a significant educational process is often necessary to get the facts correct. Fortunately, those charged with these community responsibilities generally want to do what is fair and reasonable.

People opposed to poultry farming will often promote excessively restrictive ordinances to prevent or make it exceedingly difficult to expand or build new production facilities. One of the primary methods opponents use to stop the building of poultry houses is to advocate restrictive set back distances for construction of buildings. Examples of excessively restrictive set back distances that have been advocated in Georgia have ranged from 2,000 feet to 4,000 feet from unowned dwellings. Twiggs County, Georgia actually has a 4,000 feet set back ordinance on the books. We have been working with Twiggs County on

this issue and a review of their ordinance is in process. Needless to say, set back distances of these magnitudes would prevent most farmers from building houses due to the acreage requirements necessary to comply. In many of Georgia's counties, 1,500 feet set back requirements would eliminate more than 80 percent of the poultry production operations and could result in concentrations of production with the largest, most wealthy land owners.

What has been surprising is that some of our most rural counties in south Georgia have adopted rather restrictive set back ordinances. Examples are Berrien, Brooks, Cook, Thomas, and Worth Counties in southwest Georgia. These counties are not heavily populated (Table 1) and yet they have adopted minimum set back distances for poultry houses ranging from 1,000 to 1,250 feet from unowned dwellings. The areas in square miles for this group of counties are relatively larger than many of Georgia's counties and they currently have very few poultry houses. The economy of these counties relies heavily on row crop and beef cattle production but they have adopted ordinances that make it impossible for many of their farmers to build poultry houses. These ordinances are in contrast to ones in some of our top ranking poultry counties in north Georgia where there is much more urbanization and many more poultry houses (Table 2). Most counties in north Georgia have had commercial poultry production operations for more than 50 years and have been able to coexist very well with set back distances ranging from 200 to 500 feet. The more restrictive zoning regulations put in place for the south Georgia counties were the result of negative perceptions of concentrated livestock operations that include poultry. These negative attitudes regarding poultry production continue in these counties and, as a result, expansion into this area of south Georgia has been impeded.

Table 1. Population Densities for Selected South Georgia Counties

County	Area in Square Miles	Population Per Square Mile	# of Poultry Houses
Berrien	452	37	11
Brooks	493	33	8
Cook	229	71	0
Thomas	548	80	30
Worth	570	40	14
Avg.	**458**	**52**	**13**

Table 2. Population Densities for Selected North Georgia Counties

County	Area in Square Miles	Population Per Square Mile	# of Poultry Houses
Franklin	263	82	916
Gordon	355	138	557

Habersham	278	409	780
Hall	394	479	822
Jackson	342	145	746
Avg.	**326**	**250**	**764**

As indicated earlier, our experience in Georgia has been that the development of fair and workable zoning ordinances relative to poultry production usually requires a substantial educational effort. Presenting decision makers with factual information regarding nuisance issues, set back requirements, and economic contributions of the poultry business are generally necessary for land use committees, commissioners and citizens to reach agreement on workable ordinances. In my opinion, a significant component of the educational package is the economic impact that poultry farming can have on a community. To demonstrate the economic impact of poultry for counties in south Georgia, information was put together summarizing investments for infrastructure, payroll, and contract payment to farmers provided by an integrated complex (Cunningham, 2006). A significant part of this study focused on comparing farm income levels for poultry and non-poultry producing counties in south Georgia. The results of this study are summarized in Tables 3, 4 and 5 below.

Table 3. Economics of a Four House Broiler Farm

Item	Dollars
Housing and Equipment	$640,000-$660,000
Gross Annual Income	$150,000-$160,000
Net Annual Cash Flow (during debt retirement)	$32,000-$45,000
Net Annual Cash Flow (after debt retirement)	$80,000-$90,000
Property Taxes & Insurance (annually)	$8,000-$9,600

Table 4. Infrastructure and Integrator Investments

Item	Dollars
Processing Plant	$80-$90 million
Feed Mill	$8-$10 million
Hatchery	$8-$10 million

Production Houses	$80-$90 million
Annual Payroll	$30-$32 million
Annual Contract Payments	$20-$25 million
Total	**$226-$257 million**

Table 5. Farm Income Comparison for Poultry and Non-Poultry Counties

Counties	Total Farm Income ($000)	Net Farm Income ($000)	Net Income Per Farm ($)	Net Income Per Acre ($)
Poultry	100,278	30,474	78,269	233
Non-Poultry	41,036	11,486	47,824	107
Difference	**59,242****	**18,988***	**30,445***	**126****

* Indicates significant difference between the means (P_.05).
** Indicates significant difference between the means (P_.01).

Tables 3 and 4 summarize the magnitude of the dollars involved with infrastructure investments and cash flows for broiler farms. These numbers are substantial and are generally unknown to non-poultry business people. Table 5 demonstrates that counties with contract poultry production had significantly greater total farm incomes and total net farm incomes than those counties without poultry. In addition, net incomes, when expressed as income per farm and income per acre of farm land, were also greater for farms with poultry as part of their agricultural diversification. These results in themselves are not particularly surprising to those familiar with poultry production, but the magnitude of the differences is striking. Total net farm income for poultry counties is almost three times the value for non-poultry counties ($30.4 million vs. $11.4 million), while net income per acre is almost 2.2 times greater for counties with poultry farms ($233 vs. $107). These numbers and comparisons have been very helpful in informing people of the positive economic benefits that diversification of their farms with poultry operations can provide. The economic impact of commercial poultry operations are generally evident to those working in the business, but usually it is not as apparent to those outside the industry. Numbers of these magnitudes are often very impressive to individuals interested in improving the local economy. This is particularly true in rural areas where opportunities for economic development may be limited.

Future Directions?

Increasing urbanization and loss of agricultural land will keep pressure on poultry producers with regard to land use and neighbor relations. Unfortunately, it is likely that conflicts between poultry farmers and neighbors will continue to be difficult to resolve and more frequent in occurrence in the future. If the poultry industry is to continue to grow and maintain a viable presence in the United States, it is imperative that companies and growers are pro-active in addressing these issues. The following are some thoughts and suggestions on future directions for the industry:

Nuisance Issues. In the vast majority of cases, nuisance complaints lodged against poultry producers by neighbors are without merit and are the result of a mind set of little or no tolerance for certain aspects of concentrated livestock production. As a result, nuisance complaints can be difficult to deal with and can be very costly to the grower. Once these issues reach the contentious stage between neighbors, they are very difficult to resolve amicably and are more likely to end up in expensive litigation. For these reasons, it is important for poultry producers and integrators to take these issues seriously and to respond quickly to any potential problem or developing conflict.

1. Poultry company personnel must be vigilant for operations that may not be managed with the best interest of neighbor relations and environmental impact considerations. In some cases, poultry companies have not been as aggressive in dealing with growers with developing nuisance issues as needed. Since it only takes one "bad actor" to poison the whole community against poultry farming, integrators will need to be aggressive in dealing with sub-performance farms in these areas. Grower contracts may need to include clauses defining expectations for best management practices related to nuisance concerns and the consequences of not meeting those expectations. Regardless, there is little doubt that internal policing by company personnel and growers will be even more critical in the future.

2. Companies will need to implement more restrictive policies regarding site locations for new houses. Increasing land use pressures from urbanization and lack of tolerance for farming practices by urbanites suggest that poultry farms will need increased isolation and protection from neighbors. It will, therefore, be in the best interest of the industry for poultry companies to implement policies of more restrictive set back distances (e.g. 1,000 feet from dwellings) where needed. Companies will also need to be more discerning with regard to location and size of operation considerations for new construction and expansion. Although a landowner may meet local minimal requirements (i.e. acreage and set back distances) for building poultry houses, it may not be a good idea in the long run to build on minimal site specifications or to push capacity limits of farms.

3. Poultry growers need to be committed to being good neighbors. Proactive outreach to the community helps to prevent misunderstandings. Poultry growers need to make it clear to their neighbors that poultry farming is their personal livelihood while at the same time making it clear that they want to have a positive influence on the community. There are a number of actions that growers can take to be proactive with neighbor relations (Ritz, 2005). Some of the more important actions relate to manure handling and storage. Keeping stored manure covered and dry and out of sight, if possible, can help prevent potential problems with this material. In addition, being considerate when applying manure and informing neighbors of plans for cleaning out and spreading can help reduce complaints.

4. All growers will need to implement nutrient management plans and account for nitrogen and phosphorous applications regardless of Federal and State EPA permitting regulations. The issues and potential liabilities associated with undocumented utilization of poultry manures as a fertilizer are serious and represent too great a risk to the producer to ignore. This being the case, it will be important for the future of the industry for all growers to operate from a **documented** nutrient management program regardless of whether or not they are required to do so under federal or state CAFO permit regulations. It will be important to do so in order to protect growers from liability, to assure bankers that loans are secure, and to provide for public trust.

5. The poultry industry needs to develop new design concepts and management programs for broiler breeder operations. These houses have more problems with wet conditions and fly production than other types of poultry operations and can be legitimate causes of nuisance complaints from neighbors. Years

ago, table egg producers moved away from wet manure handling systems by developing new concepts of high rise housing to collect and manage manure in a drier condition. Maybe it's time for someone to come up with a "high rise" system for broiler breeders. At the very least, future sites for these types of houses will require more isolation and protection from the community if we continue to use current housing and management practices.

Zoning Issues. The trend toward communities developing ordinances relative to poultry operations will continue. As indicated earlier, community land use plans and zoning regulations can be beneficial to farmers if they are constructed properly. Proper construction of these regulations often requires an educational process.

1. Poultry companies should become more involved in the educational process. It is not unusual for poultry company representatives to prefer not to get involved in community discussions or public meetings regarding these issues. Keeping a "low profile" is often the attitude of the day even though the company most likely has a very obvious presence in the community or area. Lack of participation by company representatives sometimes conveys an unintended message of trying to hide something. When this happens, it does not help with issues of trust. Company representatives, however, can provide valuable and helpful information to the community regarding their company's policies and their commitment to being a good citizen within that community. Participating in community discussions demonstrates the company's concerns for the community and their willingness to be open and cooperative in providing factual information regarding their operation and future plans for the community. Having growers participate in these discussions is also important since they are members of the community and can speak from a farm perspective, but having growers handle these issues by themselves is risky. Growers may not be prepared to effectively handle the accusations and misrepresentations that often occur with these issues. A good way for poultry integrators and farmers to provide more of an educational role is by providing tours of farms for key community members. This is happening more frequently and it is an effective way of showing individuals the reality of how a modern, well managed poultry farm can work in the community. Experience indicates that this educational process usually requires a concerted effort by integrators, farmers and knowledgeable experts in the field to develop a factual basis for decisions regarding zoning regulations.

2. The trend for new poultry construction is to build more and larger houses on farms. This trend is being driven by economies of the business and, as a result, will continue. It is a trend, however, that is in the opposite direction needed for reducing nuisance, environmental, and zoning issues. Larger and more concentrated operations increase the probability of these issues occurring and thus zoning regulations will become even more important and more widespread in the future. It will be important for agricultural people to participate fully in the development of these ordinances to protect their interests. Making sure that ordinances developed contain reasonable set back restrictions is imperative. In addition, zoning ordinances should contain reciprocal set back restrictions for dwellings constructed adjacent to a poultry farm to protect the poultry operation. Other provisions that are worthy of inclusion in ordinances are: 1) Reduced minimum set back waiver provisions, 2) Nuisance shield provisions, 3) Notice of agricultural adjacency waivers, and 4) Set back restrictions for manure storage facilities and application.

Summary

Increasing urbanization will keep pressure on poultry producers with regard to land use and neighbor relations conflicts. Most citizens today have little knowledge of farming practices and many have negative perceptions of concentrated animal agriculture practices while some are even intolerant to inconveniences attributable to farming operations Poultry producers will, therefore, continue to be faced with difficult

challenges with regard to new construction and expansion of operations in the future. Dealing with these challenges successfully will require more attention to best management practices on farms and more critical scrutiny of future building sites. In addition, more participation in educational programs and community discussions on land use and zoning issues by poultry producers will be required.

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CRISIS COMMUNICATION AND MEDIA RELATIONS IN AGRICULTURE

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When crises occur in agriculture, when new technologies come along that pose threats to the public (real or perceived), and when the image of the farm and the farmer and of agriculture is at stake, the media will be there to cover it. Will the coverage be accurate or inaccurate? Will it portray a good image of the particular farm and of agriculture and agricultural producers, or will it cast a shadow on these things? The answer to these questions may lie in agricultural producers' ability to understand and perform good media relations.

Media relations, to many, is something done by city folks with degrees in communications, marketing, or journalism who wear double-breasted suits and shiny wingtips. Media relations is news conferences, press packets, and web sites with backgrounders, info graphics, and streaming audio and video. But media relations is also farmers talking to reporters.

What? I would never talk to a reporter, says the farmer. I wouldn't even let one on my place. Those nosey reporters just want to dig up something negative to write about, the farmer says. And this may be true in some cases, but there is an important principle in media relations that should make producers think again: your side of the story ought to be represented to the media, lest it be *mis*represented by the media.

So when risk and crisis situations occur in agriculture, producers need to be ready. They must be willing and prepared to host journalists on their farms, and they need to have anticipated the types of questions journalists might ask. They also need to understand how to treat journalists, including how to give them what they need to do their jobs but also how to set limits before and during an interview.

This workshop, which is centered around a role-playing activity, helps agriculture agricultural producers learn the practicalities of dealing with journalists. It gives them some experience in planning a strategy and a position, developing prepared statements, determining journalists' needs, and presenting themselves in an interview situation. There is no substitute for experience in front of a television camera, so the role playing activity includes live television interviews with workshop participants. The interviews will be broadcast live for all the workshop participants to see and critique. This fun and interactive workshop should be of interest to anyone in the agriculture industry who may one day be asked to represent the industry in an interview.

PRESENTING A POSITIVE IMAGE

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In many corners of the country there are groups of people that want to portray poultry production in a negative light. These groups relate their arguments against poultry to issues regarding the environment, animal welfare, hormones/antibiotics, and grower concerns. The negative images they present are further sensationalized by the media and local politicians. Negative stories are news. It is hard to sensationalize stories about people who are in the habit of doing good things. The negative issues will be reported. Therefore, it is up to the employees and growers of the poultry industry to tell the positive aspects of the poultry industry.

What have you done lately to project a positive image? Projecting a positive image is not creating a false image, but identifying the positives of the industry and conveying this information to others. You are not a single individual; rather you are a part of thousands of growers, employees, farm families and corn growers that depend on the poultry industry for their livelihood.

So what can one individual do? First you need to know your industry and where it fits into the global food supply. You need to know your company, what does it stand for, what are its corporate beliefs. You need to know where the chickens from your complex go. Poultry plays an important role in agriculture in many states. Do you know what contribution the poultry industry plays in your state's economy?

In order to project a positive image you must be involved in your community. You can be active with the chamber of commerce, the Farm Bureau, extension councils and other civic associations. Ask yourself what leadership role you can play in your community through churches, clubs, school boards, and civic associations. Tell your story at every opportunity to civic clubs, business luncheons, schools, tours, local leaders, agriculture leaders and the community in general. Politics is an area that few want to be involved in. However, if not you, then who will be involved? We get the leadership we deserve, so be involved. Take the time to educate your political leadership about your industry. Do not wait until there is a problem or controversy. Reinforce the positive and remind all leadership of the impact of the poultry industry on the local community.

There are many issues that we can us to project a positive image. This includes:

- The economic impact of poultry to the community, state, and nation
- Value added to grain. What does having an end user of corn mean to local farmers?
- What is your role in the poultry production system?
- What role does the poultry industry play in providing the nation's food supply?
- What is your place in the food chain? How much poultry is produced on your farm and how many people does your farm or complex feed.
- Think globally. Where do you fit into the global food system?

Knowing the facts is not enough. We must also project a positive image through our actions. What image are you projecting with your farm? You can have an image of someone who cares, through a well maintained farm that has the grass mowed; it's building in good repair, and is neat and tidy. Are you a good environmental steward who has a solid nutrient management plan, litter storage buildings and

disposes of mortality properly? Are you doing the right thing and are you projecting that image to fellow growers and your community?

Get involved with the youth of your community. Support your local youth through school, youth groups or 4-H and FFA. You do not have to do it alone. Growers can band together and pool their resources. What you do today will affect generations to come. Be involved.

A positive attitude is contagious. It all begins with you.

SCALDING: EFFECTS OF ADDITIVES ON CARCASS MICROBIOLOGY AND WASTEWATER DISCHARGE

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Scalding poultry to make it easier to remove feathers has been known for centuries. Scalding is mentioned in Roman recipes and by famous writers such as Chaucer and Shakespeare. The first known use of *scalding* and *picking* in the same English sentence is in a cookbook from 1420, when books were copied by hand. Scalding was thus a common food technology long before the discovery of microscopic organisms that could spoil meat or cause foodborne disease. Except perhaps for the observation that scalded carcasses spoil faster than dry-picked carcasses, the microbiological implications of scalding have been unknown for most of the time that birds have served as food for humans.

Scalding was used mainly for carcasses that were to be consumed immediately. Faster spoilage of scalded birds and the unattractive appearance of scalded carcasses in the absence of proper refrigeration prevented the early poultry industry in the United States from using scalding until about 1928, when dry picking began to be replaced by wet picking. Scalding temperatures used by the poultry industry are still influenced by the method by which the carcasses will be chilled, in either cold air or cold water. High scald water temperatures make carcasses susceptible to tearing and damage during picking. The first mechanical picking machines were introduced about 1940 (Avery and Payne, 1952), and are a further restraint on water temperatures used for scalding.

Scalding in hot water is by far the most common method, although alternatives such as steam, hot air, and microwave scalding have been explored. Further developments with these alternative methods may occur in the future, but compared to immersion scalding, the alternatives have generally been more expensive and have had problems with excessive heat transfer to areas of the carcass such as wingtips.

One scalding innovation that has had considerable acceptance is multiple-tank or counterflow scalding, where the overall direction of water flow is opposite to movement of the carcasses. There are some single-pass tanks where water cannot mix between lines of carcasses, but many two- and three-pass tanks have dividing panels that do not reach the bottom of the tank and thus allow water to mix between lines of carcasses. Those scalders are counterflow between tanks rather than within individual tanks.

In 1992, the National Broiler Council urged member companies to install counterflow scalders along with several other modifications that reduced bacterial counts on processed carcasses. Scientific studies reported that countercurrent or multiple–tank scalding, in conjunction with other equipment changes, reduced counts of bacteria on processed carcasses (James et al., 1992; Waldroup et al., 1992, 1993), but those studies did not report numbers of bacteria that were in the scald water. Counterflow scalders have been installed in many processing plants because of the NBC recommendation.

Despite many studies that have reported sampling of scald water in older scalder designs, there are only a few reports in the literature of scald water samples taken from multiple-tank scalders. A consistent pattern of declining numbers of *Enterobacteriaceae*, coliforms, *Escherichia coli*, *Campylobacter*, and suspended solids has been reported in successive tanks of three-tank scalders, with the cleanest water in the last tank that carcasses pass through before picking (Veerkamp and Heemskerk, 1992; Cason et al., 1999b; Cason et al., 2000; Cason and Hinton, 2006). The difference between the first tank that carcasses pass through and the third tank is about three logs for coliforms and *E. coli*, so there are about a thousand times more of those bacteria per unit of water in the first tank than in the third. A reduction in bacterial concentration of that magnitude is impressive. Multiple-tank scalding appears to reduce the opportunity for cross-contamination between carcasses via the scald water, but whether that makes a difference in terms of numbers and kinds of bacteria on retail chicken is unknown.

A similar pattern appears to exist for incidence of *Salmonella* in multiple-tank scalders, with fewer positive water samples in the third tank. Total positive samples in two studies were 12 of 14 in Tank 1 versus 4 of 14 in Tank 3 (Cason et al., 2000; Cason and Hinton, 2006). Rinses of picked carcasses in those same experiments were positive for 54 of 84 carcasses, so there was a substantial amount of *Salmonella* on the carcasses passing through the tank at the same time that water samples were taken.

There are three reports of the numbers of *Salmonella* in scald water, with mean MPN (most probable number) of 13.9, 10.9, and 8.2 per 100 ml of scald water in positive samples only (Humphrey and Lanning, 1987; Cason et al., 2000; Cason and Hinton, 2006, respectively). Those numbers fall in the range of one *Salmonella* cell per 8 to 12 ml of scald water, so some older studies that reported no *Salmonella* or very low incidence in scald water are unreliable due to the likelihood of false negatives in samples as small as 1 ml. *Campylobacter* species are generally more susceptible to heat and have lower D values compared to *Salmonella*, with reductions not only in numbers, but also in incidence in successive tanks, just as with *Salmonella*.

Numbers of bacteria in scald water climb to a plateau after 20 to 60 min of operation depending on temperature and other conditions (Mercuri et al., 1974; Humphrey et al., 1981; Mead, 1989; Veerkamp et al., 1991). A plateau is also implied in scalder models (Veerkamp, 1989; Veerkamp et al., 1991; Cason and Shackelford, 1999). An equilibrium occurs when the number of bacteria in the tank builds up to the point where bacteria are entering the scald water (on carcasses and in overflow water from any later tanks) at the same rate that bacteria are disappearing (by dying, leaving in the water carried by exiting carcasses, or exiting the tank as overflow).

Many bacteria have D values (time of exposure to produce a one log or 90% reduction in numbers of bacteria) in the 5 to 20 min range for water conditions in a typical scald tank. In 10 minutes of operation, 1400 carcasses will pass through a scald tank in a plant running 140 birds per minute, so the number of bacteria in a single scald water sample will be influenced by the numbers of bacteria coming from hundreds or thousands of carcasses and the variability in counts between individual carcasses going into the tank has little impact. If the *E. coli* strain carried by the flock has a D value of 10 minutes, that means that 10% of the bacteria that entered the tank via the first carcass will still be alive 10 minutes later when another 1399 carcasses have passed through the tank and contributed their share of bacteria to the total.

A study of the rate at which bacteria leave chicken carcasses suspended in warm water has shown that the majority of *E. coli* bacteria leave a carcass very quickly, usually within the first 10 seconds in the water (Cason et al., 2006). That means that the reductions in numbers of bacteria seen with multiple-tank scalding are because lifting carcasses out of the water between tanks prevents the most contaminated water in the first tank from mixing freely and spreading throughout the entire volume of scald water in the other tanks.

The relationship between bacteria carried in feathers and bacteria in the scald water is not a simple one, however, and sampling of scald water is not a reliable way to predict what levels or incidence of various bacteria can be found on picked carcasses. Removing feathers between scald tanks has been tried in some processing plants, but a test of intermittent scalding and picking failed to show a reduction in aerobic plate count, *E. coli*, or *Campylobacter* in carcasses that were picked between scald tanks as compared to control carcasses that were scalded and picked in the conventional way (Cason et al., 1999a).

Many different chemical treatments have been tried in scalding, usually with the purpose of wetting the feathers more thoroughly and improving the efficiency of picking. The most common antibacterial treatments have involved changing the pH of scald water to reduce survival by suspended bacteria. Scald tank pH has been reported to be about 6.0 for most of an operating day, or near the pH at which *Salmonella* survives most readily (Humphrey, 1981). Increasing the pH with basic treatments has been reported to sharply reduce the survival of bacteria in scald water (Humphrey, 1981; Humphrey and Lanning, 1984; Humphrey et al., 1981, 1984;). In the opposite direction, Lillard et al. (1987) treated scald water with acetic acid up to a concentration of 0.5% acetic acid in the tank with a resulting pH of 3.6. In scald water samples, aerobic bacteria were reduced by 2 logs and Enterobacteriaceae were reduced from a concentration of 3.9 logs per ml down to undetectable levels. Rinses of feathered and picked carcasses immediately after those scald treatments failed to show any difference in carcass bacteria, however. The efficacy of antibacterial treatments of the scalder to change the microbiology of finished carcasses has not been demonstrated conclusively.

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COOLING POULTRY USING IMMERSION OR AIR CHILLING

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During commercial poultry processing, establishments are required to reduce the internal temperature of carcasses to 40°F or less within 4 to 8 hours after slaughter, depending upon the size of the carcass. The primary goal of the temperature reduction is to decrease the growth of pathogenic and spoilage microorganisms on poultry (Brant, 1974; Thomas et al., 1974; Veerkamp, 1989; James et al., 2005). Cooling of poultry is typically accomplished by one of three different methods – 1) immersion chilling where carcasses are submersed in tanks of cold water or an ice and water mix; 2) dry air chilling where carcasses are cooled by cold-air blast; or 3) evaporative air chilling where carcasses are cooled by cold-air blast and water mist (Brant, 1974; Veerkamp, 1989; Allen et al., 2000a; Mead et al., 2000; James et al., 2005). Historically, immersion chilling has been the most popular method of cooling poultry in the U.S., while companies in the European Union (EU) prefer to air chill poultry (Mead et al., 2000; USDA, 2001; James et al., 2005). In the past 5 years, interest in air chilling has increased in the U.S. because of new USDA regulations on carcass moisture retention, EU trade restrictions on immersion chilled poultry, and environmental pressures related to reduced availability of fresh water and strict waste water discharge restriction (Northcutt et al., 2006). To date, there are only three poultry plants in the U.S. that produce air chilled poultry; however, several others have made arrangements to install air chilling equipment in the near future.

In 2001, the USDA, Food Safety and Inspection Service (USDA-FSIS) publish a regulation which limits the amount of water that may be retained in meat and poultry products as a result of carcass washing and immersion chilling (USDA, 2001). According to FSIS, the regulation was designed to produce "consistency and uniformity" in the meat and poultry inspection systems. Establishments that immersion chill poultry must provide documentation on the amount of water retained in chilled carcasses and parts and disclose this information on the product label (USDA, 2001). The regulation seems to encourage evaporative air chilling as it discusses the positive benefits of this chilling method on livestock carcasses (USDA, 2001).

A number of comprehensive review articles on poultry chilling have been published (Brant, 1974; Thomson et al., 1974; Lillard, 1982; James et al., 2005). These review articles report data from a variety of sources, but almost all have found that air or immersion chilling reduces carcass bacteria counts by about 1 $\log_{10}$ cfu/mL rinse. The microbiological impact of chilling typically depends on a number of factors, such as the initial bacterial load on the live birds, processing equipment contamination (biofilms), equipment maintenance, water quality, water volume and antimicrobial treatments. Only a few studies have compared immersion and air chilling, and nearly all of these studies have come out of G. C. Mead's lab in the EU (Allen et al., 2000a; Allen et al., 2000b; Mead et al., 2000). In 2000, these researchers conducted a study which compared microbial counts from prechill carcasses to microbial counts on postchill carcasses (Allen et al., 2000a). Sampling was conducted using either macerated neck skin or body cavity swab. They found a reduction in total aerobic bacteria in the body cavity of broilers by 1.1, 0.8 and 0.5 $\log_{10}$ cfu/cavity for a completely dry air chilling, immersion chilling and evaporative spray chilling, respectively. In addition, Allen et al. (2000) reported that coliform counts were equally reduced

by immersion and dry air chilling (1.28 and 1.1 $\log_{10}$ cfu/cavity, respectively). In another study published that same year, Allen, Mead and coworkers found that an evaporative spray chill did not improve the rate of carcass heat removal when compared to a dry air chill. They also suggested that counts recovered from dry air chilled carcasses remained stable after 24 hours of cold storage while counts recovered from carcasses that were chilled using evaporative spray increased after 24 hours of cold storage (Allen et al., 2000). For this reason, we decided to conduct a series of experiments comparing the quality, functionality and microbiological characteristics of broiler carcasses chilled by immersion or dry air.

In our studies, immersion chilling was performed in a prototype tumble chiller containing an ice/water mix (33-34°F) and operated at 2 RPM for the 50 minutes chill time. Carcasses were added to the chiller (~40 gallons) to make 0.4 gallons/pound. No chlorine was added to the immersion chiller. Dry air chilling was conducted for 150 minutes in a modified cold room (32°F) with air (11.5 ft/sec) directed continuously into the body cavities. Deep breast muscle temperature was monitored continuously on a few selected carcasses. Time to reach 40°F was approximately 35 min during immersion chilling compared to 90 min during air chilling. Immersion chilled carcasses gained 9.3% moisture, while air chilled carcasses lost 2.5% moisture. Method of chilling had an effect on skin color, with air chilled chickens appearing to be darker and more red and yellow than immersion chilled carcasses. Bacteria counts were monitored using the whole carcass rinse technique (100 mL rinsed for 1 min). Immersion and air chilling reduced coliform and *E. coli* counts by 1.0 to 1.2 $\log_{10}$ cfu/mL rinse. All of the carcasses were positive for *Campylobacter* (100%) before chilling and this did not change after chilling (100% positive). Similarly, incidence of *Salmonella* (prechill 40 to 56% positive) decreased to 20 to 25% positive after chilling with no difference between immersion or air chilled carcasses. Chilling reduced the *Campylobacter* counts recovered from carcasses by 1.0 to1.4 $\log_{10}$ cfu/mL while *Salmonella* counts were reduced by 0.6 to 1.0 $\log_{10}$ cfu/mL. There was no difference in the *Campylobacter* and *Salmonella* counts recovered from immersion and air chilled carcasses.

Overall, immersion and air chilling produced poultry carcasses with comparable microbiological characteristics (levels and incidence of bacteria). Additional research is needed to address cross-contamination and to compare bacteria recovery from carcasses chilled by immersion or evaporative spray with various antimicrobial treatments.

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POULTRY CHILLING METHODS

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Introduction

Fresh poultry is a perishable food and must be chilled to refrigerated temperature soon after slaughter. Two common methods used to chill poultry are immersion chilling and air chilling. Immersion chilling, also called water bath chilling, is the most common method used to chill poultry in the United States. Air chilling is the usual method of chilling poultry in European countries. Stork manufactures both immersion and air chilling equipment for poultry.

Immersion Chilling

Immersion chilling uses cold water as the chilling medium. The water may be cooled by refrigeration or the addition of ice. Stork immersion chillers use an auger to convey products through the chilling tanks opposite or counter-flow to the flow of water. This results in the products moving into progressively cleaner and colder water and is beneficial to hygiene. Air is typically injected into the chiller tanks through flexible plastic hoses to agitate the water and reduce chill time by improving heat transfer between products and water. Immersion chilling does not adversely affect skin appearance whether the birds are hard scalded or soft scalded. The weight of eviscerated birds entering the chiller at a given time determines the length of chiller required. Auger speed and agitation can be adjusted to meet cooling and moisture absorption requirements. A typical water chiller may require 20,000 gallons of water to fill prior to daily operation. During operation water must also be added for each bird entering the chiller. In contrast air chilling requires little or no water to cool products during operation.

Air Chilling

Air chilling uses cold air moving at a certain velocity to remove heat from the bird. Birds hang by the legs from shackles and are moved through the air chiller by an overhead conveyor. As birds do not touch one another, the possibility of cross contamination is reduced. It is desirable that air chilled birds are soft scalded so that the epidermis remains intact to prevent discoloration of the skin by dehydration. Product yield can also decrease during air chilling due to dehydration. Skin appearance and yield loss can be improved by the use of strategically placed water sprays during the chilling process. Transfer of birds from the evisceration shackles to chilling shackles and from chilling shackles to distribution shackles can be accomplished manually or through the use of automatic transfer machines.

Conclusion

Water chilling and air chilling are proven methods of chilling poultry. Both methods are used by poultry companies around the world. Factors such as the cost of water, floor space, government regulation, and consumer preference influence the chilling method selected.

PUTTING THE PRINCIPLES OF WATER CONSERVATION INTO PRACTICE

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Introduction

The poultry industry processes approximately 9,000,000,000 broilers each year. Water usage varies from plant to plant, but is generally in the 4 to 8 gallons per bird range, with the average plant using approximately 6 to 7 gallons per bird. The costs to purchase water and treat wastewater also varies significantly from plant to plant, with average costs being in the range of $1.50 to $2.50 per 1,000 gallons for water and $2.00 to $4.00 per 1,000 gallons for wastewater treatment. Using a value of 6.5 gallons per bird for water usage, a water cost of $2.00 per 1,000 gallons, and a wastewater treatment cost of $3.50 per 1,000 gallons, the total cost of water purchase and wastewater treatment for the poultry industry is estimated to be approximately $321,750,000 per year. Through the use of water conservation and reuse some poultry plants have been able to reduce water usage to less than 4 gallons per bird while maintaining product quality. If the entire industry could reduce water usage to 4 gallons per bird the potential savings could be as high as $123,750,000 per year. This represents a significant opportunity to the poultry industry that can not only add value to the bottom line but also promote environmental sustainability through reducing pollutant discharges and lowering energy and chemical usage.

Pilgrim's Pride Corporation (PPC) currently operates over 20 processing plants. The average water usage for the plants is approximately 5.87 gallons per bird. Water costs are in the range of $0.50 to $3.00 per 1,000 gallons. Total wastewater costs are in the range of $0.51 to $8.33 per 1,000 gallons. The PPC Envirometrics Program tracks the water usage and water and wastewater costs for each plant. The company continually evaluates the feasibility of implementing water conservation and reuse programs at the plants, with priority being given to those facilities where the total cost of water and wastewater treatment exceeds $4.00 per 1,000 gallons.

This paper provides a summary of the water conservation and reuse efforts at PPC.

The PPC Water Conservation Hierarchy

PPC approaches water conservation and reuse through a hierarchy of steps depicted in Figure No. 1. Emphasis is first placed on avoiding water usage where waterless options exist. Water usage reduction is then emphasized through equipment selection and employee awareness. Water reuse is considered where either the combined costs of water purchase and wastewater treatment are excessive or environmental needs warrant wastewater discharge reductions. Finally, PPC completes the water conservation hierarchy by disposing of wastewaters that can not be reused in an environmentally sensitive manner. This effort is tracked by a PPC Water Reuse Synergy Team to assure that continuous improvement is always being made in the areas of water conservation and reuse.

PPC Water Usage By Plants

Table No. 1 summarizes the current water usage and water and wastewater costs for PPC processing plants. The table also shows plants that have installed water reuse systems and the estimated water savings for each plant.

PPC has installed ozone based water reuse systems in three plants. These systems are reusing a total of approximately 1.5 mgd of water. Eleven plants that have total water and wastewater costs that indicate reuse may be feasible are being evaluated with consideration being given to multiple types of reuse systems. Six plants have cost structures that do not indicate reuse would be cost effective. These plants will be re-evaluated over time or if an environmental need indicates reuse would be a viable approach.

Table No. 1
PPC Water Usage, Costs, and Water Reuse

Plant No.	Water Usage, gal/bird	Water Cost, $/1,000 gal	Wastewater Cost, $/1,000 gal	Total Water and Wastewater Cost, $/1,000 gal	Reuse System Status	Estimated Water Reused, mgd
FACILITIES WITH LARGE SCALE REUSE SYSEMS						
1	4.41	3	2.77	5.77	Ozone Based Reuse System In-Place	0.60
2	5.61	1.11	7.42	8.53	Ozone Based Reuse System In-Place	0.40
3	6.51	2.12	8.33	10.45	Ozone Based Reuse System In-Place	0.50
FACILITIES WITH LARGE SCALE REUSE UNDER CONSIDERATION						
4	6.42	1.93	3.26	5.19	Reuse Options Under Consideration	0.30
5	4.62	1.49	5.12	6.61	Reuse Options Under Consideration	0.40
6	5.13	1.69	2.92	4.61	Reuse Options Under Consideration	0.50
7	7.36	1.78	6.05	7.83	Reuse Options Under Consideration	0.40
8	5.81	1.43	3.94	5.37	Reuse Options Under Consideration	0.50
9	5.05	2.84	4.30	7.14	Reuse Options Under Consideration	0.50
10	6.68	1.19	3.47	4.66	Reuse Options Under Consideration	0.50
11	5.45	1.59	2.61	4.20	Reuse Options Under Consideration	0.50
12	6.16	1.72	2.96	4.68	Reuse Options Under Consideration	0.50
13	5.17	2.00	4.80	6.80	Reuse Options Under Consideration	0.40
14	7.02	1.68	3.90	5.58	Reuse Options Under Consideration	0.50
COST STRUCTURE DOES NOT CURRENTLY SUPPORT REUSE						

15	6.42	1.08	2.23	3.31	Cost Structure Does Not Currently Support Reuse	
16	7.72	1.35	1.96	3.31	Cost Structure Does Not Currently Support Reuse	
17	4.72	1.20	2.16	3.36	Cost Structure Does Not Currently Support Reuse	
18	6.16	0.50	3.23	3.73	Cost Structure Does Not Currently Support Reuse	
19	6.45	0.50	0.51	1.01	Cost Structure Does Not Currently Support Reuse	
20	4.6	1.35	2.20	3.55	Cost Structure Does Not Currently Support Reuse	

PPC Water Conservation Best Management Practices

The average water usage at PPC plants is approximately 5.87 gallons per bird. This water usage is believed to be at or below the industry average. PPC realizes efficient water usage through the use of a set of Water Conservation Best Management Practices. These include:

- Thorough understanding of water usage
- Maximum use of water reuse systems where approved and cost effective
- Use of state-of-the-art clean-in-place (CIP) systems
- Use of high pressure, low volume cleanings systems
- Optimization of nozzle selection for specific use areas
- Daily inspection for and elimination of leaks
- Turning off water when not used
- Partner water conservation awareness training
- Partner water conservation incentives

Know Your Flow

Monitoring water usage throughout each plant establishes a baseline and identifies areas where water use can be reduced and waste loads can be minimized. Flows are monitored during each shift to create an accurate picture of overall plant water usage.

Water Reuse

PPC attempts to take advantage of all approved water reuse opportunities where cost effective. On-Line Water Reuse is practiced at three plants and is being evaluated for several other plants. Additionally, several plants recycle stormwater and/or pretreated wastewater for non-potable uses such as screen cleaning, wash downs, pumps seals, etc.

Clean-In-Place Systems

CIP systems are used where possible to minimize water usage and chemical usage. CIP systems provide better control over water usage and eliminate the necessity to dismantle certain items of equipment.

Pick It Up – Don't Wash It Down

PPC encourages the use of dry cleaning techniques where possible prior to wet cleaning. Where wet cleaning is used high pressure, low volume cleanings systems are employed to minimize water usage and chemical usage.

Nozzles

PPC uses automatic shutoff nozzles and optimally sized spray nozzles for each specific application. Additionally, where spray bars are used the correct spray angle and spacing are used to optimize the performance of the system.

Stop Those Leaks

Partners are trained to be on the lookout for leaks at nozzles, hoses, tanks, valves, and pumps. Leaks are fixed as quickly as possible after first being noted.

Flow Valves

Control valves are used to stop water flow when production stops.

Partner Water Conservation Awareness Training

PPC Partners are trained in how to use water efficiently in their particular production area. Partners are shown current water usage and costs to improve appreciation for the significance of water conservation. Partners are provided the knowledge, data, individual tools, and process equipment needed to allow them to be successful in the area of water conservation.

Partner Water Conservation Incentives

PPC considers water as a raw material with a real cost. The concept of "if a little bit is good a lot has to be better" is taboo. Plants set water conservation goals and require Partners to take responsibility and reduce water use where at all possible. Partners are rewarded periodically through various PPC programs where water conservation objectives have been achieved.

PPC's Overall Water Conservation Objectives

PPC plants currently use approximately 5.87 gallons of water per bird processed. Water and wastewater treatment costs continue to increase at a level at or above normal inflation. Additionally, environmental regulations continue to become more and more stringent. PPC believes it is in the best interest of the Company, our Customers, and the environment that water conservation be a priority in our environmental sustainability efforts going forward. Toward that end, PPC has set a goal of reducing water usage by 5 to10 percent per year with an ultimate goal of reducing water usage to less than 4 gallons per bird processed at all plants where it is cost effective and practical.

UTILIZATION OF CHICKEN FAT AS AN ALTERNATIVE FUEL SOURCE

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Introduction

With crude oil prices routinely fluctuating between $70 - $80 per barrel, and consumers paying upwards of $3.00 per gallon for gasoline at retail pumps, there has been a renewed interest in the develop of alternative fuels. Currently, most inedible chicken fat recovered from poultry processing plants is sold as a raw material for rendering at relatively low prices. This traditional method of handling provides the industry with a simple and effective method, but neglects the fact that animal fat can actually be of more value as an alternative fuel source. Over the past several years, researchers within the Engineering Outreach Service (EOS) at the University of Georgia (UGA) have been conducting studies focused on the potential of poultry fat as an alternative fuel source. In 2002, an EOS team conducted a series of experiments that showed that various animal fats can be effective and price competitive as industrial broiler fuel (Adams, et al., 2002).

Recently, work conducted by the UGA team and funded by the Georgia Food Processing Advisory Council (FoodPAC) has begun to focus on the creation of an in-house application for poultry fat. The goal of this work is the use of poultry fat as a fuel for smaller scale boilers to provide heat or hot water within facilities that process poultry. By eliminating the need for transportation and third party processing of the fat, a cost effective fuel can be developed. In 2005, the UGA-EOS team reported their most recent findings to FoodPAC. The results of that study are highlighted here:

Georgia Alternative Fuels Study

Waste poultry fat is a plentiful commodity. It is estimated that in Georgia alone, poultry processors produce more than 44.6 million gallons of waste chicken fat each year. In a food grade state this material can be valued at up to $0.18/lb. ($1.33/gal). However, much of this fat ends up in waste streams and is recovered and sold to rendering facilities at ~$.03/lb ($.22/gal). The value of this poultry fat, based on the current market price for chicken fat sold into the food market, is $59.3 million. The equivalent in heating value to 44.6 million gallons of chicken fat is 39.9 million gallons of #2 diesel fuel. Assuming the current price of #2 diesel fuel is approximately $2.60/gallon, this results in $103.8 million in offset fuel costs. Therefore, utilizing this chicken fat as a fuel could represent a price differential of up to $44.5 million for the Georgia poultry industry.

It is logical that on-site rendering would reduce the cost of poultry fat based fuels for producers. Other domestic meat processing facilities such as those in the beef industry already render onsite as do many

non-US poultry processing facilities. Savings in transportation and overhead costs would both benefit the bottom line and reduce environmental impacts associated with transit of this material. Additionally, the proximity of the onsite facility would allow rapid rendering after collection of fatty materials from the waste stream of poultry production. This would lead to a higher quality fat for fuel use which would have reduced levels of free fatty acids and other decomposition products. Resulting fuels would have higher energy content, storability and oxidative stability.

The overall goal of this project was to develop a method by which a poultry processing facility could extract fat from their own waste streams on site and utilize it in existing oil burning furnaces and/or boilers. Multiple processes for extracting useable fat fuel from different by-products of poultry processing were examined. These included extracting low fat sources such as offal as well as fat rich materials such as leaf fat and saddle fat. Aerobic and anaerobic fermentations were studied for efficiency of extraction along with traditional thermal rendering techniques. It was determined that traditional thermal rendering processes provided the most simple, cost effective and efficient method of fat extraction from these sources.

Fat was extracted and combusted in a small (350,000 btu/hr) industrial boiler. Twenty-five individual runs were executed using a variety of fuels during the study. Critical parameters such as fuel consumption and efficiency, emissions and performance were tracked during each run. Financial feasibility of the process was determined to be dependent on both the current price of heating fuel and the value of the byproduct fat in other markets.

Study Findings

Fat Extraction by several methods was examined during this project. Anaerobic and aerobic fermentations as well as direct heat rendering and autoclave methods were investigated. Additionally, several waste products were examined for fat content and viability for fuel applications. Offal (inedible waste streams), leaf fat (fat from the upper part of the bird) and saddle fat (fat associated with the hind halves of the bird) were the three main products examined.

First, the feasibility of on-site fat extraction from an offal waste stream was examined. Successful separation of fuel quality fat from this stream would be a valuable upgrade to this by-product. Initial analysis of this material was achieved by a thermal rendering process. Final material weights were calculated. It was determined that this material was composed of approximately 10.4% fat, 47.9% water and 41.7% solid residues.

Two fermenting extraction methods were also examined; aerobic fermentation using microorganisms inherent in the offal material and anaerobic fermentation using silage cultures. Fermentation proved to be a low energy input method for recovering fat from poultry plant offal. However, high volumes, long residence times and low yields prevent this method from being economically viable. Thermal processing of offal requires less total capacity than fermentation; however the low concentration of fat in offal would require the heating of massive amounts of material. Approximately 3.4 gallons of water would have to be removed for every 1 gallon of fat recovered. At 8092 btu/gallon of water vaporized, this would require 27,512 btu per gallon of fat recovered. Each gallon of fat provides approximately 124,780 btu resulting in net energy recovery of approximately 78%.

Leaf fat and saddle fat samples were obtained in 50lb quantities from nearby processing plants. These were pulled on the line at each facility for the expressed purpose of providing a high fat containing by-product for this study. Leaf fat is generally kept on the final product but it often falls off during processing ultimately ending up in offal. Saddle fat is also treated in a similar manner as it is desired that it remains attached to the end product. However, it too often ends up in the waste stream. This material is

not 100% fat, but is much higher in fat content than offal. Thermal rendering process analysis showed leaf fat as delivered to be 75.25% fat, 8.74% water, and 14.58% other solids. As delivered, saddle fat was 43.43% fat, 29.53% water, and 27.05% solids. Only thermal rendering was examined for these highly concentrated fat source byproducts. This is the only method that provided large enough quantities of fuel grade fat for testing in our industrial boiler. Additionally the energy yield on this process was much higher than that of offal processing as dewatering of leaf fat has nearly a 99% energy yield and that of saddle fat is about 96%.

Ultimately, it was determined that non-pressurized, thermal extraction of concentrated fat containing waste material such as the leaf fat and saddle fat examined in this study was determined to be the most likely candidate for fuel fat production at a poultry processing plant. Fermentation methods, while technically feasible, were deemed economically unviable due to large treatment volumes and extended residence times. Autoclave methods were also deemed unfeasible both technically and economically as the high pressure used in these systems resulted in incomplete extraction even with extended treatment times.

Fuel properties were measured and are summarized in Table 1. Tests included Energy Content, Specific Gravity, Viscosity, Ultimate Elemental Analysis (C,H,O,N,S – ASTM D5291 and ASTM D4239), Triglyceride Profile, Moisture (AOCS Ca 2b-38), Insolubles (AOCS Ca 3a-46), Unsaponifiables (AOCS Ca 6A-40) and Free Fatty Acids (AOCS Ca 5a-40). Triglyceride profiles are shown in Table 2.

Interestingly, fat that was stored for over one year had similar energy content to the leaf fat provided by and freshly extracted in UGA laboratories. Saddle fat had slightly less energy than the other two examined fat sources; it also contained significantly more water as delivered, which may have had a diluting effect on the energy content of this material. Stored fat clearly had much higher free fatty acid content which is attributable to oxidative effects associated with long term storage. However, this increase in FFA did not have a large impact on energy values as the products of oxidation have similar energy content to the native triglycerides found in these oils. The 80% poultry fat/20% diesel mixture also had high free fatty acids and slightly higher energy content than pure fats as diesel fuel contains more energy than fat. Carbon and hydrogen levels were consistent throughout all fuels, but fats had much more oxygen which generally enhances combustion and reduces emissions. Petroleum based fuels (UMO, D2) had much more sulfur which is the source of sulfur oxide emissions.

The consistency seen in fatty acid profiles among the three different fats studied here is significant. Poultry from different parts of the bird, differently handled birds and variable storage conditions all generally had similar fatty acid composition. This is important to note as it suggests variability of fuels will not be dependent on the source of the fat, but on extraction methods and handling procedures.

Table 1. Fuel Properties of Tested Fuels (percent composition unless otherwise noted)

Properties	Stored Fat	80%Fat: 20%D2	Saddle Fat	Leaf Fat	D2	UMO
Ash	0.1	0.193	0.12	0.076	0.01	0.807
Carbon	79.2	77.5	76.77	70.7	86.2	81.1
Hydrogen	12.5	12.4	12.40	12.2	12.8	13.5
Nitrogen	0.14	0.02	0.20	0.024	0.04	0.26
Oxygen	7.96	9.83	10.43	10.7	0.841	0.95
Sulfur	0.1	0.01	0.01	0.01	0.0488	0.372
MIU	1.22	14.83	1.38	1.19	n/a	n/a
Moisture	0.1	1.27	1.09	0.36	n/a	n/a
Insoluble	0.44	0.05	0.16	0.1	n/a	n/a

Unsaponifiable	0.68	13.51	0.13	0.73	n/a	n/a
FFA	9.4	10.5	0.45	0.4	n/a	n/a
Viscosity (cP)	15.60	9.24	15.90	14.40	1.42	18.00
Specific Gravity (g/mL)	0.887	0.88	0.88	0.885	0.852	0.87
Energy Content (BTU/lb)	17047	17547	16488	17062	19144	19155

Table 2. Triglyceride Profiles of Tested Fats (percent composition)

Fuel	Stored Fat	Saddle 1	Saddle 2	Saddle Top	Leaf
C14:0	0.57	0.5	0.51	0.5	0.64
C14:1	0.22	0.22	0.24	0.25	0.25
C16:0	23.5	23.63	24.31	23.9	25.48
C16:1	8.33	8.91	9.28	9.52	8.78
C18:0	5.37	5.14	4.97	4.61	5.52
C18:1	41.71	44.68	44	45.12	42.5
C18:2	16.86	14.37	14.22	14.17	13.8
C18:3	1.01	0.81	0.82	0.79	0.77
C18:4	0.18	0.14	0.15	0.15	0.14
C20:1	0.54	0.56	0.54	0.57	0.65
C20:2	0.18	0.15	0.14	0.14	0.13
C20:3	0.18	0.12	0.13	0.12	0.1
C20:4	0.41	0.15	0.15	0.14	0.12
Unknown	0.74	0.62	0.54	0.63	0.61

Extracted poultry fat samples were combusted in the Clean Burn CB 350 CTB boiler. Stack emissions were measured using an ENERAC 3000E. The team recorded both average and instantaneous measurements of flue gas concentrations for oxygen, carbon monoxide, carbon dioxide, combustible gases, excess air, nitric oxide, nitrogen dioxide, NOx (NO + NO2), and sulfur dioxide. Test results including emissions and performance data are summarized in Table 3.

Table 3. Emissions and performance of various fuels in CB350 CTB boiler.

Fuel	100 PRF(4)	Leaf Fat(1)	Saddle Fat(4)	Avg*	80/20(2)	UMO(3)	D2(11)
Stack Temp (°F)	352	362	364	360	356	367	360
Oxygen (%)	4.00	4.03	5.17	4.67	3.98	3.35	4.30
Carbon Monoxide (lb/min)	0.0059	0.0062	0.0065	0.0063	0.0078	8.5029	0.0049
Carbon Dioxide (%)	14.98	16.56	13.94	0.00	15.00	15.56	13.83
Combustibles (lb/min)	2.47E-07	1.03E-06	1.41E-06	1.02E-06	1.31E-06	2.42E-06	1.02E-06
Excess Air (%)	22.12	22.78	31.16	27.38	21.81	17.89	24.13
Nitric Oxide (lb/min)	0.00073	0.00037	0.00043	0.00051	0.00036	0.00099	0.00030
Nitrogen Dioxide	0.00022	0.00019	0.00022	0.00021	0.00023	0.00006	0.00017

(lb/min)							
Oxides of Nitrogen (lb/min)	0.00095	0.00056	0.00065	0.00072	0.00059	0.00105	0.00047
Sulfur Dioxide (lb/min)	0.00007	0.00000	0.00006	0.00005	0.00008	0.00053	0.00006
Consumption (gal/hr)	2.43	2.38	2.51	2.46	2.42	2.37	2.22
Efficiency (%)	78.19	72.67	79.87	78.32	76.79	81.77	79.18
ΔT (°F)	24.69	24.17	25.77	25.11	24.92	28.52	24.81

*Average refers to the average of the three poultry fat samples. Numbers in parentheses indicate number of runs per fuel type.

In all cases, poultry fat had reduced emissions as compared to used crankcase oil (UMO), the fuel the CB 350CTB was designed to burn. However, when poultry fat emissions were compared to diesel fuel emissions, diesel had slightly lower emissions although the difference was not significant. Performance of poultry fat fuels was near that of the petroleum based fuels. As these fuels have slightly less energy value, the overall consumption of these fuels was slightly higher over the course of the study. ΔT, which is the difference in temperature between incoming water and outgoing water, was comparable between poultry fat (25.11°F) and diesel fuel (24.81°F). The higher BTU value of used crankcase oil resulted in a significantly higher ΔT of 28.52°F. Efficiency was also observed to be the highest when the boiler was fueled on UMO, its intended fuel. Diesel fuel and poultry fat had almost identical efficiencies of 79% and 78% respectively.

A brief study on the effects of regulation of oil and air flow on emissions and efficiency was conducted with little significant impact on boiler performance. Changes to aspiration pressure, oil pressure and air intake led to unpredictable changes in emissions but resulted in no net change in performance or efficiency.

Conclusions and Expected Impact

The collection and extraction of concentrated-fat containing materials from poultry processing lines is a feasible method of providing an alternative to petroleum based #2 fuel oil for industrial boilers. The collection of these materials inline can be accomplished manually or with mechanical defatters. In other situations, this material can simply be redirected from waste streams. Regardless of the collection method this material must then be thermally processed and filtered to separate fat from water and solids. This is a straightforward process requiring the introduction of steam heated retort or kettle systems. As poultry processing generally requires steam heat, this should be readily available for introduction into the new processing environment. The only capital investment needed in these applications is the purchase of heating vessels used to dewater and melt the poultry fat and a filter system to remove solids after water is removed.

On-site fat extraction from offal and other waste streams proved to be resource intensive as compared to simple extraction from higher-grade fat-containing products. The low yield of fat from offal (approximately 10%) necessitates high residence volumes and high energy inputs for extraction. Dewatering of offal accounts for most of the energy needed as the product examined was about 48% water. Ultimately, the processing of offal was beyond the scope of this study. Processing fat after it has entered the wastewater stream would require the implementation of large volume, large footprint rendering equipment more suited to an actual rendering facility than on-site in a poultry processing

facility. Initial capital investment and required real estate would make it a long-term return project, whereas simple on-site extraction of fat-rich materials is quite feasible.

Even with the limitation of using high-fat containing material captured before waste streams in poultry fat a significant financial impact can be realized. If only 20% of the 44.6 million gallons of poultry fat created in the state is recovered this could displace 8.9 million gallons of diesel fuel used in poultry processing. At a possible income sacrifice of $1.33/gal, its use will displace $2.60/gal in fuel costs for a net savings of $1.27/gal or $11.3 million for the state poultry industry. The capital investment for such a recovery system is relatively small as only steam jacketed kettles or retorts are needed with a simple filtration system. The required energy input of the system is only about 20% of that recovered. Taking this energy expense into account, the energy return is still near $9.0 million a year after initial capital investment is recovered. This is a conservative estimate as the price for petroleum has reached $70+ per barrel driving the price of diesel over $3.00/gal in some parts of the state. Additionally, the $.18/lb ($1.33/gal) price for poultry fat assumes the fat itself would have been kept in the box and sold for human consumption or other high-value use. Likely, much of the fat (up to 60%) would end up in offal for a price near $.03/lb ($.22/gal). If this system were to be implemented state-wide, the actual economic benefit to the state poultry industry could ultimately exceed the $11.3 million predicted above. Full copies of this report are available on the UGA-EOS website: http://www.engr.uga.edu/service/outreach.

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APPLICATION OF IMAGING TECHNOLOGY TO CHICKEN CARCASSES AND HATCHING EGGS

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Abstract

Machine vision technology has been utilized by many sectors of the food and agriculture industry to facilitate sorting, inspection, and field mapping. A specific application, hyperspectral imaging, has been adapted to detect the fertility/early development of hatching eggs and fecal material on chicken carcasses. Commercial broiler hatcheries could decrease utility usage and improve sanitation by removing the 15-20% of infertile eggs prior to incubation. Application of carcass imaging could lead to decreased water usage in broiler processing plants via selective washing of the relatively few contaminated carcasses.

Introduction

Approximately 1.2 billion broiler eggs are placed in hatcheries each year, resulting in over one billion broilers produced for eventual processing in the U.S. Infertility and early embryo death results in 15-20% of incubated eggs not hatching, and possibly contaminating large numbers of otherwise healthy eggs. This may lead to further reduction in hatchability and possibly poor chick health from pathogenic organisms. Broilers, when processed, must not have visible fecal material on the carcass prior to chilling. In response, plants have resorted to widespread usage of inside-outside bird washers (IOBW) to wash every carcass, greatly increasing the water usage of processing plants. Therefore, research projects have been designed and conducted to determine the feasibility of applying hyperspectral imaging technology to detecting infertile or non-developing eggs prior to or during early incubation, and detecting fecal material on carcasses during processing.

Detection of Egg Fertility/Development

Poultry hatcheries receive and incubate approximately 1.2 billion eggs per year while maximizing efficiency by controlling equipment, utility, and labor costs. However, 1% to 18% of these eggs will not hatch due to infertility and an additional small percentage of embryos will die during the first days if incubation. These eggs could harbor and grow pathogenic bacteria or molds, contributing to cross-contamination when these eggs build up pressure during decomposition and "explode" in the incubator. Hatcheries continually spend money on labor and sanitation supplies to eliminate or control molds in the environment. Other practices tend to also increase "problem" eggs. Incubators are usually loaded to maximum capacity, which may decrease hatchability by 0.5% to 2% from decreased ventilation and higher temperatures in the egg racks (French, 1997). Actual incubator temperatures have been reported to be higher than thermometer readings leading to overheating in the racks (Mauldin and Buhr, 1995). Hatchery practice typically includes candling about 5% of eggs after several days of incubation to determine flock fertility. Infertile/non-developing "clear" eggs are removed, but all of the infertile/non-developing eggs in the other 95% of uncandled eggs remain in the incubator.

De Ketelaere, *et al.* (2004) reviewed machine vision and other visual techniques that have been developed to address various egg problems. Methods for determining blood spots and bloody whites in intact eggs via analysis of light transmission through the egg have been reported. (Brant *et al.*, 1953; Gielen *et al*, 1979; Patel *et al.*, 1996; Schouenberg, 2003). Other researchers have analyzed the spectra of transmitted

light in various ways to determine fertility or early development in hatching eggs (Das and Evans, 1992a; Das and Evans, 1992b; Bamelis *et al.*, 2002; Liu *et al.*, 2004). Bamelis *et al.* (2002) have also attempted to use acoustic resonance for detection of embryos. Chalker (2003) reported on a system to detect infertile, dead, or contaminated eggs after 18 days of incubation, during vaccination and transfer to the hatcher.

To determine if hyperspectral imaging technology could detect infertile/non-developing eggs prior to or during early incubation, the following system was assembled: a SensiCam 12 bit digital camera with a silicon CCD detector, connected to a spectrograph and lens assembly. The camera was attached to a computer with software capable of capturing a hypercube image, where each pixel in the image contained spectra from approximately 400 to 900 nm. During experiments eggs were placed on a flat surface with a 29 mm diameter cutout with a tungsten-halogen (150 watt) light mounted below the opening to provide a candling effect, with the camera assembly above the egg.

The following experiment was reported by Smith *et al.* (2005): A commercial hatchery provided layer-type white shell eggs from Single-Comb White Leghorns (SCWL) for each of two trials utilizing 48 eggs each. Eggs were incubated at 37.5 C (99.5 F), 85% relative humidity, with hourly automatic turning. On Day 0 and at Days 1, 2, and 3 of incubation, 12 eggs were removed from the incubator, imaged, and broken out for visual confirmation of fertility or development. Images were taken with the egg lying horizontal to the camera. Twelve brown shell broiler-type eggs were obtained locally from broiler layers and incubated at settings as described above. On Day 0 twelve eggs were imaged, then the same 12 eggs were incubated for 1, 2, and 3 days; imaging was conducted on the same 12 eggs each subsequent day. On Day 6 the eggs were visually assessed for embryo development. Images were taken with the egg standing vertical to the camera, with the air cell up.

SCWL white shell eggs were exposed for 30 ms and a ratio of transmission images at two wavelengths, 576 and 655 nm was used for analysis. The ratio was used to differentiate pixels from the entire image as positive or negative fertility or embryo development, using an algorithm to mask the negative pixels in the image interior and non-essential background exterior pixels. The same process was used for broiler chicken brown shell eggs, except they were exposed for 250 ms and wavelengths used were 576 nm, then a range of wavelengths (682+/-13nm, varying across eggs). Using a range was necessary as the brown shell pigments resulted both in decreased light transmission and increased the amount of variability between individual eggs. The lower wavelength (576 nm) was chosen as it provided the maximum spectral difference between infertile and fertile eggs in layer-type eggs. The upper wavelength was chosen (655 nm for layer eggs, 682 nm plus or minus 13nm for broiler eggs) as it represented the maximum light transmission through the egg (peak signal to the detector).

The hatching egg study originally reported by Smith *et al.* (2005) produced the following results (summarized in *Table 1*). The hyperspectral imaging system detected fertile and developing embryos from layer type white shell eggs at the following rate: on Days 0 and 1 only 1 of the 46 eggs confirmed as positive by breakout was detected; on Day 2 60% of the 20 eggs were detected; on Day 3 91% of eggs were detected (21 of 23). The hyperspectral imaging system inaccurately detected one of the 7 infertile eggs as fertile on Day 2. For broiler-type brown shell eggs, the hyperspectral imaging system detected 13 of 24 eggs as developing, and 14 of 24 on Day 2. On Day 3, 20 of 24 eggs (83%), were detected as developing. All 24 of the brown shell eggs were fertile, so false positive rates were not determined.

Table 1. White shell layer-type eggs confirmed by breakout, number detected and accuracy of imaging system on Days 0-3 of incubation, and brown shell broiler-type eggs (summarized from Smith et al, 2005).

Egg type	Incubation Day	# Eggs	# Confirmed	# Detected	% Detection
Layer,	0	24	23	1	4
white shell	1	24	23	0	0
	2	24	20	12	60
	3	24	23	21	91
Broiler,	1	24	24	13	54
brown shell	2	24	24	14	58
	3	24	24	20	83

The 576 nm wavelength found to be an important indicator of development in this study was probably associated with visible blood as reported by other researchers (Brant *et al.*, 1953; Das and Evans, 1992a). The hyperspectral system is likely detecting the early formation of red blood cells, capillaries, and blood ring associated with early embryo development. The difficulty in identifying one specific upper wavelength for brown shell eggs was likely due to low light transmission through the egg due to pigmentation. This required the use of a band of wavelengths, from 668 to 695 nm. Previous researchers have also reported a decrease in light transmission through brown shell eggs (Liu *et al.*, 2004; Shafey *et al.*, 2004). Multiple wavelength bands were also utilized by Liu *et al.* (2004), where 20-nm wide bandwidths were used with average transmittance calculated for the bandwidth. The detection of early embryo development using hyperspectral imaging systems is possible, but further research is necessary to improve accuracy and pre-incubation fertility detection.

Detection of fecal material on carcasses

The poultry slaughter process presents several opportunities for fecal material to contaminate broiler carcasses. This contamination may persist on the carcass throughout processing (Byrd *et al.*, 2002). The Food Safety Inspection Service (FSIS) has established a zero-tolerance policy regarding visible fecal material on poultry carcasses (USDA, 1996). No visible fecal contamination is allowed on any carcass prior to entering the immersion chiller tank in order to prevent cross-contamination among carcasses. Currently, the inspection process for fecal contamination is through visual observation by human inspectors. To comply with the regulation processors have installed IOBW's that continuously operate and wash all carcasses prior to chilling.

Research has been previously been conducted to develop hyperspectral and multispectral imaging techniques to detect fecal contaminants on poultry carcasses (Lawrence *et al.*, 2003a; Park *et al.*, 2002a; Windham *et al.*, 2003a). Further research to refine these techniques have been reported by Lawrence *et al.*, 2003b, Windham *et al.*, 2003a, Liu *et al.*, 2003; Park *et al.*, 2004; Windham *et al.*, 2003c, and Park *et al.*, 2002b. Hyperspectral and multispectral imaging techniques conducted in the above studies utilized carcasses contaminated with ingesta, duodenum, ceca and colon material varying in size and location on the carcass. Windham *et al.* (2005) also tested the ability of the hyperspectral imaging system to detect intestinal contents of known mass.

The hyperspectral imaging system as described Lawrence *et al.* (2003a) consists of several components: an imaging spectrograph with 25-mm slit width - Grating Type I (ImSpector V9, Spectral Vision, Ltd.); a high resolution CCD camera (SensiCam, Cooke Corp.); 1.4/23 mm compact C-mount lens, (Xenoplan,

Schneider) and associated optical hardware; motor for lens motion control (Newport); frame-grabber (12-bit PCI interface board, Cooke Corp.); and computer (Pentium III, 500 MHz). The spectrograph has a nominal spectral resolution of 2.5 nm and is connected to a 2/3" silicon based CCD sensor with a 1280 x 1024 pixel resolution. Two 150-watt tungsten-halogen DC stabilized fiber-optic illuminators (Fiber-Lite A240, Dolan-Jenner, Inc.) are used for lighting, which may be adjusted for quality image acquisition.

The typical process used to capture hyperspectral images was described by Windham *et al.* (2005): at the beginning of each imaging session, HyperVisual software (ProVision Technologies, Stennis Space Center, MS) was used to collect system noise (ie. dark current), 99 % reflectance panel, and gradient panel measurements for percent reflectance calibration and validation. Carcasses were hung on a standard evisceration shackle, which was welded to a stainless steel support rod, and imaged immediately. Black cloth was hung behind the bird to provide contrast between the bird and background. HyperVisual software was used to control the camera, which was set at 4 by 2 binning resulting in 320 horizontal spatial pixels and 512 vertical spectral pixels measured per line-scan image. The exposure time was 50 ms. and it took about 40 s. to collect a 400 line-scan image (vertical spatial) needed to image an entire carcass half. After an uncontaminated ("clean") carcass was imaged, contaminants were applied. The clean carcasses and the application of fecal contamination were video taped so that the exact location of the contaminant was documented. While videotaping the clean carcass, a poultry scientist verbally documented any unusual features on carcasses. Some of the items noted on the "clean" carcasses were the locations of feathers, blood clots/hemorrhages, bruises, cuticle, scabs, and numerous other abnormalities. Image hypercubes of "clean" and contaminated carcass halves were calibrated to percent reflectance values as described earlier (Lawrence *et al.*, 2003b). The background was removed from the carcass image by applying a background threshold mask with a value of 6 % reflectance. Next, a ratio image was created by dividing a 565-nm image by a 517-nm image. The background mask was applied to the ratio image. The ratio of reflectance values at 565 and 517 nm has been determined earlier to be well suited for the detection of fecal contaminants (Park *et al.*, 2002a). Typically, feces and ingesta reflectance spectral data increase with frequency from 420 nm to 708 nm whereas, spectra of skin, meat, and bones decrease from 500 to 560 nm (Lawrence *et al.*, 2003).

A number of previous research reports from our laboratory have shown that the hyperspectral imaging system is capable detecting fecal contamination on broiler carcasses. The system correctly detects ingesta, duodenal, cecal, and colon content contamination on broiler carcasses, and is able to differentiate between contaminant types, with further work conducted on software applications (Lawrence *et al.*, 2003a; Lawrence *et al.*, 2003b; Liu *et al.*, 2003; Park *et al.*, 2004; Windham *et al.*, 2003a; and Windham *et al.*, 2003c). The major problem with the detection system has been false positives. Lawrence *et al.* (200) reported that scabs presented the main source of false positives. Windham *et al.* (2005) reported skin showing through small amounts of contaminant was the prime source of false positives in that study. Boundaries around contaminant-positive pixels, feathers, shadows, and glare have also been reported to cause false positives. Many false positives are multiple results from a few birds in each study. Further refinement of software applications is currently being conducted to reduce, if not eliminate, false positives.

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POULTRY LITTER ASH AS A DIRECT SUBSTITUTE FOR DICALCIUM PHOSPHATE IN BROILER DIETS

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The overall project that complements this research is the assessment of the feasibility of an integrated ethanol and poultry production (IPEP) system in North Alabama that uses poultry litter as an alternative source of process energy for corn/ethanol production. Practical alternatives to land application of poultry litter are needed because of concerns about phosphorus runoff into surface waters. Poultry litter ash (PLA) that results from the combustion of broiler litter has potential for use as a phosphorus supplement in poultry diets and has greater value in this respect as compared to its fertilizer value. Local sources of products obtained from the corn ethanol production system such as PLA provide a distinct economic advantage in reducing feed costs and maintaining bird performance.

Initially, two experiments were conducted to evaluate graded levels of PLA in broiler chicken diets and to evaluate nutrient bioavailablity of PLA a source of macro minerals for the broiler chicken.

Materials and Methods

Evaluation of Poultry Litter Ash

Initial analyses were completed to determine the mineral composition of the litter poultry ash (Table 1) along with values for the nutrient composition of macro and micro minerals used in the computer formulation matrix.

Experiment 1

Direct substitution of PLA for dicalcium phosphate on a weight:weight basis was accomplished at dietary levels of 0, 25, 50, 75, and 100%. (Table 2). All feeds were computer formulated to meet or exceed recommended nutrient requirements for broilers. A starter feed was fed from 0-21 days of age followed by a grower feed from 21-41 days of age (Table 2). For each of the five dietary treatments, nine replicates of eight birds were used. In this study, birds were reared in heated wire batteries with eight birds per pen. This experiment was terminated when birds were 41 days of age. Birds were provided feed and water *ad libitum* throughout the course of the experiment. Birds were weighed at 21 and 41 days of age. On day 41, femur bones were obtained from three birds per pen and pooled (by pen) for ash analysis.

Table 1. Composition of Poultry Litter Ash

Nutrient	Analyzed Values[1]	Computer Values[2]
Calcium (%)	16.68	16.70
Phosphorus (%)	10.08	10.00
Copper (%)	0.165	1500.00 ppm

Iron (%)	0.593	5000.00 ppm
Magnesium (%)	2.650	2.70 %
Manganese (%)	0.209	1900.00 ppm
Potassium (%)	7.64	7.5 %
Sodium (%)	4.34	4.2 %
Chloride (%)	0.99	1.0 %
Zinc (%)	0.136	1300.00 ppm
Selenium (ppm)	2.40	2.4 ppm
Fluoride (ppm)	436.0	
Aluminum (ppm)	7,260	
Antimony (ppm)	<5	
Arsenic (ppm)	52.0	
Cadmium (ppm)	0.80	
Chromium (ppm)	34.0	
Lead (ppm)	4.4	
Mercury (ppm)	<0.1	
Vanadium (ppm)	26.0	

[1]Values obtained from analysis of sample submitted to Eurofins, Memphis, TN
[2]Values assigned to Poultry Litter Ash when used as an ingredient in the computer feed formulation matrix.

Experiment 2

This study evaluated nutrient bioavailability of PLA as a supplement source of macro minerals for the broiler chicken. Those minerals of interest include: calcium, phosphorus, and potassium. This study was simultaneously conducted with Experiment 1. For this study, the 45 pens of birds were utilized for a 24-hour total excreta collection to calculate mineral bioavailability. Birds were introduced to the grower diets (Table 2) on day 21 of the experiment and allowed a one-day orientation period. On the 22nd day, feed weights were obtained and excreta collection trays were lined with aluminum foil. Following a 24-hr period, feed weights were obtained and excreta were quantitatively collected from all 45 pens. Excreta were pooled, freeze-dried, ground and analyzed for nitrogen, calcium, phosphorus, and potassium. Bioavailability for each of these minerals was determined as a percentage of the difference between amount consumed versus amount excreted.

Table 2. Composition and calculated analysis of experimental diets (Experiments 1 and 2)

	Starter Diets					Grower Diets				
	Level of Poultry Litter Ash (%)									
Ingredient	0	25	50	75	100	0	25	50	75	100
	g/100 g									
Ground yellow corn	58.52	58.52	58.52	58.52	58.52	64.00	64.00	64.00	64.00	64.00
Soybean meal (48% CP)	30.80	30.80	30.80	30.80	30.80	25.67	25.67	25.67	25.67	25.67
Poultry by-product meal (50% CP)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Poultry oil	2.80	2.80	2.80	2.80	2.80	2.77	2.77	2.77	2.77	2.77
Dicalcium phosphate[1]	1.40	1.05	0.70	0.35	0.00	1.28	0.96	0.64	0.32	0.00
Limestone (38% Ca)	1.12	1.12	1.12	1.12	1.12	0.98	0.98	0.98	0.98	0.98
Poultry litter ash[2]	0.00	0.35	0.70	1.05	1.40	0.00	0.32	0.64	0.96	1.28
Salt	0.40	0.40	0.40	0.40	0.40	0.42	0.42	0.42	0.42	0.42
DL-methionine	0.26	0.26	0.26	0.26	0.26	0.22	0.22	0.22	0.22	0.22
L-lysine	0.12	0.12	0.12	0.12	0.12	0.08	0.08	0.08	0.08	0.08
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis										
Crude protein (%)	22.00	22.00	22.00	22.00	22.00	20.00	20.00	20.00	20.00	20.00
Metabolizable energy (kcal/kg)	3087.	3087.	3087.	3087.	3087.	3153.	3153.	3153.	3153.	3153.
Calcium (%)	0.93	0.90	0.88	0.85	0.83	0.84	0.82	0.79	0.77	0.75
Non-phytate phosphorus (%)	0.45	0.44	0.39	0.36	0.33	0.42	0.39	0.37	0.34	0.31
Methionine (%)	0.62	0.62	0.62	0.62	0.62	0.56	0.56	0.56	0.56	0.56
Met + Cys (%)	0.95	0.95	0.95	0.95	0.95	0.86	0.86	0.86	0.86	0.86
Lysine (%)	1.27	1.27	1.27	1.27	1.27	1.10	1.10	1.10	1.10	1.10

[1] Contains 18.5% phosphorus and 24.1% calcium.

[2] Poultry litter ash was added to the diet at the expense of dicalcium phosphate on a weight:weight basis.

[3] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.

[4] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.

[5] Monensin Sodium; Elanco Animal Health, Inc., Indianapolis, IN 46285.

Statistical Analysis

Data from this experiment was analyzed by analysis of variance using the General Linear Models procedure of the Statistical Analysis System (SAS Institute, 1985; Cary, NC). Diet main effects were tested using replicate pens as the error term. All percentage data were subjected to arc sine square root transformation prior to analysis; however, actual data are reported. Feed efficiency was corrected for mortality. When significant ($P<0.05$), means were separated by Tukey's HD multiple comparison procedure.

Results and Discussion

Concern for the levels of dioxin in animal feed ingredients as well as other contaminants has been an ongoing concern and a feed safety-related issue. Dioxins are a group of chemical compounds that share certain chemical structures and biological characteristics, but exhibit a wide envelope of toxicity. Several hundred dioxin compounds exist including the well-known family of polychlorinated biphenyls (PCBs). The most toxic form of dioxin is 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). Dioxins are usually the result of a combustion process and are extremely persistent and stable compounds. The PLA was analyzed for dioxins and results were subjected to a toxic equivalency factor (TEF) where compounds are assigned a relative TEF value when compared to the toxicity of 2378-TCDD. To find the actual amount of dioxin in a sample based on the toxic equivalency quotient (TEQ), one multiplies the TEF by the concentration and adds each together. In 1998, the World Health Organization (WHO) derived the TEFs that most of the world uses now. Currently, the maximum limit for dioxin in a feed ingredient that falls into the category for PLA is 1.0 ng WHO-PCDD/F-TEQ/kg. Results from the dioxin analysis of PLA and the associated calculation of TEF indicate a level of 0.632 ng/kg, which is less than the current EU maximum limit for a mineral class of feed ingredient. The level of non-quantified PCBs was found to be 115 ng/kg. Results of the dioxin and PCB analysis indicates that there are no related compounds that appear to be significant to bird health or that pose a potential threat to the quality of meat that will be obtained from the slaughter of birds fed the PLA. Therefore, PLA was deemed safe for use as a feed supplement in poultry diets.

In Experiment 1, PLA was fed at graded levels (0, 25, 50, 75, and 100%) as a substitute for dicalcium phosphate. Diets in this study were based on direct substitution of PLA as a replacement for dicalcium phosphate on a weight:weight basis. The principle use for PLA is as a substitute for meeting the bird's phosphorus requirement. Phosphorus is the second most expensive ingredient in the diet, after protein, and PLA may offer exceptional advantage as a source of phosphorus. Although PLA contains micro minerals such as iron, zinc, copper, manganese, and selenium, changes in the rate of micro mineral addition were not altered via the trace mineral premix in this experiment. This approach to diet formulation resulted in decreasing levels of calcium and phosphorus as levels of PLA increased in the diet. It can be recognized that this approach may produce adverse effects due to inadequacies in meeting nutrient requirements, but may also challenge the bioavailability of minerals contained in the test ingredient.

Results indicated a slight growth response from poultry litter ash at the 25% substitution rate (Table 3). Factors contributing to this increased performance could not be identified. While a significant growth decrease occurred at the 100% substitution rate during the starting period, any effect on growth rate disappeared by the conclusion of the study at 41 days. Since the resulting diets were formulated based on an equal substitution of dicalcium phosphate with PLA, the concomitant decrease in phosphorus and calcium levels in the diet may have contributed to this decline in performance. Results indicate that the complete substitution of dicalcium phosphate with PLA failed to compromise growth rate, feed consumption or feed efficiency in market age broilers.

With increasing level of ash there was a significant ($P<0.001$) increase in excreta moisture (Table 4). It was not determined whether this increase is related to an increased water intake by birds fed increasing levels of PLA; however, this type of assumption would be justified. Although bone ash percentages varied among treatments, no specific pattern was observed (Table 4). Birds receiving the highest level of PLA exhibited the highest bone ash, while those receiving the 25% poultry litter ash treatment exhibited a significantly lower ash value. Bone integrity should not be compromised by the use of PLA and it is interesting to note that even though dietary phosphorus and calcium levels decreased as level of PLA increased, there appears to be no negative impact on bone mineralization.

Results from Experiment 2 indicate pronounced differences in the dry matter digestibility of specific nutrients (Table 4). Although differences in digestibility of nitrogen were detected, they are more likely related to differences in feed intake and not to PLA usage. Dry matter digestibility of calcium and phosphorus tended to increase ($P<0.05$) with increasing level of poultry litter ash. Such a relationship infers that calcium and phosphorus component of the diet was more efficiently utilized as level of PLA increased. It is plausible that the calcium and phosphorus contained in PLA may be more available to the bird as compared to the dicalcium phosphate used in the control diet.

Table 3. Performance of mixed sex broilers fed graded levels of poultry litter ash (Experiment 1)

Ash[1]	Bodyweight (g/bird)[2]		Bodyweight gain (g/bird)			Feed Consumed (g/bird)			Feed Efficiency (f:g)[3]		
(%)	21-day	41-day	0-21d	21-41d	0-41d	0-21d	21-41d	0-41d	0-21d	21-41d	0-41d
	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
0	866.1[ab]	2359.0	819.8[ab]	1416.8	2236.6	1146.1	3042.4	4188.9	1.317	2.118	1.773
25	878.8[a]	2299.0	831.8[a]	1370.7	2202.5	1169.5	2964.6	4134.6	1.307	2.166	1.787
50	848.8[ab]	2278.6	802.3[ab]	1368.0	2170.3	1119.9	2956.3	4076.6	1.319	2.146	1.789
75	839.3[ab]	2237.4	792.7[ab]	1350.7	2143.4	1110.4	2888.9	3999.6	1.314	2.141	1.783
100	824.0[b]	2263.7	778.3[b]	1362.6	2140.9	1124.6	2967.7	4092.6	1.323	2.124	1.776
SEM[4]	11.07	37.72	11.07	29.74	36.42	20.40	51.94	65.01	0.009	.026	.014

[ab]Means in a column with different superscripts are significantly different ($P<0.05$).

[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.

[2]All values represent least square means of measurements on eight battery cages each having eight birds.

[3]Feed efficiency calculated as amount of feed consumed per gram of bodyweight gain, corrected for mortality.

[4]Pooled standard error of mean.

Table 4. Percentage of excreta moisture, dry bone ash and dry matter digestibility of nutrients in broiler diets utilizing graded levels of poultry litter ash (Expriment 2)

Ash[1]	Excreta Moisture	Bone Ash	Nitrogen	Calcium	Phosphorus	Potassium
0	72.93[a]	69.39[ab]	61.72[a]	26.32[a]	30.23[a]	27.99[ab]
25	73.63[a]	68.71[b]	67.08[b]	37.71[b]	35.21[a]	30.68[a]
50	76.45[b]	69.49[ab]	66.28[b]	56.37[cd]	35.67[a]	25.70[ab]
75	79.49[c]	69.88[ab]	61.17[a]	50.42[d]	42.29[b]	22.87[b]
100	81.72[c]	70.60[a]	62.28[a]	58.65[c]	42.68[b]	27.99[ab]
SEM[2]	0.64	0.38	0.93	1.82	1.53	1.54

[ab]Means in a column with different superscripts are significantly different (P<0.05).
[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.
[2]Pooled standard error of mean.

NUTRITIONAL AND ECONOMIC VALUE OF POULTRY LITTER ASH AS A COMMERCIAL FEED SUPPLEMENT FOR BROILER CHICKENS

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Practical alternatives to land application of poultry litter are needed because of concerns about phosphorus runoff into surface waters. Poulry litter can be used as an alternative source of process energy for corn/ethanol production. The poultry litter ash (PLA) that results from the combustion of broiler litter has potential for use as a phosphorus supplement for use in poultry diets. The use of PLA has not been investigated to any extent and it is of interest to evaluate the use of PLA under commercial conditions as a phosphorus and calcium feed supplement for broiler production.

Materials and Methods

For this experimental trial a total of 1600 broiler chicks were obtained from a commercial hatchery (Cobb X Ross) and 25 birds were randomly assigned to each of 64 pens, each being 1.98 x 2.29 m in dimension. The open-sided housing had thermostatically controlled heating, curtains, and cross-ventilation. Pens were separated by wire partitions with concrete floor and isles. Electric brooders and forced-air furnaces supplied heat and natural curtain and fan ventilation was typical of that found in the commercial broiler industry. Each pen had fresh pine shavings and was equipped with one hanging feeder (22.5 kg capacity) and nipple water line system. Standard husbandry and good management practices were followed and meet industry guidelines. Chicks were vaccinated for Marek's disease at the hatchery

Birds were fed starter (1.8 lbs/bird), grower (3.5 lbs/bird), and finisher (6.7 lbs/bird) diets to meet or exceed National Research Council (NRC) recommendations (Table 1). For diet formulation, PLA (16.70% Ca, 10.00% P) was substituted for dicalcium phosphate (dical-P) (24.1% Ca, 18.5% P) in the computer formulation of nutrient adequate diets. The eight dietary treatments were 0, 25, 50, 75, or 100% PLA in the starter, grower, and finisher diets or 25, 50, or 75% in the starter diet followed by 100% supplementation with PLA in the grower and finisher diets. Diets and water were available *ad libitum*. Birds were weighed at 14, 28 and 41 days of age to determine live performance results. Feed consumption was also determined for the duration of the experiment. The experiment was terminated at 41 days of age.

Values for nutrient composition of macro and micro minerals used in computer formulation of diets were as follows:

Nutrient	Analyzed Values[1]	Computer Values[2]
Calcium (%)	16.68	16.70
Phosphorus (%)	10.08	10.00

Copper (%)	0.165	1500.00 ppm
Iron (%)	0.593	5000.00 ppm
Magnesium (%)	2.650	2.70
Manganese (%)	0.209	1900.00 ppm
Potassium (%)	7.64	7.5
Sodium (%)	4.34	4.2
Chloride (%)	0.99	1.0
Zinc (%)	0.136	1300.00 ppm
Selenium (ppm)	2.40	2.4 ppm

[1]Values obtained from analysis of sample submitted to Eurofins, Memphis, TN
[2]Values assigned to Poultry Litter Ash when used as an ingredient in the computer feed formulation matrix.

Dietary treatments for the experiment were as follows:

Treatment	Starter	Grower	Finisher
	Level of Poultry Litter Ash (%)		
1	0	0	0
2	25	25	25
3	50	50	50
4	75	75	75[1]
5	100	100	100
6	25	100	100
7	50	100	100
8	75	100	100

[1]An adequate amount of poultry litter ash was not available to formulate a 75% finisher diet and substitution with the control diet (0% poultry litter ash) resulted.

Processing and Yield Determination

Carcass yield was evaluated (at 42 days of age) for ten broilers from each pen at the AU Poultry Science Research Unit Processing Facility. Individual birds were randomly selected at terminal weighing when on full feed. Ten birds per pen were wing-banded, and placed back in the pens. Feed and water withdrawal was introduced eight hours (11 p.m.) prior to processing. A second weighing prior to processing followed the eight-hour feed withdrawal period. Carcass and abdominal fat weight were determined after a two-hour ice chilling to slightly less than 40 F. Following chilling, the front half and rear half were separated, weighed and the respective yield of each component calculated as a percentage of preslaughter live weight.

Table 1. Composition and calculated analysis of experimental diets

	Starter					Grower					Finisher[1]			
	Level of Poultry Litter Ash (%)													
Ingredient	0	25	50	75	100	0	25	50	75	100	0	25	50	100
	g/100 g													
Ground yellow corn	55.75	55.44	55.14	54.79	54.47	63.00	62.70	62.31	62.01	61.62	72.54	72.25	71.95	71.33
Soybean meal (48% CP)	35.09	35.12	35.14	35.17	35.19	29.70	29.71	29.81	29.82	29.93	21.76	21.82	21.87	21.97
Poultry oil	4.53	4.65	4.77	4.90	5.02	3.28	3.41	3.53	3.65	3.77	1.98	2.08	2.18	2.41
Dicalcium phosphate[2]	1.73	1.30	0.86	0.43	0.00	1.60	1.20	0.80	0.40	0.00	1.38	1.03	0.69	0.00
Limestone (38% Ca)	1.23	1.12	1.01	0.90	0.79	1.09	0.99	0.89	0.80	0.70	1.02	0.94	0.85	0.68
Poultry litter ash[3]	0.00	0.80	1.60	2.41	3.22	0.00	0.74	1.48	2.22	2.96	0.00	0.64	1.28	2.56
Salt	0.45	0.37	0.28	0.20	0.11	0.45	0.37	0.30	0.22	0.14	0.45	0.39	0.32	0.20
DL-methionine	0.27	0.27	0.27	0.27	0.27	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24
L-lysine	0.12	0.10	0.10	0.10	0.10	0.07	0.07	0.07	0.07	0.07	0.12	0.12	0.12	0.12
Vitamin premix[4]	0.50	0.50	0.50	0.50	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[5]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Coban-60[6]	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis														
Crude protein (%)	21.50	21.50	21.50	21.50	21.50	19.50	19.50	19.50	19.50	19.50	16.50	16.50	16.50	16.50
Metabolizable energy (kcal/kg)	3142.	3142.	3142.	3142.	3142.	3153.	3153.	3153.	3153.	3153.	3175.	3175.	3175.	3175.
Calcium (%)	0.93	0.93	0.93	0.93	0.93	0.84	0.84	0.84	0.84	0.84	0.75	0.75	0.75	0.75
Non-phytate phosphorus (%)	0.45	0.45	0.45	0.45	0.45	0.42	0.42	0.42	0.42	0.42	0.37	0.37	0.37	0.37
Methionine (%)	0.62	0.62	0.62	0.62	0.62	0.56	0.56	0.56	0.56	0.56	0.54	0.54	0.54	0.54
Met + Cys (%)	0.95	0.95	0.95	0.95	0.95	0.86	0.86	0.86	0.86	0.86	0.79	0.79	0.79	0.79
Lysine (%)	1.27	1.27	1.27	1.27	1.27	1.10	1.10	1.10	1.10	1.10	0.92	0.92	0.92	0.92

[1] An adequate amount of poultry litter ash was not available to formulate a 75% diet and substitution with the control diet (0% poultry litter ash) resulted.

[2] Contains 18.5% phosphorus and 24.1% calcium.

[3] Poultry litter ash was added to the diet at the expense of dicalcium phosphate.

[4] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.

[5] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.

[6] Monensin Sodium; Elanco Animal Health, Inc., Indianapolis, IN 4628.

Statistical Analysis

Data from this experiment was analyzed by analysis of variance using the General Linear Models procedure of the Statistical Analysis System (SAS Institute, 1985; Cary, NC). Diet main effects were tested using replicate pens as the error term. All percentage data were subjected to arc sine square root transformation prior to analysis; however, actual data are reported. Feed efficiency was corrected for mortality. When significant ($P<0.05$), means were separated by Tukey's HD multiple comparison procedure.

Results and Discussion

Results indicate that there were no significant effects ($P>0.05$) on bodyweight, bodyweight gain or feed consumption when broilers were fed graded levels of the PLA up to 100% replacement for dicalcium phosphate in the diet (Table 2). However, bodyweights and bodyweight gains tended to trend downward (not significant) for those birds that were fed the highest levels of PLA in the starter and grower feeds. These differences were not as great by day 41, indicating that compensatory growth may have been achieved to a slight degree. Also, there were no significant differences ($P>0.05$) in the processing performance of broilers at 41 days of age that received graded levels of the PLA as a substitute for dicalcium phosphate in the diet (Table 3). Results indicate that the complete substitution of dicalcium phosphate with PLA failed to compromise growth and processing performance in commercial broilers.

Economic Evaluation of Poultry Litter Ash

The value of the PLA is more directly related to the value of dicalcium phosphate or defluorinated phosphate that will be used to meet the bird's phosphorus requirements. In the 100% supplemented starter, grower and finisher diet, substitution of dicalcium phosphate with PLA was 1.73 vs. 3.22 lbs, 1.60 vs. 2.96 lbs, and 1.38 vs. 2.56 lbs, respectively. As a result, there is a requirement to use almost twice as much (ca. 46% more) PLA to meet the phosphorus requirements of the broiler. The breakeven value of the PLA used in these experiments can be estimated at approximately 54% the value of dicalcium phosphate on a weight:weight basis.

Table 2. Bodyweight, bodyweight gain, feed consumption, feed efficiency, and mortality of mixed sex broilers fed graded levels of poultry litter ash in the diet

Level of Addition[1] Start/Grow/Finish (%)	14-d Body Weight (g/bird)[2]	14-d Feed Consumed (g/bird)	14-d FE (g/g)	14-d Mortality[3] (%)	28-d Body Weight (kg/bird)	14-28 d BW Gain (kg/bird)	14-28 d Feed Consumed (kg/bird)	0-28 d Feed Consumed (kg/bird)	14-28 d FE (g/g)[4]
0/0/0	452.2	515.7	1.142	1.50	1.476	1.071	2.041	2.557	1.491[b]
25/25/25	469.6	511.1	1.089	0	1.517	1.095	2.081	2.592	1.500[b]
50/50/50	465.6	514.4	1.105	1.50	1.500	1.082	2.085	2.599	1.519[ab]
75/75/75	464.0	521.2	1.123	0.50	1.495	1.079	2.059	2.580	1.491[b]
100/100/100	461.2	485.8	1.054	1.00	1.452	1.038	2.037	2.523	1.570[a]
25/100/100	473.5	520.7	1.101	1.50	1.452	1.025	2.065	2.585	1.580[a]
50/100/100	466.9	512.0	1.097	0	1.462	1.042	2.051	2.563	1.550[ab]
75/100/100	464.9	519.1	1.118	1.50	1.477	1.059	2.087	2.606	1.552[ab]
SEM[5]	5.47	8.47	0.019		0.017	0.014	0.026	0.032	0.014
Probability	NS	NS	NS	NS	NS	NS	NS	NS	0.0001

Table 2. Continued

Level of Addition[1] Start/Grow/Finish (%)	0-28 d FE (g/g)	14-28 d Mortality (%)	41-d Body Weight (kg/bird)	28-41 d BW Gain (kg/bird)	28-41 d Feed Consumed (kg/bird)	0-41 d Feed Consumed (kg/bird)	28-41 d FE (g/g)	0-41 d FE (g/g)	28-41 d Mortality (%)	0-41 d Mortality (%)
0/0/0	1.375[ab]	0.51	2.557	1.080	2.295	4.852	2.129	1.898	0.50	2.50
25/25/25	1.364[b]	0.50	2.567	1.049	2.294	4.886	2.193	1.904	1.01	1.50
50/50/50	1.389[ab]	0.51	2.603	1.103	2.334	4.933	2.120	1.895	3.57	5.50
75/75/75	1.377[ab]	0	2.562	1.066	2.240	4.820	2.105	1.881	2.10	2.50
100/100/100	1.381[ab]	1.52	2.517	1.065	2.261	4.784	2.128	1.901	0	2.50
25/100/100	1.422[a]	0.51	2.537	1.085	2.213	4.799	2.044	1.892	3.57	5.50
50/100/100	1.393[ab]	1.0	2.555	1.093	2.307	4.870	2.119	1.906	1.52	2.50
75/100/100	1.397[ab]	1.52	2.596	1.119	2.394	5.000	2.036	1.926	5.24	4.50
SEM[5]	0.012		0.044	0.042	0.074	0.056	0.034	0.014		
Probability	0.036	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.
[2]Values are grand means involving 64 pens each with 25 chicks at placement.
[3]Total mortality percentages were transformed to the arcsine √ for GLM, whereas there is no valid SEM since data were transformed and subject to analysis.
[4]Feed efficiency calculated as amount of feed consumed per gram of bodyweight gain, corrected for mortality.
[5]Pooled standard error of mean.
[ab]Means in a column with different superscripts are significantly different.

Table 3. Processing performance of broilers at 41 days of age fed graded levels of poultry litter ash

Level of Addition[1] Start/Grow/Finish	Pre-Slaughter Live Weight[2]	Carcass Yield[3]	Chilled Carcass[4]		Abdominal fat[6]		Front-half		Rear-half	
(%)	(g)	(%)	Weight (g)	Yield[5] (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)
	NS[7]	NS	NS	NS	NS	NS	NS	NS	NS	NS
0/0/0	2648	71.39	1938	73.20	48.00	1.81	1072	40.49	818	30.90
25/25/25	2686	74.19	2045	76.00	48.50	1.81	1109	41.25	887	32.94
50/50/50	2701	70.07	1945	71.92	50.00	1.86	1072	39.60	823	30.46
75/75/75	2649	71.36	1944	73.23	49.63	1.87	1048	39.45	847	31.90
100/100/100	2654	72.85	1983	74.77	51.13	1.93	1075	40.47	857	32.37
25/100/100	2707	71.69	1993	73.66	53.25	1.97	1100	40.62	840	31.07
50/100/100	2641	70.45	1912	72.38	51.13	1.94	1057	39.99	804	30.46
75/100/100	2688	70.83	1955	72.75	51.63	1.92	1087	40.43	817	30.40
SEM[8]	66.74	1.16	61.29	1.16	1.78	0.051	32.56	0.419	33.55	0.978

[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.

[2]All values represent least square means of eight pens, each providing data from ca. 10 carcasses.

[3]Statistical analysis employed transformed values (arcsine $\sqrt{\%}$), whereas the respective SEM values were estimates derived from actual percentages.

[4]Carcass without neck and giblets after 2 hr of slush-ice chilling and removal of abdominal fat expressed on an absolute basis and relative to the full-fed live bird. Depot fat removed from the abdominal cavity of carcasses without neck and giblets after 2 hr of slush ice chilling expressed on an absolute basis and relative to the full-fed live weight.

[5] As percent of pre-slaughter live weight.

[6]Abdominal fat expressed on an absolute basis and relative to the chilled carcass.

[7]NS = Not-significant (P>0.05)

[8] SEM = Pooled standard error of mean.

BACTERIAL PATHOGEN DIE-OFF IN POULTRY MORTALITY COMPOST

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Composting has been demonstrated to be an environmentally sound, inexpensive method of processing poultry mortalities for disposal on land. Although composting does not dispose of mortalities, the process biologically transforms the mortalities into material that is amenable to land spreading for final disposal. To facilitate composting, the mortalities are combined with poultry litter, a carbon source such as wood chips, straw or peanut hulls, and water to achieve about 40% moisture in the total combined materials. One recommended procedure for composting poultry mortalities is to layer the materials in the compost bin in the following approximate ratio: 2 to 3 parts poultry litter; 1 part poultry carcasses: 0.1 parts wheat straw: 0.5 parts water (Donald and Blake, 1991).

One of the objectives of composting is to destroy pathogens (Haug 1993). Heat inactivation is not the only mechanism involved in the destruction of pathogens during the composting process. Competition from other microbes, antagonism, and inhibitory substances produced by competitive microbes such as antibiotics and bacteriocins are also likely to play a role in eliminating pathogens in compost. However, temperature and time are important criteria recommended by the U.S. EPA (1999) for class A municipal solid waste intended for distribution and marketing to the public. During composting, the temperature should reach 50C and remain at this level for five days. This temperature and time condition is readily achieved with poultry mortality composting. Studies conducted in the past have demonstrated that adequate heat generation during composting can be expected to kill pathogenic bacteria, viruses, fungi, protozoan cysts, and helminth eggs (Hanks, 1967). Because composting recipes, ingredients, and conditions are highly variable; microbiological testing should be conducted to verify that pathogens are destroyed by the composting process used.

Bacterial Pathogen Survival Methodology

The fate of *Escherichia coli* 0157:H7, *Listeria monocytogenes* and *Salmonella typhimurium* inoculated into compost was determined by studies conducted in the laboratory and not on commercial poultry farms to avoid contaminating the farms. High levels (~10^8/g compost) of the bacterial pathogens were inoculated into 5 g of primary compost which had been sterilized by autoclaving five times for one hour, each time in a BioHazard bag. Sterilization of the compost was necessary to eliminate the indigenous microflora which would interfere with enumeration of the bacterial pathogens. The pH of the compost was determined before and after autoclaving to determine the decline in pH due to ammonia volatilization. After autoclaving, the pH of the compost was adjusted to the initial pH (from pH 7.2 to 8.2) with reagent grade ammonium hydroxide diluted 1:10 with sterile water. Approximately 0.3 mL of 1:10 diluted ammonium hydroxide per 5 g of compost was required to readjust the compost pH. The pH of the primary compost from 10 previous compost studies ranged from pH 7.3 to 8.8 with an average pH of 8.1. When compost piles were moved, particularly primary compost, the compost always had an

extremely intense ammonia odor. Therefore, the addition of ammonium hydroxide to the sterile compost to restore the original pH appeared to be appropriate. Under actual composting conditions, the concentration of ammonia is likely to be higher than in the 5 g quantity of compost used to conduct the pathogen survival studies because the former has less surface area for release of ammonia. The ammonia as well as the indigenous microflora, are probably major factors limiting the survival of bacterial pathogens during the composting of poultry mortalities with poultry litter. Therefore, the laboratory studies to determine the survival of *E. coli* 0157:H7, *L. monocytogenes* and *S. typhimurium* in poultry mortality/litter compost probably do not limit the survival of pathogens as much as the actual composting process. To simulate composting conditions in the laboratory 5-g quantities of compost were placed in 47 mm diameter dishes and inoculated with 0.5 mL of a 24-hour Brain Heart Infusion (BHI) broth culture. Each culture was inoculated into 15 dishes which permitted three replicate dishes to be analyzed for pathogen survival at five heating periods. The inoculated dishes were placed inside a BioHazard bag containing a paper towel wetted with 10 mL of 1:10 diluted ammonium hydroxide solution. Prior to inoculation into the compost, the cultures were subcultured five consecutive times in BHI broth containing 10% volume of a 1:10 dilution of water extract of the compost. This was performed to help acclimate the cultures to the compost, and enable them to survive better in the compost. Replicates of each culture in 5 g of compost were placed in each of three BioHazard bags. A thermocouple was attached to one dish with 5 g of compost to monitor temperature inside the bag. One bag was incubated at 40C, one at 50C, and one at 60C. At timed intervals, a set of dishes which included each of the pathogens was removed from each of the bags and plated on agar medium to enumerate survivors. *Listeria* was enumerated on BHI agar and *Salmonella* and *Escherichia* were enumerated on Xylose Lysine Desoxycholate agar. The agar plates were incubated 2 days at 37C prior to enumeration of the survivors.

Results And Discussion

High temperatures achieved during composting are necessary to eliminate bacterial pathogens that might be associated with the poultry litter and mortalities. Enteric pathogens such as *Escherichia coli* 0157:H7 and *Salmonella* species are generally killed within 0.5 h at 60C. *Listeria monocytogenes* is more heat tolerant, but it too is easily killed by heat. Studies were conducted to determine the survival times of the bacteria in compost containing poultry mortalities and poultry litter. Three replicate studies demonstrated that the pathogens were killed in compost at 50C within a few hours. *Listeria* was reduced from 199 million viable bacteria/g of compost to one bacterium/g in 10 h (Fig. 1). *Escherichia coli* 0157:H7 was reduced from 100 million bacteria to one bacterium in 6 h (Fig. 2), and *Salmonella typhimurium* from 100 million to one viable cell in about 5 h (Fig. 3). At 50C all the pathogens were reduced by 8 logs in 10 h. It is unlikely that 100 million viable bacteria would be present in the initial compost. Therefore, lower initial counts reduced by 8 logs during composting would achieve adequate safety from the pathogens. This study demonstrated that the pathogens were killed in 10 hours. However, additional safety from pathogens is achieved during the 20 to 30 day period that the material is composted. At 60C the die-off of pathogens was faster than at 50C, but at 40C the pathogens persisted for more than 3 days with viable counts of over 10^5g of compost (Figure 4). The determined decimal reduction values for the pathogens in compost revealed L. *monocytogenes* to be more heat-tolerant at 50C than the other two pathogens. *Listeria* required 1.2 h at 50C to reduce the viable count by 90% (1 log), *Escherichia* required 0.75 h and *Salmonella* 0.56 h (Table 1). Ammonia generated during the composting process probably contributes substantially to the die-off of pathogens in compost. As a general recommendation to ensure the elimination of *L. monocytogenes, E. coli* and *S. typhimurium* from poultry mortality/poultry litter compost, the

average temperature of all portions of the compost should attain 50C or higher for 5 days cumulative during the primary and secondary stages of composting.

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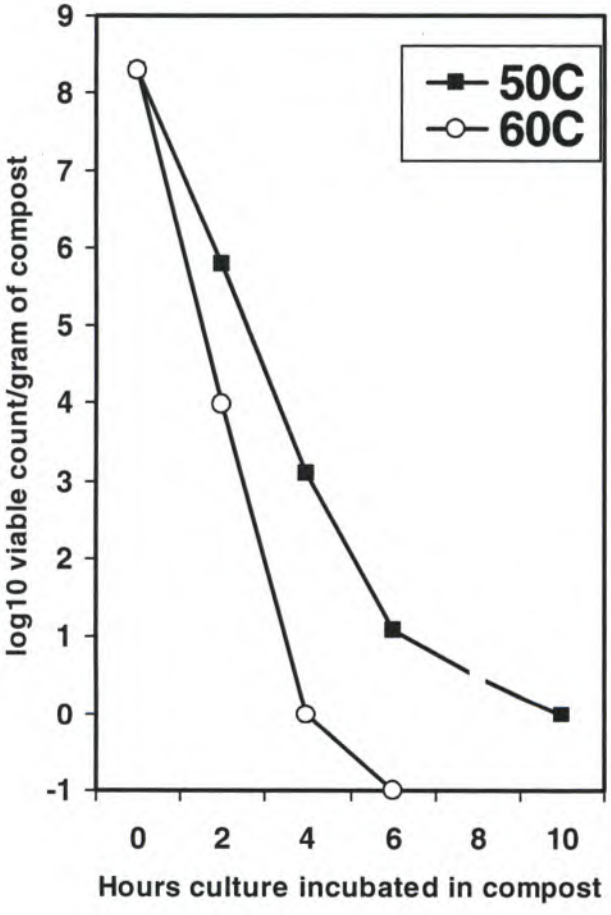

Fig. 1. Viability of L. monocytogenes in compost incubated at 50C and 60C

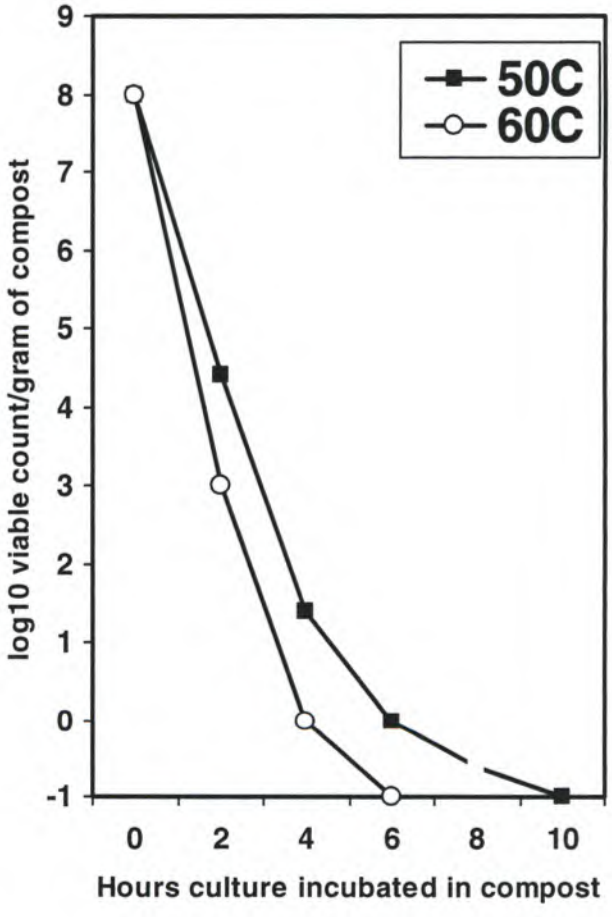

Fig. 2. Viability of E. coli 0157:H7 in compost incubated at 50C and 60C

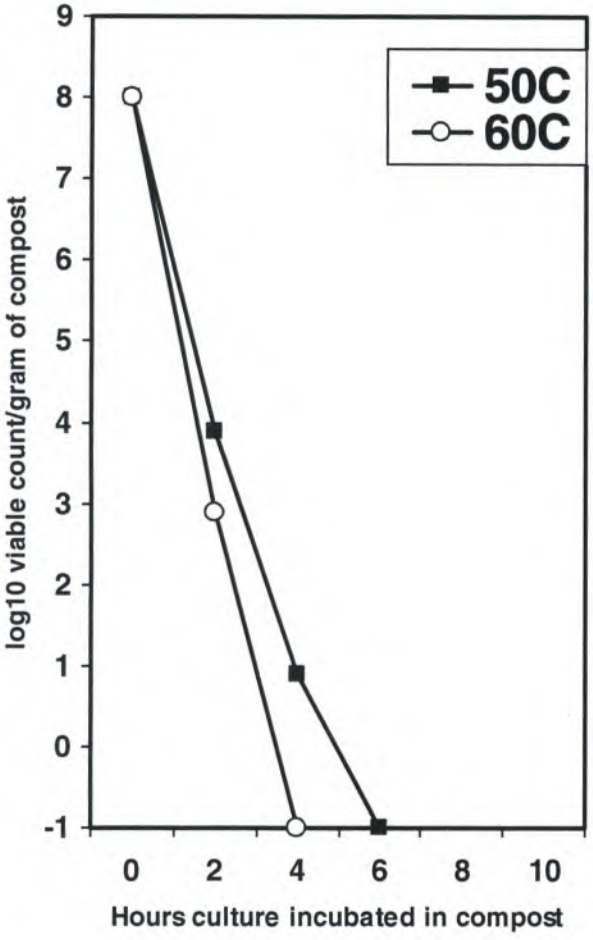

Fig. 3. Viability of S. typhimurium in compost incubated at 50C and 60C

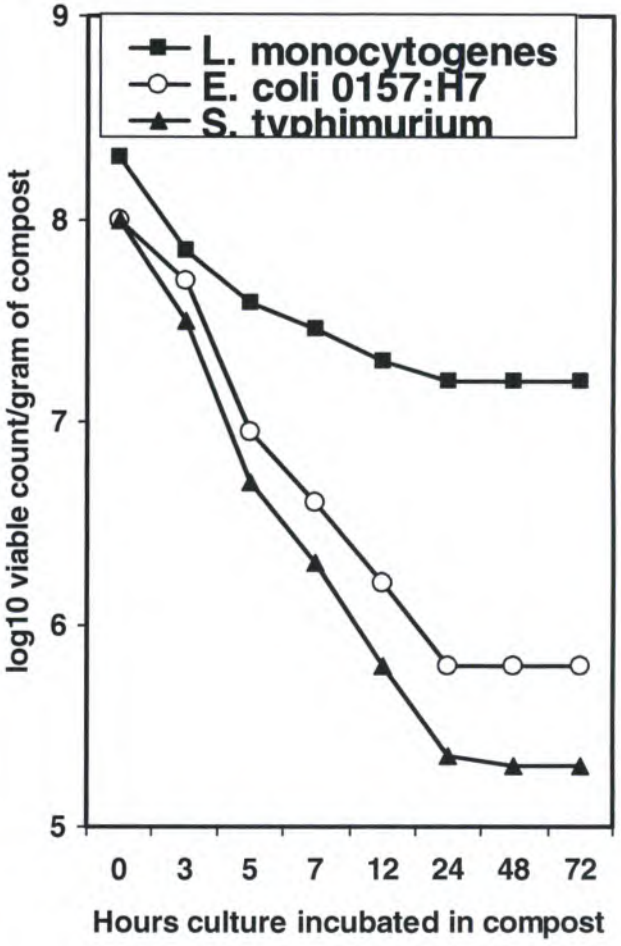

Fig 4. Survival of L. monocytogenes, E. coli, and S. typhimurium in compost incubated at 40C

Table 1. Decimal Reduction Values[a)] for Elimination of Bacterial Pathogens During Composting of Poultry Mortalities With Poultry Litter.

Pathogen	50C	60C
	- - - - D-value[a)] - - - -	
Listeria monocytogenes	1.20	0.48
Escherichia coli 0157:H7	0.75	0.50
Salmonella typhimurium	0.56	0.39

[a)]Time (hours) required to reduce number of survivors by 90% or 1 log.

BROILER CAKE POTENTIAL TO EMIT AMMONIA

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Abstract

Spatial differences for ammonia (NH_3) flux from litter are evident within broiler houses especially when considering friable litter and caked surfaces. The objectives of this study were to quantify NH_3 generation potential between different sources of cake (two separate farms having variable length of litter reuse), to compare sample size, and investigate the condition of the sample (whether broken or intact). Cake samples were collected approximately one-third of the length of the houses (48 m) from the tunnel fans, and width-wise near the center to avoid feeder and waterer influences. A randomized complete block (n=4 air supply manifolds) design compared 50 g single-piece cake samples, 50 g cake samples broken into four pieces, and 25g single-piece cake samples from two farms, 8 vs.18 flocks originally placed on pine shavings. Air passed over samples housed in individual 1000 mL containers where exhaust air and volatilized NH_3 were captured in boric acid and titrated daily for three days. Previous work has shown that leaving broken cake in houses can intensify NH_3 production. The current results suggest that the NH_3 generation potential of cake can be similar between farms (p=0.8895) without concern for litter age. Two additional inferences emerge as related to exposure of moist surface area of cake samples: (1) that larger samples of cake, not surprisingly, emit more NH_3 (p=0.0023) but, also, the rate of release is more rapid, and (2) break up of same-size samples generates more NH_3 (p=0.0411). Provided the lack of farm effect is proven in replicate studies, management practices for cake handling may be simplified with confidence. The results for effect of size and condition should be further explored to determine methods for reducing emission potential, such as rapid drying of broken cake surfaces.

Introduction

Accumulations of manure in areas of the broiler house where birds cluster form a cake-like layer over the litter or bedding. In commercial houses, areas of usual cake formation are near feeder/waterer lines and near the exhaust fans of tunnel ventilated houses where light infiltration through the fans is suspected to increase bird density and activity. The relative amounts of cake to friable litter and consequent effects on NH_3 flux from the floor surface area have been scarcely identified. The cake is compacted by the birds walking over it, allowing it to sometimes act as a physical seal to block NH_3 volatilization (Miles et al., 2006b). In addition, high moisture in the cake, though the upper limit is not defined, can cause it to become anaerobic; diminishing NH_3 volatilization (Carr et al., 1990). Ammonia generation in litter is expected to rise with increasing pH, temperature, moisture, wind speed, and litter ammonium concentration (Carr et al., 1990; Reddy et al., 1979). Yet, an animal facility survey of European NH_3 emission factors reported neither chemical nor physical means have been able to explain all variations in NH_3 release (Groot Koerkamp et al., 1998).

Decaking between flocks is a popular management strategy in the U.S. It is generally considered a benefit to farmers by reducing the amount of material for field application as fertilizer or to dispose of, if property is limiting (Sistani et al., 2003). Another benefit of decaking/litter reuse is

that the cost of new bedding is not realized with each new flock. However, NH_3 emissions do not fit simply into only one part of the flock cycle. Apportionment of total emissions, into the growout, waste storage, and land spreading in a recent broiler study were 28 %, 15 %, and 57 %, respectively (Nicholson et al., 2004). Obviously, handling of cake throughout the flock cycle potentially affects NH_3 generation especially when the cake is broken up causing exposure of increased surface area. The objectives of this study were to quantify NH_3 generation potential between two commercial broiler farms having variable length of litter reuse, to compare sample size of these cakes, and investigate the condition of the sample (whether broken into pieces or intact).

Materials and Methods

A chamber acid trap (CAT) system (Figure 1), similar to Moore et al. (1996) except improved by precision flow control, was used to assess the NH_3 generation potential of cake samples from two commercial broiler farms. The system was initially tested to determine the range of variability in NH_3 generation for a homogenous litter sample (± 2.6 %, unpublished data) and to compare litter to cake for potential NH_3 losses (Miles et al., 2006a). Four manifolds supply NH_3 free, humidified air to 12 individual (48 total) 1000 ml containers (chambers). Weighed cake samples, described below, were placed in each air tight chamber. Exhaust air from each chamber flowed through a series of two boric acid traps (50 ml flasks) at approximately 100 ml/min. The solution from the two flasks was combined into a single sample and titrated with HCl daily for three days. The NH_3 trapped in solution is reported as mg N recovered, or synonymously as mg NH_3-N.

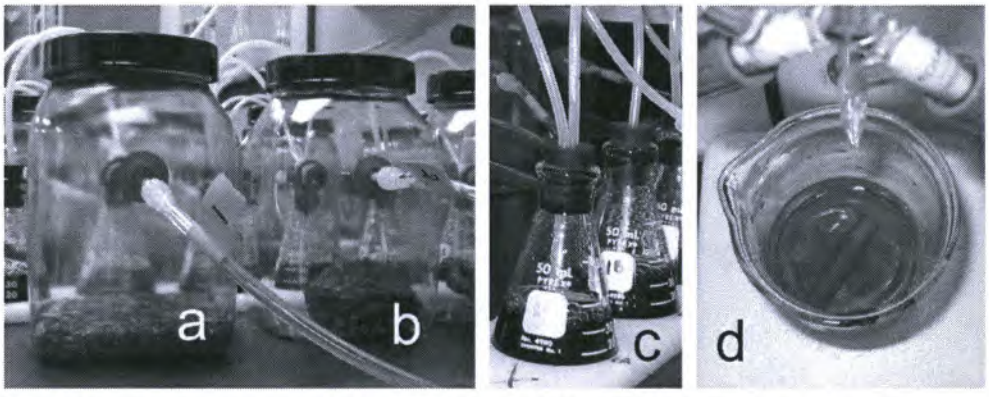

Figure 1. System components for capturing NH_3 from broiler litter or cake samples: (a) litter sample housed in chamber, (b) intact cake sample, (c) boric acid traps, and (d) titrated trap solution.

In Mississippi, winter cake samples were collected approximately one-third of the length of the houses (48 m) from the tunnel fans, and width-wise near the center to avoid feeder and waterer influences. A randomized complete block (n=4 air supply manifolds) design compared 50 g single-piece cake samples (intact), 50 g cake samples broken into four pieces (broken), and 25 g single-piece cake samples from two farms originally placed on pine shavings. Eight previous flocks had been grown in the Farm A house; Farm B had 18 flocks prior to this study. Moisture by loss in weight and pH (1:5 cake to deionized water) was determined on the samples. Estimates for least squares means were determined using the mixed procedure of SAS (2000) and are reported in Figures 2, 3, and 4. The probability of treatment effect on day 3 is given on each figure.

Results and Discussion

Temperature, pH, and moisture have been recognized for influencing NH_3 volatilization from litter sources (Elliott and Collins, 1982). Temperature was not a particular factor during the current trial as all samples were subject to room temperature. The moisture and pH of the cake from both farms were surprisingly similar. Farms A and B cake samples exhibited moistures of 40.9 % and 40.7 %, respectively; the pH was 8.97 and 9.04, respectively. The moisture analyses seem reasonable compared to a report by Sistani et al. (2003) indicating a range for cake moisture of 44.0 to 47.7 % for three commercial MS farms. The results contrasting the cake samples between Farm A and Farm B in Figure 2 show that the NH_3 generation appeared no different (p=0.8895), which may partially be explained by the similarity in original pH and moisture content.

The effect of the condition of the cake samples, whether broken or intact shown in Figure 3, appears significant (p=0.0411); the broken sample produced approximately 11 mg more NH_3-N after the 3 day experiment. Breaking up the cake exposed moisture rich surface planes to air, which would be expected to increase volatilization of NH_3.

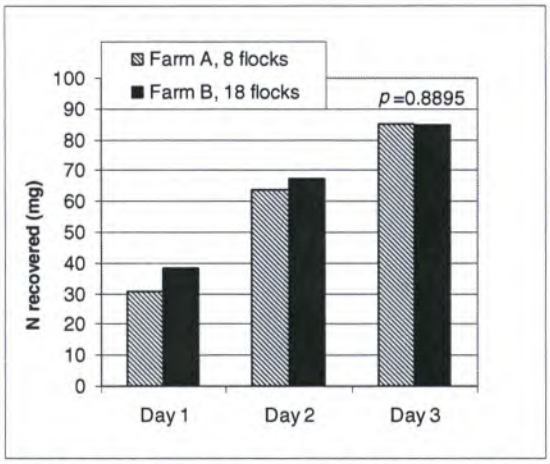

Figure 2. Farm contrast of cake samples for cumulative NH_3 volatilization.

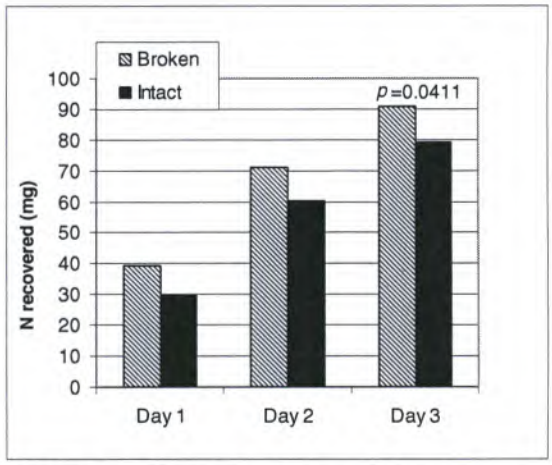

Figure 3. Effect of cake condition on cumulative NH_3 generation potential.

Cake sample size appeared to be a significant factor for potential NH_3 generation (Figure 4) with the probability estimated as p=0.0023. After 3 days, the 25 g samples had released approximately 55 % of the amount of NH_3-N that the 50 g samples discharged. Not surprisingly, the larger sample generated more NH_3 and the larger sample appears to have had a more rapid liberation of NH_3 when viewing the cumulative data. The dash lines in Figure 4 indicate a steeper slope for the larger sample, which would be expected from the greater surface area exposure. It is interesting to note the trends in daily NH_3 volatilized between the two sample sizes in Figure 5. The daily NH_3 recovered in the 25 g sample decreases with time and is just less than half of that of the 50 g sample on days 2 and 3, but the day 1 recovery was approximately 70 % of the 50 g sample. In contrast, the 50 g sample emitted nearly the same quantity of NH_3 on both days 1 and 2 before declining on day 3. More rapid drying of the exposed surface area of the 25 g samples may be responsible for the reduced volatilization.

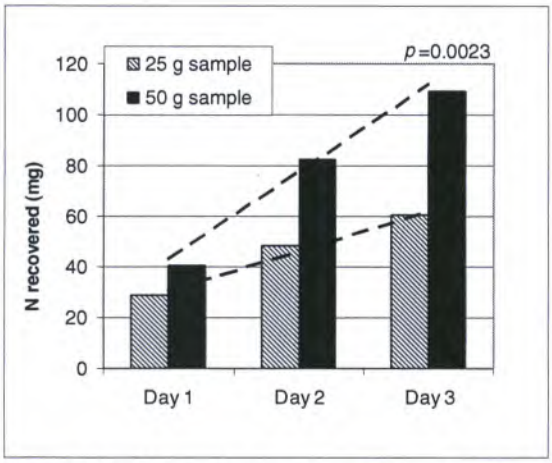

Figure 4. Sample size comparison of cumulative NH_3 volatilized from cake samples.

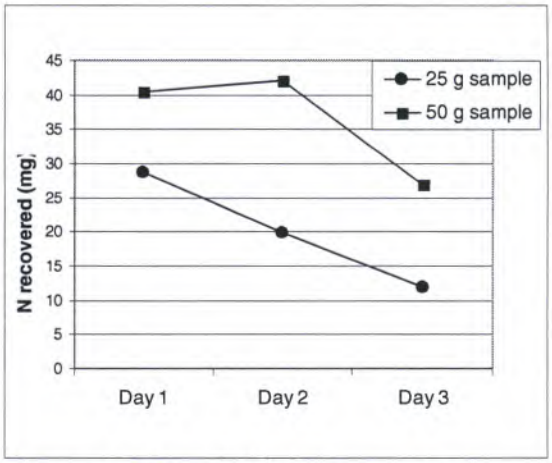

Figure 5. Daily NH_3 recovered from small and large cake samples.

Conclusions

The formation of cake may be inevitable in current litter systems. Previous research has shown a positive correlation exists between diminished NH_3 flux from the floor area and caked surfaces during the growout. However, results from the current study indicate that subsequent handling (i.e. breaking up caked litter) can significantly impact NH_3 release from cake. The NH_3 generation potential of cake was similar between farms that had previously grown 8 or 18 flocks on reused pine shavings litter. The simple study reveals that opportunities exist for greater understanding of the mechanisms of NH_3 generation with respect to the physical condition of caked litter. Though questions remain unanswered with respect to cake handling and storage options, rapid drying of exposed cake surfaces may present a prospective management solution to reduce NH_3 emissions.

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NATIONAL LIVESTOCK AND POULTRY ENVIRONMENTAL LEARNING CENTER http://lpe.unl.edu/

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Introduction

Significant challenges exist in the delivery of science-based information on animal manure management issues to non-researchers who influence the decisions of livestock and poultry producers. These challenges result from the expectation of animal producers to adopt practices so that they meet environmental policy. It continues to be a challenge for USDA Agricultural Research Service (ARS), land grant universities (LGUs), and others contributing new knowledge, to rapidly translate research findings in a meaningful way for non-research clientele.

This paper describes a new national initiative to improve the delivery of science-based information. The vision of the Livestock and Poultry Environmental Learning Center is to provide individuals involved in public policy issues, animal production, and delivery of technical services for confined animal systems with on-demand access to the nation's best science-based resources that is responsive to priority and emerging environmental issues associated with animal agriculture. USDA Cooperative States Research, Education, and Extension Service (CSREES) sponsored National Integrated Water Quality Program (National Facilitation Project) has provided initial funding of $300,000 for a national Learning Center targeting priority water quality issues specific to animal manure management. It is the intent of this initiative to test and demonstrate the role of a national Learning Center in improving the access of those individuals who influence livestock and poultry producers on animal manure management decision to the best science of land grant universities and agencies. This paper will describe a collaborative effort of land grant universities, USDA ARS and Natural Resources Conservation Service (NRCS), US Environmental Protection Agency (USEPA), US Geological Survey (USGS) and others to cooperate in the delivery of that science to our customers.

Information Outreach Challenges and Initiatives

The quality of and timely accessibility to science-based information is a significant weakness of our current outreach infrastructure. Friedman (2005), staff scientist at Environmental Defense and co-leader of a recent national effort to identify alternative technologies for the dairy industry, discusses the challenges of accessing public sector research:

"A primary reason for the inadequate use of research by programs and policies is the lack of well established cross-agency communication channels. There is no formal or continuous means for agencies such as NRCS, Extension, or US EPA to receive and utilize information from research entitles such as ARS and land grant universities. As a result, new developments ... are slow to reach producers ... A second challenge is language. Too often, ... the format and language of research papers is not user friendly for producers, their advisors, policy makers, or the general public.... The third challenge is the overwhelming volume of sites and papers distributed around the internet... -- and little if any verification

of quality or validity of the documents -- even those sources that are available become significantly less valuable and hard to find."

Many agricultural organizations have assembled resources to help animal producers. These include a wide range of state University and regional educational programs including three national resources: the Livestock and Poultry Environmental Stewardship (LPES) curriculum, the *CAFO Fact Sheet* series, and the White Papers developed by National Center for Manure and Animal Waste Management (National Center). Producer organizations such as the National Pork Board (NPB) have assembled producer curriculum (Environmental Assurance Program), implementation guides for Comprehensive Nutrient Management Plans (CNMP), and regulation summaries. US EPA provides access to a wide range of compliance assistance publications through its Agriculture Compliance Assistance Center (Ag Center). USDA-NRCS has developed technical design and management standards, software, and employee training programs (National Employee Development Center).

Despite the wealth of available information, the message being delivered can be confusing and inconsistent. The Internet is becoming a common source for real time information among a variety of audiences. A "Google" web search revealed a vast array of educational, government, commercial, and organizational resources. A review of the top fifty listings reveals that the land grant universities are the most likely source of information from which individuals will find information through the web. The bad news is that much of the premier educational and research information was not accessible to our customers through searches of the Internet. Our customers often find a range of answers of varying quality. Customer access to reliable science-based knowledge from our LGU system and partnering organizations is questionable. A nationally coordinated initiative is needed to address the EPA and USDA criticism expressed in the National Unified Strategy for AFO's of a "fragmented structure of our research and data collection efforts".

Commitments of this Project

A national team representing a broad spectrum of those creating, delivering and utilizing research-based knowledge will demonstrate a national Livestock and Poultry Environmental Learning Center. This project team is committed to:

- Implementing a customer driven approach that will identify critical or emerging issues and evaluate innovative technology transfer models.
- Coordinating for each priority issue the assembly of our best science-based information from multiple organizations for national delivery of timely and user-friendly resources.
- Developing and testing innovative outreach models for connecting those who are creating new research knowledge with the end users of that knowledge.
- Identifying appropriate national learning center roles that best support an existing network of organizations committed to an outreach mission.

Our ultimate customer for this project is the livestock or poultry producer. However, this project is committed to utilizing and supporting the existing network of public and private sector organizations delivering information to this customer. Our implementation plan includes three objectives.

Objective 1. Implement a national outreach education initiative that is responsive to customer identified priority issues.

This project has initiated a "Customer Advisory Team" representing stakeholders that will identify priority and emerging issues, assist in the delivery of the innovative outreach models tested by this project, and evaluate the effectiveness and impact of a National Learning Center. Our customer advisory committee currently includes representatives of the National Cattlemen's Beef Association, National Milk

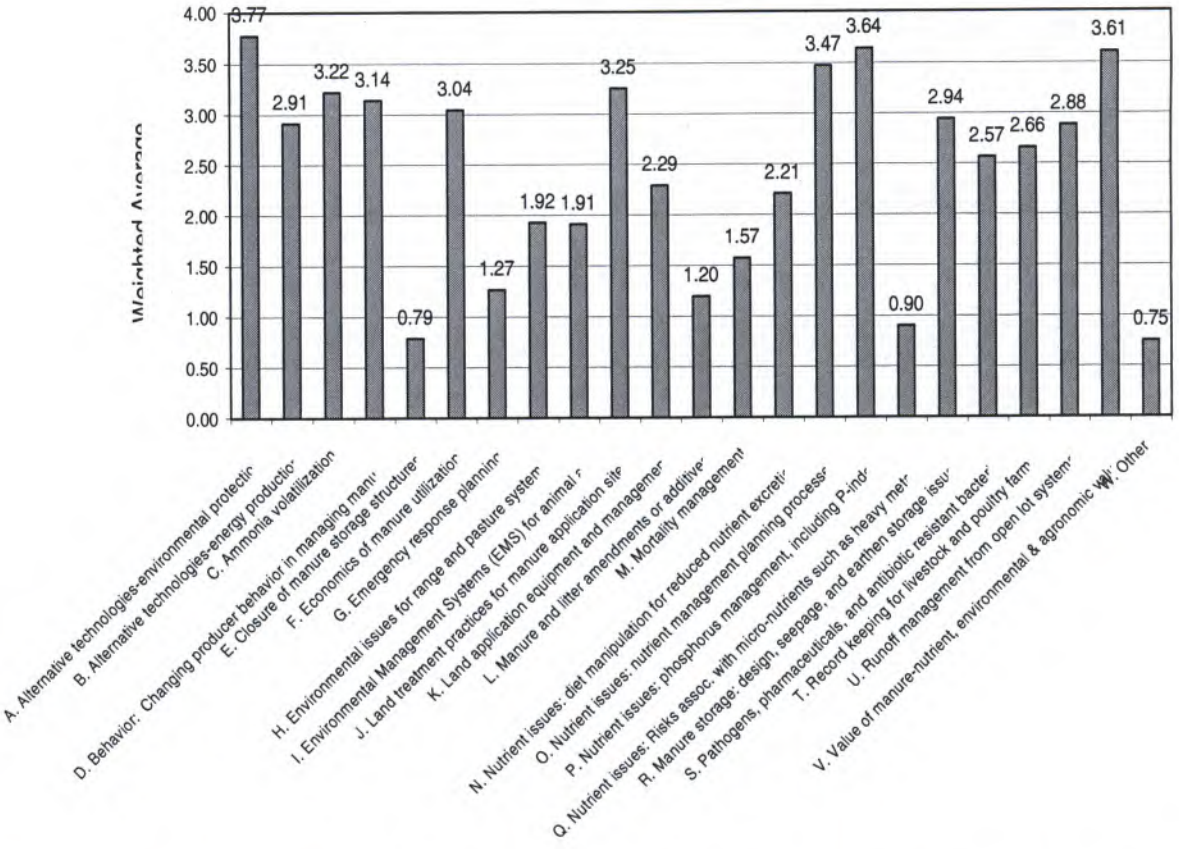

Figure 1. Priority issues ranking of 22 potential issues based upon responses of 345 returned surveys (weighted average with higher number indicating higher priority).

Producer's Federation, US Poultry and Egg Association, American Farm Bureau, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Association of State and Interstate Water Pollution Control Administrators, National Association of County Agricultural Agents, USDA National Agricultural Library, US Environmental Protection Agency, National Association of State Dept. of Agriculture. Don Parish, America Farm Bureau, is providing leadership for the team.

The customer advisory team led the implementation of a national wide survey of water quality issues associated with animal production. The information provided a basis for the advisory team's selection of priority issues for this project. 345 survey responses were received representing 41 states. Those who responded were asked to rank their 10 most important issues from a list of 22 possible topics. The ranking of these issues is illustrated in Figure 1. Based upon survey results an professional judgments, the customer advisory committee selected three priority issues for the Learning Center project; 1) Integrated nutrient management planning, 2) Value of manure, and 3) Alternative technologies. Upon a review by the project's implementation team of these priorities as well as the resource people on our team, a priority specific to pathogens and pharmaceutical water quality issues was added.

Objective 2 Establish the infrastructure for a sustained national outreach initiative with its foundation based upon a multi-disciplinary, multi-organization "National Outreach Team" of experts.

This National Outreach Team will improve linkages between organizations with outreach capabilities and organizations that produce research, educational, and planning products. The Outreach

Team includes over 20 individuals. Additional individuals will be invited to assist as experts for the four priority issues. To implement the activities proposed by this national outreach initiative, this team will initiate work groups or activities addressing:

- Customer identified priority issues.
- Innovative research delivery methods for communicating with non-research audiences.
- Electronic learning technologies (eXtension and web cast workshops) that will support that researcher and non-research clientele connection.

Objective 3 Deliver innovative products that provide a national audience on-demand access to our best science-based resources.

The Learning Center will test innovative learning technologies for connecting experts with individuals that influence livestock and poultry producer decisions. Our national survey attempted to understand current and future technologies that our customer prefers for learning new information. Those completing the survey prefer one-on-one communications, educational programs or workshops, or farm tours for learning new information (Table 1). Web sites, email, and electronic listserves were listed among the most frequently used technologies. When asked which future delivery technologies they would use to learn new information, "Research Updates" for lay audiences and jointly sponsored websites rated the highest. Web-cast workshop and virtual on-farm tours were rated between medium and high. The project proposes to test three innovative approaches for a national delivery of our best science-based resources:

National Web-Cast Educational Workshops. This project will deliver live educational workshops utilizing web-casting technologies on customer identified priority issues starting in September 2006. The seminars will be archived on the Learning Center web site for later viewing by individuals or as part of a local educational program.

Web-based Learning Center. This project will partner with the eXtension initiative to implement a the Learning Center. eXtension[1] will provide the tools for an effective web-based Center.

Table 1: Delivery approaches currently used to learn new information (345 responses).

Source	Average rating frequency[1]	Average rating preference[2]
Educational programs or workshops	2.07	1.79
Farm tours	2.67	1.97
Online courses or workshops	3.59	3.22
One-on-one communication	1.79	1.66
Print media: newsletters, magazines, educational publications	2.26	2.36
Research journals or other research publications	2.43	2.38
Radio	3.83	3.55
Television programming: videos, satellite/cable	3.76	3.37
Websites, email or electronic listservs	1.96	2.15

1: Frequency scale was 1=often, 3=some, 5=never
2: Preference scale was 1=prefer, 5=dislike

For additional information go to http://about.extension.org/wiki/eXtension:About

Additional Customer-Friendly Outreach Models. The Outreach Team will explore development and implementation of additional innovative outreach models such as virtual on-farm tours of innovative and emerging technologies and concise and timely "Research Updates for Non-Researchers".

Conclusions

The rapidly changing expectations of livestock and poultry producers to address livestock and poultry environmental stewardship challenges our current delivery of research based information in a timely fashion to our non-research customers. The Livestock and Poultry Environmental Learning Center will address these challenges through the development and implementation of new information and innovative delivery strategies. Our team includes a dynamic and diverse group of individuals that welcomes additional participation. Please feel free to contact any of authors or visit our website if you would like to participate in the outreach efforts.

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EVALUATION OF TEN RECIPES FOR COMPOSTING POULTRY MORTALITIES

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Ten recipes with poultry mortalities, poultry litter, water and a supplementary carbon source of peanut hulls, hay or no added carbon source were evaluated on two commercial broiler poultry farms. The carbon sources were selected based on their current use on the two farms. One farm routinely used peanut hulls and the other poor quality Coastal Bermudagrass hay which was not suitable for beef cattle feeding. Many poultry compost operations in Alabama do not add a supplementary carbon source in order to reduce cost and labor of composting. To evaluate this emerging composting practice, four of the ten compost recipes evaluated had no added carbon source. The compost recipes selected for evaluation were based on proportions of compost ingredients routinely used on each farm and proven to compost satisfactorily. Variations in the recipes used on these farms served as the basis for the 10 compost recipes evaluated. Earlier studies evaluated compost recipes with carbon: nitrogen (C:N) ratios of 15:1 and higher, but none were practical or economical for composting poultry mortalities with broiler poultry litter. Compost recipes with C:N ratios of 15:1, 20:1, and even up to 30:1 are generally advocated to promote efficient composting. However, due to the low carbon content of broiler poultry litter and poultry mortalities, carbon from peanut hulls, straw, hay, wood chips or some other source must be added in substantial amounts to achieve C:N ratios of 15:1 or higher. With higher C:N ratios, a much higher percentage of the compost bin is occupied with the carbon amendment, making less space available for composting poultry mortalities and poultry litter.

Composting Procedure

Composting was done in bins with dimensions of at least 8.00 m^3. All compost bins were constructed of 2" x 6" treated lumber on concrete slabs in pole barns. Mass of compost ingredients used for each recipe depended on the stage of production of each poultry producer and averaged 4132 kg (range 1965 to 5115 kg). For each recipe, poultry mortalities, carbon source, water and poultry litter (in that order) were weighed in the given proportions and layered into the compost bin. The amount of material used per layer was determined by the weight of the poultry mortalities for that day. Two thermocouples for monitoring temperature were placed in each of the layers as the bin was filled. Two times the quantity of poultry litter used per layer during filling the composter was used as the base and cap on the compost pile. After each composter was filled, the quantity of all the ingredients was tallied to determine the weight ratio of ingredients loaded into the composter. Metal yardsticks placed at each of the four corners and at the middle of the back wall of the composter were used to determine volume reduction during primary and secondary stages of composting. Temperature of the primary compost was monitored daily for at least 14 days. After the maximum temperature was reached and steadily declined for approximately one week, the compost was loaded onto a truck and weighed to determine weight loss during the primary compost stage. Samples of the compost were collected, pooled, and mixed to yield representative

samples for proximate and mineral analyses. The compost from the primary stage was mixed and aerated during cleanout. It was then weighed and placed back into the same bin for the secondary compost stage. Thermocouples were placed into the material about 0.18 m above the concrete floor and every 0.15 m thereafter. At each height interval in the compost pile, two thermocouples were used to monitor temperature. After the maximum temperature was reached and the temperature declined for about one week (about 26 days for secondary composting) the compost was weighed and samples collected for analysis as described previously. Proximate analysis was conducted by AOAC procedures (1984). Mineral analysis was performed using inductively coupled argon plasma spectroscopy, according to procedures outlined by Hue and Evans (1986). Total kjeldahl nitrogen was determined on wet samples and calculated on a dry matter basis. Ammonia-N and oxidized-N were determined in a KCl extract of the wet sample (AOAC, 1984). All other analyses were conducted on oven-dried samples.

Results And Discussion

The ten compost recipes evaluated are shown in Table 1. Three recipes had three levels of peanut hulls as the carbon amendment, three recipes had three levels of hay, and four had no added carbon source. The moisture content of the compost recipes averaged 35.2% and ranged from 26.5 to 39.8% (Table1). The recipes were formulated to obtain a target moisture content of 40%; however, the moisture content of the compost may be different after primary and secondary composting due to variations of the compost in the compost bin. It might be advisable to increase the added water to compost to achieve between 35 and 45% moisture. Below 35% moisture the two-stage composted poultry mortalities/poultry litter will be too dry, which will limit digestion of the mortalities, and greater than 45% moisture will limit air penetration into the compost, also limiting organic matter digestion. All recipes had adequate moisture for composting except recipe PH-high. The two-stage compost was dry and dusty; however, there was adequate digestion of the poultry mortalities

The C:N ratios of the compost recipes averaged 7.6:1 and ranged from 6.9:1 to 8.4:1 (Table1). Initially, recipes with C:N ratios ranging from 10:1 to 14:1 were formulated, but when the compost piles were under construction, it became apparent that a high proportion of the compost bin would be occupied with added carbonaceous material rather than with poultry mortalities and poultry litter. When the no-added carbon recipes (NC) were admixed with poultry mortalities and litter, the C:N ratio for these four compost recipes ranged from 6.9:1 to 8.4. The C:N ratios of the ingredients used in the ten compost recipes are shown in Table 2.

The moisture content, bulk density, and N-P-K content of the two-stage compost for each of the ten recipes are shown in Table 3. The moisture content of the final compost ranged from 27.7 to 40.7% and averaged 36.0%. The bulk density ranged from 484.7 to 730.4 kg/m^3 and averaged 626.5 kg/m^3. Bulk density comparison of the composts relative to the ratio of ingredients used in formulating the composts was difficult because moisture content of ingredients may vary from time to time. In general, compost recipes which employed no carbon amendments (NC recipes) appeared to have higher bulk densities than compost containing hay as the carbon amendment (Table 3). Compost ingredients amended with peanut hulls had a bulk density that appeared to be intermediate to hay (BH recipes) and the non-carbon (NC) amended recipes.

The nitrogen content of the finished compost for all recipes ranged from 3.85 to 8.23% and averaged 5.30%, expressed on a dry weight basis (Table 3). The compost from the non-carbon (NC) amended recipes had a higher N content (avg. 6.63% N) than the carbon amended recipes (avg. 4.42% N; PH and BH recipes). Because the carbon amendments have a low N content, their addition would be expected to reduce the content of N in the finished compost. The conversion of proteinaceous N in the poultry

mortalities to ammonia might also be limited in compost mixtures which lack adequate carbon reserves for microbial activity. A survey of broiler litter collected from 106 farms in Alabama showed that the N content of the litter ranged from 2.3 to 6.0% of dry matter and averaged 4.0% (Stephenson et al., 1990). Therefore, poultry mortality/poultry litter compost in general had a higher N content than average quality poultry litter; however, the data also indicated that some of the recipes yielded compost with N contents similar to that of poultry litter alone. The finished compost had similar levels of P and K as reported for poultry litter.

The temperatures achieved during first stage and second stage composting for each of the ten compost recipes are shown in Table 4. Based on the cumulative days during first stage and second stage composting, all compost recipes achieved > 50C for at least 15 days except recipes BH-low and NC-1. Recipe NC-2 had similar ingredient levels compared to recipe BH-low, yet NC-2 achieved 26 days of heating above 50C. Compost should achieve 55C and maintain or exceed this temperature for at least 3 days to eliminate pathogens according to EPA recommendations (U.S.EPA, 1999). When this criterion was used to evaluate the 10 compost recipes, the following four recipes failed to achieve an average 55C in all layers of the compost: PH-low, PH-medium, BH-low and NC-1. The lower temperatures of these compost mixtures cannot be explained on the basis of moisture content or C:N ratios of the recipes. Mass loss, which is indicative of biological activity was higher (avg. 20.1%) in these recipes compared to the other compost mixtures (avg. 16.8%). Although temperatures achieved in compost recipes PH-low, PH-medium, BH-low and NC-1 were lower than the other compost recipes, the compost mixtures exhibited good degradation properties. The major apparent difference of the compost mixtures was their inability to achieve 55C.

A summary of the composting efficiencies of the 10 compost recipes is shown in Table 5. The average mass reduction during both stages of composting for the 10 compost recipes was 18.1% and varied from 8.2% to 28.8%. Due to variations in mass loss among the recipes, it is difficult to determine whether the addition of a carbon source or the type of carbon source had any effect on mass reduction. Mass reduction was not related to the temperature attained in the compost bin. Some compost recipes maintained $\geq$50C for $\geq$15 days during both stages of composting and had some of the lower mass reductions, such as recipes BH-medium and NC-3. Recipe NC-1 had the second highest mass reduction (26.3%) but the compost did not attain a temperature of 50C in either the primary or the secondary compost stage. Eight of the 10 recipes attained $\geq$50C for 15 days or more, which indicated that this criterion should be adopted as a guideline for determining whether composters are working properly. This criterion also should be adopted as the minimum acceptable temperature and time for elimination of bacterial pathogens from compost.

Volume reductions during two-stage composting ranged from 4.3 to 26.3% and averaged 12.5% (Table 5). The extent of volume reduction was not related to mass reduction, temperature during composting, or the initial moisture content of materials placed in the primary composter. Volume reductions would appear to be related to the amount of carbon addition to the compost recipe. This observation is based on recipe BH-high, which contained an excessive amount of hay. Recipe BH-high compost was not free-flowing but rather resembled a large bale of hay, making removal of the compost from the compost bin difficult. The hay obviously compacted during the composting process, which accounted for the highest percent volume reduction (26.3%) of the 10 compost recipes evaluated. Bulk density of the final BH-high compost was the lowest (Table 3) of all the compost recipes, indicating that the compost was less dense and more subject to volume reduction. The bulk density of the BH-high compost increased 13.9% while the majority of the compost recipes decreased in bulk density. The increase was associated with settling of the compost which is characteristic of bulky materials.

Nitrogen content of the final compost averaged 5.30% (dry basis) and ranged from 3.85 to 8.23% (Table

3). During two-stage composting the nitrogen content decreased an average of 14.6% and the loss ranged from 8.6 to 23.0% (Table 5). The addition of carbon to the compost mixture, either as peanut hulls or hay, increased nitrogen loss compared to mixtures without these carbon amendments. Nitrogen loss from carbon-amended recipes averaged 17.9% while the loss from non-carbon-amended recipes averaged 9.7%. The nitrogen content (dry basis) of the finished compost averaged 4.41% for the carbon-amended recipes and 6.63% for the non-carbon-amended recipes.

This study revealed that all recipes except two would have been satisfactory for two-stage composting of poultry mortalities to achieve the recommended temperature of 50C for 15 days (Table 5). The 5:1 ratio of litter-to-mortalities with a low level of hay (BH-low) and the 6:1 ratio of litter-to-mortalities with no added carbon (NC-1) failed to achieve 50C during composting. Also it was noted that all recipes with no added carbon failed to achieve 50C for 15 days during first-stage composting. This indicates that mortalities composted in poultry litter alone must be turned at least once to achieve adequate heating to kill pathogens prior to movement of the litter off premises or prior to land spreading.

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Table 1. Initial Moisture and C:N Ratio of Compost Recipes

Compost Recipe[a)]	Ingredient Ratio BL/CS/PM/WR[b)]	Moisture %	C:N
PH-low	3.40/0.24/1.00/0.50	37.9	7.2:1
PH-medium	2.00/0.35/1.00/0.42	39.8	7.7:1
PH-high	4.50/0.68/1.00/0.29	26.5	7.6:1
BH-low	5.00/0.10/1.00/1.00	35.4	8.3:1
BH-medium	2.80/0.10/1.00/0.50	33.9	8.3:1
BH-high	3.00/0.50/1.00/1.00	37.3	7.0:1
NC-1	6.00/0/1.00/1.00	34.7	7.3:1
NC-2	5.00/0/1.00/1.00	34.7	7.4:1
NC-3	4.50/0/1.00/0.75	36.0	6.9:1
NC-4	4.00/0/1.00/1.00	35.9	8.4:1
Average		35.2	7.6:1
Range		26.5 to 39.8	6.9:1 to 8.4:1

[a)]Carbon sources used were peanut hulls (PH), Coastal Bermuda grass hay (BH), and no added carbon source (NC)
[b)]BL=Broiler Litter; CS=Carbon Source; PM=Poultry Mortalities; WR=Water.

Table 2. C:N Ratios of Compost Ingredients

Ingredient	C:N ratio
Broiler litter	8.0:1
Peanut hulls	42.5:1
Hay	16.6:1
Poultry mortalities[a)]	5.0:1
Water	0

[a)]Murphy and Handwerker, 1988.

Table 3. Moisture, Bulk Density and N-P-K of Final Compost

Compost	Ingredient Ratio	Moisture	Density	N	P	K
Recipe[a)]	BL/CS/PM/WR[b)]	%	kg/m^3	- - - - % of DM - - - - -		
PH-low	3.40/0.24/1.00/0.50	36.2	606.5	4.99	2.16	3.09
PH-medium	2.00/0.35/1.00/0.42	36.1	677.4	4.47	2.42	3.47
PH-high	4.50/0.68/1.00/0.29	27.7	556.8	3.85	3.73	4.07
BH-low	5.00/0.10/1.00/1.00	40.7	637.3	4.46	2.47	3.16
BH-medium	2.80/0.10/1.00/0.50	39.9	597.3	4.04	2.81	2.35
BH-high	3.00/0.50/1.00/1.00	38.0	484.7	4.66	2.09	3.16
NC-1	6.00/0/1.00/1.00	35.1	641.8	5.80	2.53	3.17
NC-2	5.00/0/1.00/1.00	33.5	730.4	7.54	2.54	3.26
NC-3	4.50/0/1.00/0.75	36.7	688.3	8.23	2.97	3.67
NC-4	4.00/0/1.00/1.00	36.2	644.2	4.95	2.24	2.79
Average		36.0	626.5	5.30	2.60	3.22
Range		27.7 to 40.7	484.7 to 730.4	3.85 to 8.23	2.09 to 3.73	2.35 to 4.07

[a)]See footnote a) Table 1.
[b)]BL=Broiler Litter; CS=Carbon Source; PM=Poultry Mortalities; WR=Water.

Table 4. Temperatures of Primary and Secondary Compost

	Ingredient Ratio	Primary Compost			Secondary Compost		
Compost Recipe[a)]	BL/CS/PM/WR[b)]	>50C	>55C	Max	>50C	>55C	Max
		- - days[c)] - -		C	- - days[c)] - -		C
PH-low	3.40/0.24/1.00/0.50	27	0	52.7	12	0	51.8
PH-medium	2.00/0.35/1.00/0.42	0	0	46.6	15	0	53.1
PH-high	4.50/0.68/1.00/0.29	37	25	64.2	32	13	57.9
BH-low	5.00/0.10/1.00/1.00	0	0	40.2	0	0	49.4
BH-medium	2.80/0.10/1.00/0.50	8	1	56.0	29	5	56.3
BH-high	3.00/0.50/1.00/1.00	21	10	58.1	8	7	62.3
NC-1	6.00/0/1.00/1.00	0	0	41.4	0	0	47.0
NC-2	5.00/0/1.00/1.00	0	0	49.9	26	16	59.4
NC-3	4.50/0/1.00/0.75	0	0	48.9	15	5	56.0
NC-4	4.00/0/1.00/1.00	6	3	56.9	26	2	55.2

[a)]See footnote a) Table 1.
[b)]BL=Broiler Litter; CS=Carbon Source; PM=Poultry Mortalities; WR=Water.
[c)]Number of days average temperature of all layers was >50C or >55C.

Table 5. Summary of Composting Efficiency for the Ten Mortality Recipes

Compost Recipe[b]	Ingredient Ratio BL/CS/PM/WR[c]	Days ≥50C[d]	Percent Change[a] Mass	Volume	Bulk Density	TKN
PH-low	3.40/0.24/1.00/0.50	39	-18.9	-4.3	-15.1	-13.6
PH-medium	2.00/0.35/1.00/0.42	15	-21.8	-18.8	-3.6	-14.3
PH-high	4.50/0.68/1.00/0.29	69	-28.8	-12.0	-19.2	-20.7
BH-low	5.00/0.10/1.00/1.00	0	-13.3	-6.7	-7.0	-15.2
BH-medium	2.80/0.10/1.00/0.50	37	-8.2	-7.3	-1.0	-23.0
BH-high	3.00/0.50/1.00/1.00	29	-16.0	-26.3	+13.9	-20.5
NC-1	6.00/0/1.00/1.00	0	-26.3	-10.3	-17.9	-11.1
NC-2	5.00/0/1.00/1.00	26	-14.9	-12.2	-3.1	-9.1
NC-3	4.50/0/1.00/0.75	15	-13.9	-16.8	+3.6	-9.8
NC-4	4.00/0/1.00/1.00	32	-18.9	-9.8	-10.1	-8.6
Average		26	-18.1	-12.5	-6.0	-14.6
Range		0 to 69	-8.2 to -28.8	-4.3 to -26.3	-19.2 to +13.2	-8.6 to -23.0

[a]Percent change is the difference between the raw materials and the secondary compost.
[b]See footnote a) Table 1.
[c]BL=Broiler Litter; CS=Carbon Source; PM=Poultry Mortalities; WR=Water.
[d]Cumulative days temperature in primary and secondary composters was ≥50°C.

COMPARISON OF COMMERCIALLY AVAILABLE MEDIA IN RECOVERING *Clostridium perfringens* FROM POULTRY LITTER

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Summary

One of the more important pathogenic bacteria found in poultry litter is *C. perfringens*. Several different media are commercially available for the isolation and cultivation of *C. perfringens*. To date no research has been performed to determine which medium is best for the recovery of this significant pathogen in litter samples. In this study five differential and two selective media were examined for their ability to recover *C. perfringens* from litter samples. Additionally the ability of this media to recover *C. perfringens* from pure cultures was determined. One of the differential mediums, TSC had shown to be most effective in getting accurate *C. perfringens* counts.

Introduction

Clostridium perfringens is widely distributed in the environment, occurring naturally in soil, dust, and in the intestine as part of the normal microflora in warm blooded animals. Under the right circumstances *C. perfringens* can induce either necrotic enteritis or gangrenous dermatitis in poultry. Besides being in poultry's gut, this potential pathogen is often found in the litter occasionally at high levels. Enumeration of *C. perfringens* from litter is often performed using media that have been adapted from typical food safety *C. perfringens* determination. These media are effective for determining *C. perfringens* numbers in food; however their effectiveness in determining litter *C. perfringens* numbers has never been determined. The purpose of this study was to determine the best selective or differential medium for cultivating *C. perfringens* from litter. In order to determine the best media two trials were performed using two selective media and five differential media.

Material and Methods

Trial 1

Media: Eight different media were used in this study. One, the reduced blood agar (RBA), was the unselective media that, for the known samples, would give the baseline counts. Two selective media: Clostrisel, and reinforced clostridial agar (RCM) and five differential media: McClung-Toabe agar (MT), oleandomycin polymyxin sulphadiazine perfringens agar (OPSP), Shahidi-Ferguson perfringens agar (SFP), sulfite polymyxin sulfadiazine agar (SPS), tryptose sulfite cycloserine agar (TSC). All of these media were bought as premixed powder and were made according to the manufactures directions. There was a modification in SPS and TSC; these two media were made without the addition egg yolk. Not using egg yolk is often performed and has no adverse effect on recovery of *C. perfringens*.

***C. perfringens* isolates:** In this trial five known *C. perfringens* isolates were utilized. Three (K1-K3) of the five isolates were taken from clinical cases of necrotic enteritis, one (K4) from a clinical case of gangrenous dermatitis and one (K5) was ATCC culture 43402. All five isolates were removed from a -80C freezer and grown on RBA overnight at 37C under anaerobic conditions. A single colony that displayed typical *C. perfringens* double zone hemolysis on RBA was then taken and used to inoculate 10ml of reduced brain heart infusion broth. This broth was grown anaerobically at 37C; after 24 hours each isolate was serially diluted in sterile saline

(0.85% NaCl). Each sample had 0.1 ml spread plated to the following media in duplicate: Clostrisel, MT, RCM, OPSP, SFP, SPS, TSC and RBA. After incubating for 24 hours at 37C under anaerobic conditions the plates were counted.

Litter Microbiology: Pine shaving litter that had at least two subsequent flocks on it was selected for sampling. Six samples were collected using the grab sample technique described previously (Macklin et al.). Briefly, samples were collected from three areas within the pen using a clean glove. These three areas were under the feeder, under the watering line and from the middle of the pen. They are then combined in a sterile bag and thoroughly mixed and transported to the laboratory. In the lab, pooled samples were diluted 1:10 in sterile filter bags using sterile saline and thoroughly mixed in a stomacher for 90 seconds. After being stomached, the 1:10 dilution would than be serially diluted with sterile saline. From these dilutions 0.1ml would be plated onto the following media in duplicate: Clostrisel, MT, RCM, OPSP, SFP, SPS and TSC. These plates were incubated anaerobically at 37C for 24 hours, after which all suspect *C. perfringens* colonies were counted from each plate. From each plate five suspect positive colonies were streaked onto RBA then incubated anaerobically at 37C overnight. A positive *C. perfringens* is one that exhibits double zone hemolysis. From these results a ratio was created that would be used to adjust the final suspect *C. perfringens* count to give the final overall count.

Trial 2
Same procedures were followed as in trial 1 except that the 6 litter samples came from different pens.

Statistical Analysis: Data collected from both trials were converted to log10, combined then analyzed using SPSS ver 12.0. A GLM was performed with the $P<0.05$, if there was any significant difference between the media, the means would be separated out using Tukeys Multiple Comparison Test.

Results

Medium MT for both tables was removed due to consistently poor results, which left RBA, Clostrisel, RCM, OPSP, SFP, SPS and TSC. Overall the result presented in table 1 show that all the media produced similar results, compared to the unselective media (RBA). The only significant differences involved OPSP. This medium recovered 1.7 and 0.6 $\log_{10}$ lower *C. perfringens* amounts than RBA for K2 and K3 respectively. The other medium that produced lower bacterial counts is Clostrisel with sample K3. Clostrisel recovered 1.3 $\log_{10}$ less bacteria than RBA for sample K3.

The dirty litter produced *C. perfringens* numbers that ranged from over 0 to over 7.0 $\log_{10}$. These differences are not surprising, given that the litter was unseeded and the variable nature of *C. perfringens* in the litter. As can be seen in table 2 the two non-differential media Clostrisel and RCM consistently had higher counts. This is not unexpected since these two media are selective only for Clostridium and do not differentiate species of that particular genus. Between these two media, RCM was consiostently overwhelmed with Clostridium at the tested dilutions used. Clostrisel recovered 0.5-2.8 $\log_{10}$ less Clostridium colonies then RCM. The four differential media (OPSP, SFP, SPS and TSC) produced comparable results to each other. TSC gave either the highest or close to the highest number of positive colonies for *C. perfringens* on 10 of the 12 samples tested. SFP produced high numbers on 7 of the 12 samples, with SPS and OPSP producing high numbers on 6 of the 12 samples. The medium that produced the lowest overall counts was SPS which produced the lowest number 5 out of 12 times. OPSP and SFP produced the low counts 4 out of 12 times. TSC had low counts only 1 out of 12 times. The differences in

the amount of *C perfringens* recovered from these four media were as extreme as 3.5 $\log_{10}$ in sample L12 to a close as 0.05 $\log_{10}$ for sample L4.

Discussion

The results present herein show that the pure cultures of *C. perfringens* were most readily recovered using RCM, SFP, SPS and TSC when compared to the number of colonies that grew on RBA. Clostrisel and OPSP were inhibitory with strain K3, which is a clinical *C. perfringens* isolate from a chicken that had necrotic enteritis. Strain K2, when plated on OPSP, also was not fully recoverable. The results concerning OPSP were not unexpected, since several authors (de Jong et al, Hauschild and Hilsheimer) have reported that this media can suppress growth of *C. perfringens.* The similarity in the counts for K1-K5 when plated on SFP, SPS and TSC are not surprising, since these three media only differ in the type of antibiotic(s) used (de Jong et al). RCM and Clostrisel are selective for *Clostridium* spp. and not for *C. perfringens* only. These two should have good recovery of *C. perfringens* when compared to RBA. Overall this statement held true, especially with RCM; however with isolate K3, Clostrisel had a significantly lower recovery when compared to RCM or RBA. The main inhibitory ingredient with Clostrisel is sodium azide. Since this isolate was tested two separate times in duplicate, it can be inferred that this isolate of *C. perfringens* is susceptible to sodium azide.

Litter samples, which contained an unknown number of *C. perfringens*, were best recovered with TSC. This medium was followed by SFP, OPSP and SPS. Clostrisel was able to isolate a fair number of suspect *Clostridium* spp bacteria, while RCM was overgrown at the dilutions tested. From these results RCM is not selective enough for determining the Clostridium that may be present in litter. Colonies formed on Clostrisel were only tested for the presence of *C. perfringens* and not other *Clostridium* spp that may have grown. For recovery of overall Clostridium counts Clostrisel is a good medium of choice. The differential media that had the lowest recovery were OPSP, SFP and SPS. Perhaps the failure of these three media to culture *C. perfringens* is due to their composition. As mentioned above OPSP is known to suppress some strains of *C. perfringens*. A problem that both OPSP and SFP share is that they both tend to allow sulfite reducing facultative anaerobic bacteria to grow. This requires that these two media require additional testing to confirm the presence of *C. perfringens* and that this testing may incorrectly skew the results to the low side. SPS occasionally fails to produce black colonies (Adams and Mead), which would produce incorrectly reported low counts.

Our results show that TSC is the best medium for isolating *C. perfringens* from poultry litter. Other investigators have shown that TSC is the preferred medium for isolating *C. perfringens* from ground beef (de Jong et al.), shellfish (Abeyta et al.) and lean meats (Abeyta et al., Adams and Mead). The only problem experienced with TSC is that it would occasionally give false positives, though at a lower rate than OPSP and SFP.

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LARGE-SCALE COMPOSTING OF SPENT LAYING HENS

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Introduction

In emergency situations, disposal of large volumes of poultry mortality is consistently a daunting task. A common challenge during catastrophic disease events is to ensure that carcass disposal keeps pace with the rate of infection and exposure. It is likely that a combination of disposal methods will need to be employed to accomplish the mortality management needs during any time of significant death loss. On-site management of mortality is preferred over off-site management to reduce potential spread of disease organisms and environmental impacts. Adherence to proper management practices is the key to the successful use of any method.

Composting has been used in poultry operations for daily mortality disposal for many years. Composting larger volumes of mortality has been tested and demonstrated to be effective in emergency disposal situations. However, reluctance to use the method during mass disposal efforts may be based on lack of information and expertise regarding the process and quantity of materials needed to accomplish the task.

The disposal of spent hens is a continual problem for the table egg industry. There are a limited number of processing plants willing to accept them for human consumption and while a significant number of spent hens are euthanized on-site and taken to rendering plants, these plants may also only accept a certain volume of hens per their needs and processing capabilities. During market downturns, sale or disposal of spent hens may actually cost companies revenue. Composting of spent hens may provide an additional avenue of spent hen utilization which will result on a usable if not salable end product.

The objective of this exercise was to demonstrate to a large table egg company the procedures, materials, and personnel training requirements to dispose of an entire house of birds and to be able to use this method in situations of mass mortality or spent hen disposal.

Materials and Methods

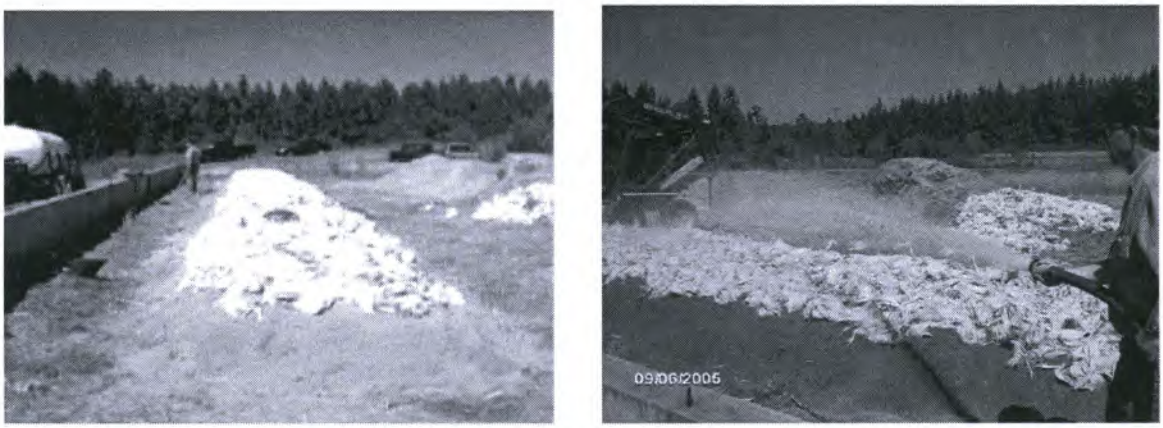
A company-owned site in rural Georgia was available approximately 2 miles from a laying complex. The site contained retaining wall foundations for two 500' X 60' pullet house never completed. With a gated entrance and wooded area on three sides, the composting site was not visible from the public road. A well that delivers a minimum of 33 gallons per minute was also on-site.

Thirty-two thousand spent hens were depopulated from a laying house, euthanized with CO2 gas, and transported to the composting demonstration site. At 3.5 lbs per bird (56 tons of carcass), it was estimated that 150 tons of sawdust were needed to complete the process as no litter or used bedding material was available for the process. Water was applied during windrow construction with a 3" fire hose at the discretion of the author based on visible application rate and moisture content target of 40-60 % for optimal composting. Water volume was evaluated after windrow construction to determine the volume used to accomplish the compost process.

The estimated time for this exercise from the initial day of windrow construction through one complete turning of the compost was anticipated to be between 3 and 4 weeks. This would be followed by the compost curing for at least an additional 3 weeks. At that time, depending upon the condition of the compost, it would be permitted to be used for field application. Evaluation of the methodology used to compost in this demonstration consisted of an analysis of the temperatures reached and observed quality of the final compost.

Windrow construction: The participating company provided a front end loader with an experienced driver and assistant. Using recommended formulas of approximately 3 parts carbon to 1 part bird carcass, two different types of windrows were constructed. Method 1 is a layering process and Method 2 is a direct mixing of the carcasses and carbon material. Additionally two different capping methods were used in this exercise. Individuals were assigned to visit the site twice weekly to manually record the temperatures and observe the site.

Method 1(Layering): A base layer of 10 inches of sawdust was spread to an area of 10' X 60'. Carcasses were then placed in a layer of approximately 8-10 inches in depth. The windrow was constructed with successive layers of birds and carbon with the completed windrow consisting of 3 layers of carcasses with 8-10 inches of carbon between them. Final height of the windrow reached 6-7 feet.



Water is added during the initial layering of carcasses on the sawdust base.

Method 2 (Mixing): A second type of windrow mix was prepared to compare the results of mixing the carcasses directly with the carbon and windrowing the material as opposed to the standard and more labor intensive layering technique. A base layer of 10 inches of sawdust was spread to an area of 10' X 60'. Whole bird carcasses were mixed at a 3:1 volume of sawdust to birds. These were mixed by the bobcat and then formed into a windrow to a height of 6-7 feet. Water was added during and after the mixing process.

Carcasses mixed with sawdust formed into a windrow.

Capping of Windrows: Once completed, the windrows were capped with 6-8 inches of fresh sawdust. Proper capping assists in moisture control, suppression of seepage, and to discourage wildlife from disturbing the windrows. In addition to the carbon material cap, two of the windrows were covered with a compost fleece to compare temperature build-up and moisture retention. The fleece was a commercially-available product, made from 1/8 inch thick porous felt.

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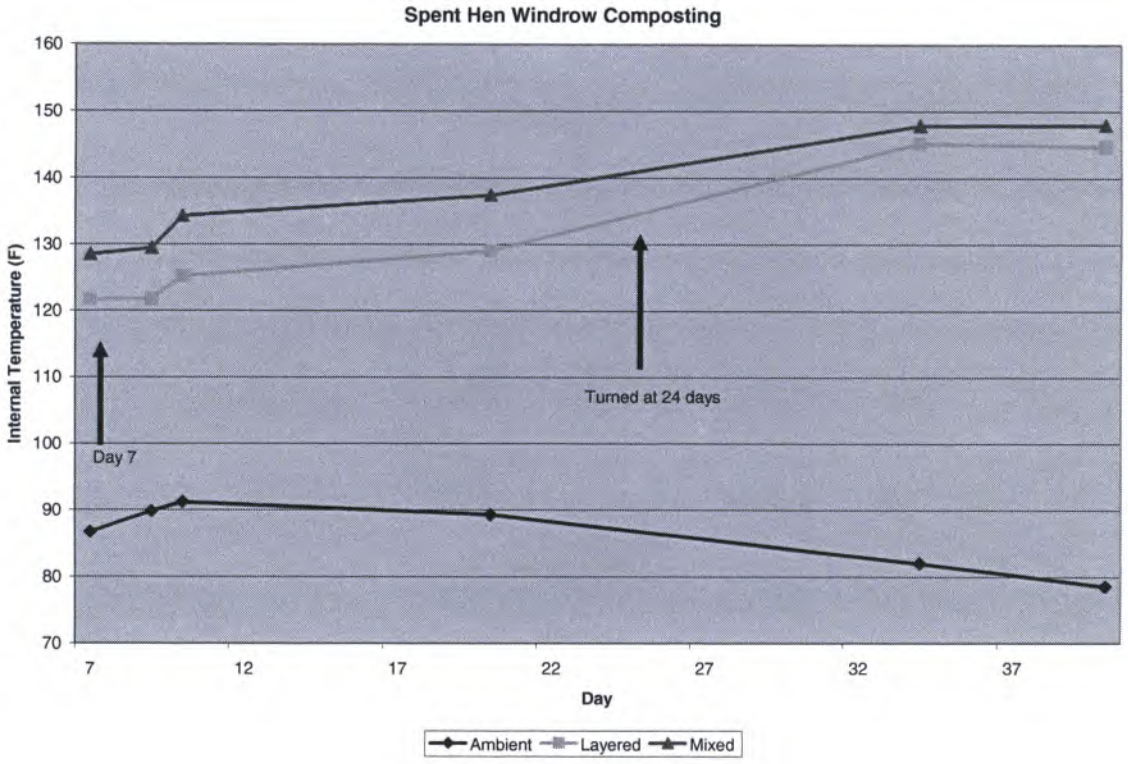
Windrow completed and covered with fleece

Windrow Turning: The temperature profile of the windrows was monitored as an indicator of composting activity and the need to aerate for additional oxygen. On day 19 of the demonstration, the windrows were completely turned. There was no offensive odor at the site. Most of muscle tissue was decomposed with mainly long bones and wing feathers remaining. No detectable wildlife disturbance of the windrows was noted. Additional water (9,900 gallons) was added during the turning process.



Conclusions and Lessoned learned

Windrow Construction and Materials:

1) Sawdust amount projections are dependent upon grind of sawdust used. More carbon material was needed than anticipated; likely a function of the fineness of the sawdust.

2) Experienced equipment operator is extremely important.

3) The addition of sufficient water is the time consuming and rate limiting process in building the windrows. The ability to deliver large volumes of water rapidly is essential. The amount of water needed is based upon type and moisture content of carbon material used, bird type, and environmental conditions at the time of windrow formation. A water meter would be helpful to determine specific amounts utilized.

General Items of Interest:

1) A large amount of bird carcass (56 tons) can be successfully disposed of by composting on an acceptable site.

2) Mixing of carcasses led to higher composting temperatures and was less labor intensive.

3) Use of the compost fleece promoted higher temperatures and greater moisture retention within the windrows when compared to uncovered windrows.

4) Ability to deliver large volumes of water rapidly to the composting mix during construction is essential.

5) Source of carbon material must be sufficient to accommodate the large volume of material required to complete the process.

Projections and Calculations

Calculations are based on composting 32,000 leghorn type birds @ 3.5 pounds per bird or 56 tons of carcasses.

Carbon/Sawdust Material
Amount of Sawdust/Carbon needed (estimates based on 3:1 carbon to carcass recipe)
Estimated amount----------150 tons
Actual amount used---------- 205 tons

Worker Time
Time needed for construction of windrows with one loader operator and one assistant
Estimated ----------8 hours +
Actual time (over 2 days)-------10 hours.

Time needed for turning windrows at 3 weeks with one loader operator and one assistant
Estimated time ----------8 hours +
Actual time ----------5 hours.

Water Volume
Flow rate from hose approximately 33 GPM (Gallons per minute)
Construction of windrows ---7 hours X 33 GPM = 13,800 gallons
Turning of all windrows-------5 hours X 33 GPM = 9,900 gallons for turning.

Space Required to Compost:
Assumptions: Windrow base is 10 feet wide. Three layers of birds can be incorporated within the windrow. Windrow will be 6-7 feet high. In this demonstration, windrows of all types occupied approximately 270 linear feet.
THEREFORE: About 6 linear feet of windrow (3 tiers high) and 10 feet wide is needed per ton of carcasses.

PROCESS DESCRIPTION AND ECONOMIC ANALYSIS FOR THE MANUFACTURE OF BROILER LITTER-BASED ACTIVATED CARBONS

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Abstract

Broiler litter continues to represent a significantly large and problematic portion of the U.S. agricultural waste generated yearly. Granular activated carbons, GAC made from broiler litter could help to add value to the litter while reducing the poultry litter disposal problem. The objective of this study was to develop a conceptual capital and operating cost estimate using a process simulation program to estimate the cost of manufacturing broiler litter-based GAC. In the study, it was assumed that the activated carbon facility obtains the poultry litter from various farmers at a cost of $5.50/MT and $27.50/MT for transportation. The carbon manufacturing facility processes 20 daily MT (44,000 lbs) of broiler litter and converts it into granular activated carbon for a final carbon yield of 21.6%. This facility operates continuously, 330 days of the year. Several parameters were included in the study including capital costs (equipment) and operating costs, such as labor, utilities, maintenance, and equipment depreciation. The largest contributor to the cost of producing the activated carbon is the equipment cost of the combined pyrolosis/activation furnace. At an estimated equipment cost of $1,200,000 this makes up approximately one third of the total production cost. This study indicates that activated carbon can be produced by this method at a cost of about $1.44/kg ($0.65/lb).

Keywords: Activated Carbon; Broiler Litter; Copper Ion Remediation, Economic Analysis

Introduction

Broiler litter disposal continues to be an increasing problem to all involved. Approximately 9 million metric tons of broiler manure was produced in 2003. With most of this waste being land applied as fertilizer, there is an associated public health concern and an environmental threat when excessive land application occurs. Consequently, there is an urgent need to identify new uses for broiler litter, specially those uses that result in products of considerable added value. One such opportunity would be to manufacture high-value activated carbons. This value-added approach transforms broiler litter into a high porosity, high surface area material that can potentially be used in environmental remediation applications.

Our laboratory at the Southern Regional Research Center, Agriculture Research Service, in New Orleans, Louisiana has shown that granular activated carbons made from pelletized broiler litter adsorb various positively charged heavy metals from laboratory prepared solutions. In that regard, their effectiveness exceeds that of available commercial GAC's as well as reference carbons made from common carbon precursors such as coal, coconut shells and hard wood. GAC's produced from broiler litter adsorbed up to 6 times the amount of Cu^{2+}, Cd^{2+} and Zn^{2+} adsorbed by the reference carbons (Lima and Marshall, 2005a, b, c).

Broiler litter-based GAC's have the potential of filling a much needed niche market of heavy metal removal from contaminated wastewater. Therefore, consideration should be given to process scale-up for the manufacture of such carbons to help determine the ultimate marketability of the carbons. The objectives of this investigation were to develop process flow diagrams for the large-scale production of broiler litter-based carbons and to carry out an economic evaluation to estimate the cost to manufacture these carbons.

Methodology

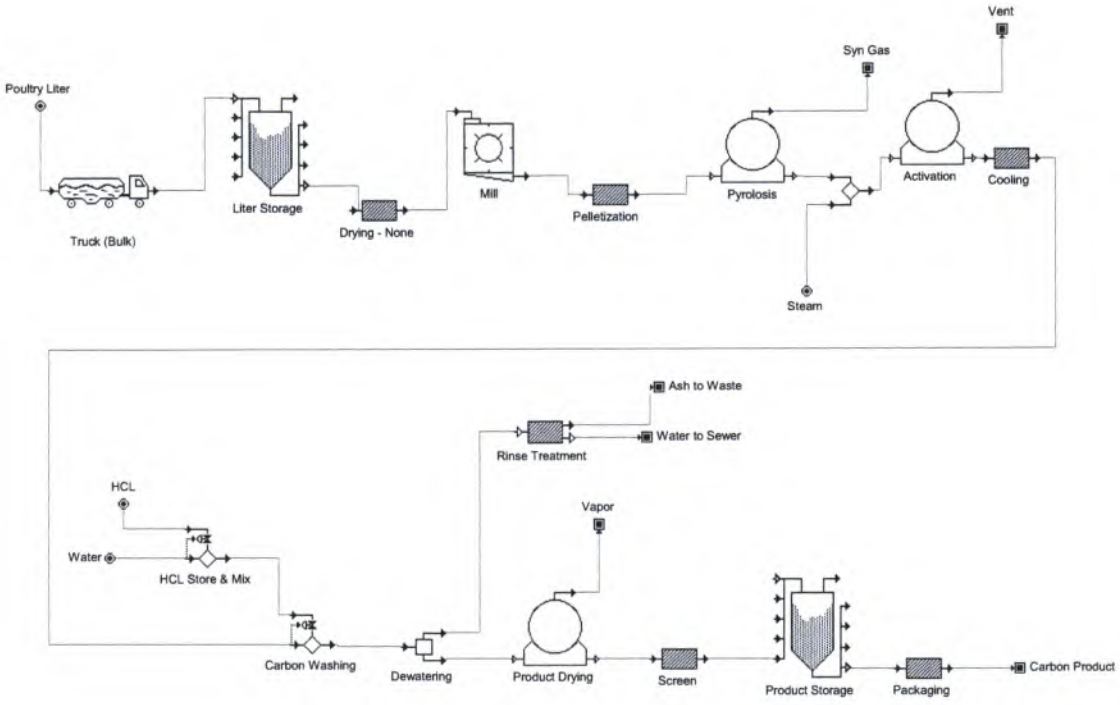
A process flow diagram (Figure 1) with equipment parameters and mass flows for the production of steam-activated broiler litter-based granular activated carbon was developed using the Superpro Designer process simulation program V5.5 (Intelligen Inc.)™. The unit operations include sample storage, milling, pelletizing, pyrolysis/activation, acid washing/water-rinsing, drying, screening and collecting of the final product. After sizing the pertinent equipment, capital and operating cost estimates were then developed from this information.

Carbon manufacture

Twenty thousand kilograms (22 tons) of broiler litter per day are fed into a grinder mill and milled to a particle size less than 1 mm. The milled material is pelletized to produce 3/16 in x 3/16 in pellets. Milled broiler litter with moisture content below 25% is required for carbon production. Pellets are fed onto a rotary kiln where pyrolysis and steam activation occur at 700°C for 1 hr and 800°C for 45 min, respectively, under a nitrogen atmosphere. Carbons are cooled to less than 100°C after which they go through an acid wash (0.1 N HCl) and water rinse step. The washed and rinsed carbon is dried and sieved. The above

pyrolysis/activation conditions result in an estimated final yield of 21.6% carbon, resulting in a production rate of 4.32 MT (9,500 lbs) carbon/day.

Figure 1. Process flow diagram for the production of granular activated carbon from broiler litter.



Cost analysis

Estimation of equipment and capital costs

Budgetary quotations were obtained for the two items that make up 80% of the equipment costs. Conceptual cost estimates and allowances were used to determine the remaining equipment charges. Price quotes and size and/or capacity for all equipment are presented in Table 1. Total capital costs were developed from the equipment costs through the application of an installation factor of capital costs to equipment costs. [Capital costs = 3 times equipment costs] (Table 2). Excluded from the capital costs were charges for environmental controls, land acquisition and site development, working capital and the cost of capital during construction.

Table 1. Equipment specification and cost

Name	Size/Capacity	Cost ($)
Silo/Bin for litter holding	26.13 m^3	50,000
Mixer	3877.3 kg/h	50,000
Mill	833.0 kg/h	17,000
Pelletization	833.0 kg/h	250,000
Furnace Pyrolysis/activation	17.33/0.62 m^2	1,200,000
Cooling (w/pyrolysis)	242.33 kg/h	-
HCl Store & Mix	3877.3 kg/h	50,000
Mixer for carbon washing	4119.6 kg/h	25,000
Water rinse	3902.1 kg/h	15,000
Dewatering	4119.6 kg/h	20,000
Screen/Grading	139.94 kg/h	25,000
Drier	1.94 m^2	49,000
Silo/Bin for carbon storage	30,733 m^3	50,000
Packaging	139.94 kg/h	25,000
TOTAL		1,776,000

Table 2. Summary of costs for the production of granular activated carbons from broiler litter.

Equipment Purchase Cost	$1,776,000
Installation	$3,551,000
Total Plant Direct Cost	$5,327,000
Total Capital Investment	$5,327,000
Operating Cost	$1,599,000/yr
Production Rate	1,108,356 kg of carbon/yr
Unit Production Cost	$1.44/kg of carbon

Estimation of operating costs

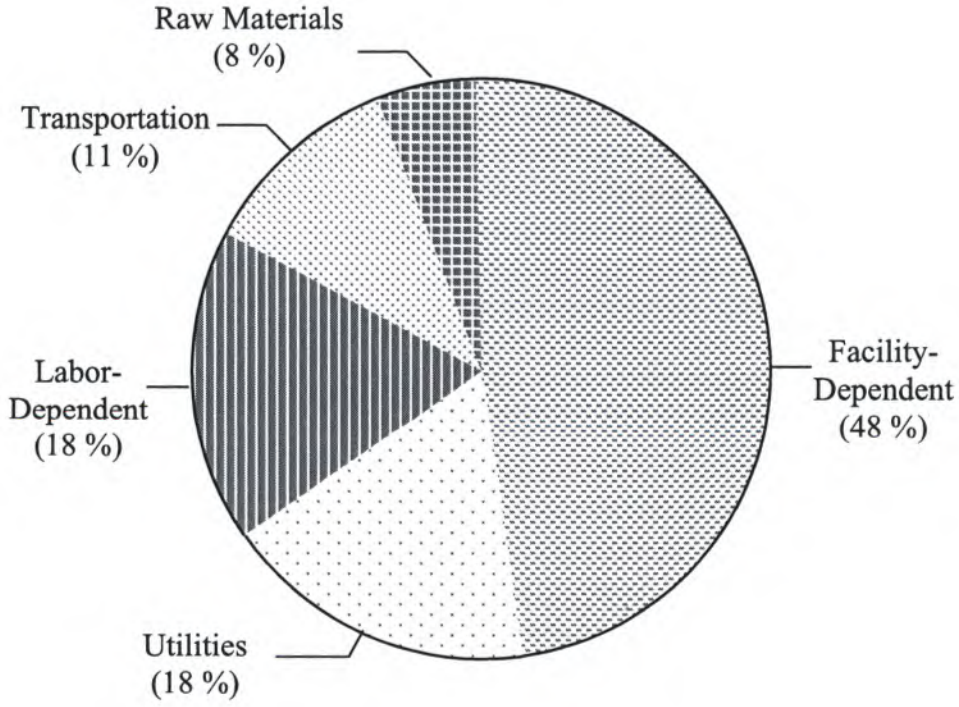
The activated carbon facility obtains broiler litter from various farmers at a cost of $5.50/MT and transports it an average of ten miles to the processing facility at a cost of $27.50/MT. The processing facility converts the poultry liter into activated carbon and is operated on a continuous basis twenty four hours a day, 330 d/yr. Plant labor is based on four operators, one per shift for a total of 8,320 hr/yr at an all inclusive rate of $23.47/hr. One supervisor for 2080 hr/yr at $40/hr is also included (Table 3). Utility charges were developed from the estimated electric, natural gas and cooling water requirements of the various equipment items. Maintenance charges are included at two percent of capital costs, insurance fees at 1% of capital costs and factory expenses at two percent of capital costs. Equipment depreciation is calculated on a straight line basis with a 15 year life. Figure 2 gives a breakdown of the

annual operating costs. The largest slice corresponds to the facility-dependent costs. The smallest contribution comes from the raw materials.

Table 3. Annual operating costs

	Unit Cost	Annual Amount	Annual Cost ($)
Raw material cost			
Water	$0.001/kg	30,601,979 kg	22,000
Poultry Litter	$0.006/kg	6,597,360 kg	36,000
HCl	$0.100/kg	304,040 kg	30,000
Total		37,503,379 kg	88,000
Litter Transportation	$0.028/kg		181,427
Labor cost			
Plant Workforce	$23.47/h	8,320 h	195,000
Supervisor	$40.00/h	2,080 h	83,000
Total		10,400 h	278,000
Utilities cost			
Electricity	$0.05/kWh	3,532,117 kWh	176,606
Natural gas	$0.29/kg	342,103 kg	98,868
CT Water	$0.07/MT	35,999,952 kg	2,520
Total			277,993
Facility-Dependent			767,000

Figure 2. Annual Operating Cost Breakdown (%).



Summary

A study has been prepared to predict the cost of producing activated carbon from broiler litter by a process developed by the USDA's Agricultural Research Service Southern Regional Research Center. Based on a yearly production of 1,108,356 kg of broiler litter-based carbon and an annual production cost of $1,599,000, this study indicates that broiler litter-based GAC can be produced by this method at a cost of about $1.44 per pound. It is clear that despite higher initial capital costs, a larger manufacturing plant will be able to produce carbons at a lower cost.

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

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Abstract

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

Introduction

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

This has left livestock and poultry producers with the need to implement effective best management practices to control both ammonia and VOCs emissions from animal housing and manure storage facilities (Dragosits, et al. 2002). This is also critical to European livestock & poultry producers as the BMPs implemented there were not enough to reach the emissions targets set in the Netherlands for the year 2000. It has been suggested that the only way to reach the target goals for NH_3 emissions ($30GgNH_3/yr$) set for 2030 in the Netherlands would be to completely eliminate all poultry & swine production and house all cattle in low-emission stables year-round (de Vries, et al. 2001). In addition, tremendous consumer focus on animal welfare has instituted strict limits on ammonia levels inside confinement animal facilities, mostly poultry & swine. Since the current management strategies often rely on being able to exhaust as much ammonia from the house as possible, alternatives are clearly needed (Ritz, et al. 2004).
The release of ammonia from animal manure is dependent upon the amount of ammoniacal nitrogen present, pH, surface area, temperature, and the amount of urease present (Mutlu, et al., 2005; Gay and Knowlton, 2005). Therefore, for any emissions intervention to be effective, it must exploit at least one of these avenues to prevent NH_3 release into the atmosphere (Jongebreur and Monteny, 2001). VOCs are mostly derived from the bacterial degradation of manures soon after

excretion (Mitloehner, 2005). Decreasing the bacterial activity in freshly excreted manures should then reduce the production & subsequent emissions of VOCs.

Sodium Bisulfate Characteristics

Sodium bisulfate (SBS) is a dry, granular acid salt that has been used for many years as a pH reducer in a variety of agricultural, industrial, and food applications. The anti-bacterial properties of sodium bisulfate have been exploited in its application as a toilet-bowl sanitizer (i.e. EPA Reg #1913-24-AA) and as a preservative in EPA method #5035 "Closed-System Purge-and-Trap & Extraction for Volatile Organics in Soil & Waste Samples," to prevent microbial activity leading to VOC release. These properties along with the safety and ease of use of SBS have led to its use for ammonia binding (Fig.1) and bacterial reduction in poultry, dairy, and equine manure and bedding materials (Ullman, et al., 2004; Blake and Hess, 2001; Sweeney, et al., 1996; Harper, 2002). Currently, 30-40% of all broilers produced in the United States are raised on SBS (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). 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 real differences between treatments (Fig. 2).

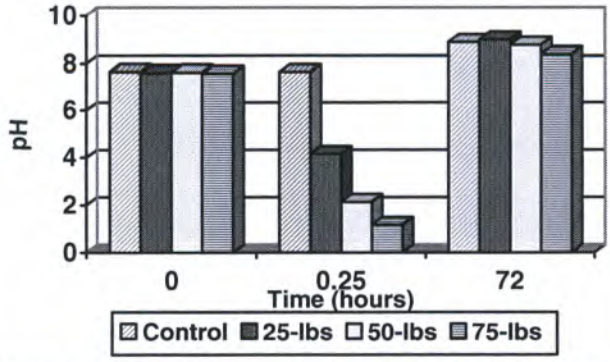


Figure 2. pH readings of dairy slurry treated with SBS (lbs/1000 sqft) over time.

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 with a substantial return on

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

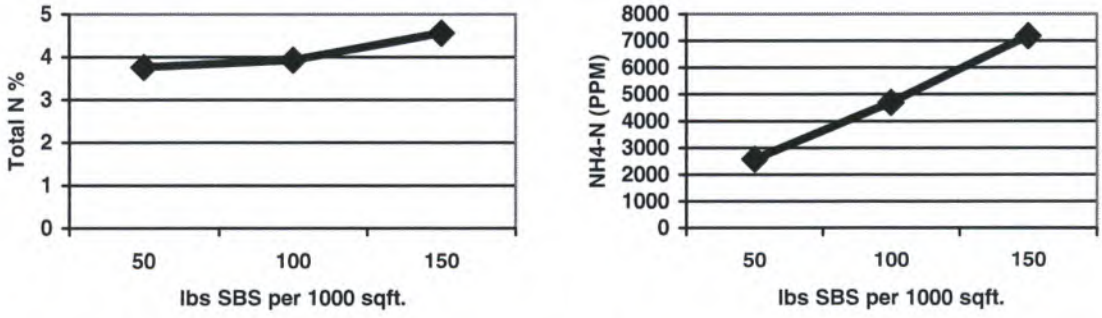
investment that would support increased PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998; Terzich et al, Apr 1998).

Current SBS Research in Poultry

A 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. 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. 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

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.

Footnote

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

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POTENTIAL FOR IMPROVING THE SAFETY OF FOODS USING AN EGGSHELL MEMBRANE WASTE PRODUCT

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Approximately 28% of all eggs produced are sent to commercial breaking operations for the production of egg products (Buddington, 1999). The total annual eggshell waste originating from these plants is 18 billion eggshells or about 250,000,000 pounds of waste per year (Hemple, 1999). Of this, approximately 90% is calcium carbonate shell and 10% is eggshell membrane. The eggshells from these breaking operations represent a significant waste product.

Although not often associated with food safety, great potential lies in the area of egg shell waste. In preliminary studies, Poland and Sheldon (2001) demonstrated that eggshell membrane-bound components were capable of reducing the heat resistance and/or inhibiting the growth of selected Gram-positive and Gram-negative foodborne bacterial pathogens suspended in 0.1% peptone water. Reductions in thermal decimal reduction times (D-values) of 83 - 87% were observed for *Salmonella enterica* serovars Typhimurium and Enteritidis ($D_{54°C}$) and *Escherichia coli* O157:H7 ($D_{52°C}$) and up to a 3 log reduction in *L. monocytogenes* populations following incubation with eggshell membranes (ESM) for 30 min at 37°C. These membranes may have a significant economic value if the enzyme-rich shell membranes could be easily extracted and used as a food preservative, processing aid or immobilized in fluidized bed reactors to inhibit food-borne bacterial pathogens and spoilage organisms associated with the production of liquid foods, pharmaceuticals or other applications. For example, raw milk could be initially pre-treated with the membrane using a fluidized bed reactor, and then pasteurized to receive its terminal heat treatment. The overall thermal process requirements might be reduced resulting in a product of improved nutritional quality and functionality, but with lower overall processing costs.

Methods to extract these enzyme-rich shell membranes are readily available (MacNeil, 2001) and offer egg processors potential economic value. However, a greater understanding of the egg shell membrane is essential to better determine how it may be used in practical applications. The objectives of this study were to determine the biological activity (D-value determination) of ESM as a means of identifying the membrane components responsible for the observed antibacterial activity and their mechanisms of action and to evaluate the enzymatic and biological activities of ESM as a function of bird breed, age and ESM stabilization treatments.

Materials and Methods

Chemicals. Chicken egg white lysozyme (EC 3.2.1.17), chicken egg white ovotransferrin (#C-0755), porcine pancreatic lipase (EC 3.1.1.3, #L-3126), wheat germ lipase (EC 3.1.1.3, #L -3001), *Thermomyces lanuginosus* lipase (EC 3.1.1.3, #L-0902), *Candida albicans* lipase (EC 3.1.1.3, #L-4777), *Micrococcus lysodeikticus* ATCC 4689 (#M-3770) and 4-nitrophenyl N-acetyl-β-D-glucosaminide (#N-9376) were all obtained from Sigma Chemical Company. Tosyl-phenyl-chloro-ketone (TPCK)-treated bovine pancreas trypsin (#T-1426) was also obtained from Sigma and immobilized on controlled pore glass beads following the procedures described by Janolino and Swaisgood (1982). Brain Heart Infusion (BHI) broth and agar were obtained from Difco Laboratories (Sparks, MD). Hen egg white ovotransferrin and β-N-acetylglucosaminidase were obtained using the extraction procedures described by Ahlborn and colleagues (2006). All other chemicals and buffers used were certified A.C.S grade.

Eggshell membrane extraction. Egg shell membranes from one hundred fresh (within 2 days of lay), non-fertile, White Leghorn (Hyline) eggs were extracted using a 'commercial-like' modified procedure described by Poland and Sheldon (2001). Filter cakes of the compacted membrane fragments were pooled together and stored in a sterile petri dish wrapped in aluminum foil and refrigerated until used (less than 1 week).

β-NAGase, lysozyme, and ovotransferrin assays. For measuring β-NAGase activity in units/mg, the release of p-nitrophenol from 4-nitrophenyl N-acetyl-β-D-glucosaminide was followed using a modified procedure of Lush and Conchie (1966), Donovan and Hansen (1971), and Winn and Ball (1975). Lysozyme activity in units/mg was determined using an adaptation of the assay described by Shugar (1952) as measured by the change in optical density (450 nm) following exposure of *Micrococcus lysodeikticus* to the ESM. For measuring ovotransferrin activity, the iron-binding properties of the ESM were determined using a modified protocol described by Tranter et al. (1983) and Crogennec et al. (2001). The activities of all three proteins were evaluated in triplicate, and the values presented as means.

D-value determinations. Decimal reduction times (D-values) were determined using the combined methods of Poland and Sheldon (2001) and the immersed sealed capillary tube (ISCT) procedure described by Schuman and colleagues (1998) and Foegeding and Leasor (1990). Mid-log phase cells of *Salmonella enterica* serovar Typhimurium ATCC 14028 (ST) were selected on the grounds that in preliminary trials cells from ST showed the greatest sensitivity to ESM (2005). Zero to one gram of the pooled and treated ESM fragment extracts were added to 20 ml of the peptone water bacterial suspension and incubated with agitation at 37°C for 30 minutes. Following incubation, ESM were removed from the peptone water bacterial suspension and the inoculated PW (0.05 ml) was dispensed into individual glass capillary tubes. Filled capillary tubes were then heat-sealed and preheated (54°C) in a circulating water bath. At six to eight evenly spaced intervals, duplicate tubes were removed from the water bath, cooled, and the population of surviving organisms determined on BHI agar plates. Triplicate thermal inactivation trials were conducted and survivor curves were plotted for each trial from the various treatments described below. Best-fit linear regression lines were drawn through the linear portion of each plot and D-values were calculated as the negative reciprocal of the survivor slope obtained by regression analysis. D-values represent the average of the three thermal inactivation trials.

Statistical Analysis. Mean decimal reduction times obtained via the ISCT procedure were calculated comparing the control (no membrane) treatment with the experimental (with membrane variables) treatment. Statistical analysis of the D-values was determined by analysis of variance (ANOVA, $P \leq 0.05$) and the means separated by comparison of each mean pair using the student's t-test (LSD, $P \leq 0.05$). The residual replicate by treatment mean square was used for testing the main effects (treatment, replicates). Statistical analysis of enzyme activity studies were determined using the General Linear Model (GLM) and Least Squares Means (LSM) with $P \leq 0.05$ (SAS Institute, 1990).

Minimum inhibitory concentration (MIC) treatment. Ten ml of the PW/bacterial suspension (ca log 7-8 CFU/ml) were placed in seven sterile Erlenmeyer flasks. One gram (representing a 1:10 ratio), 0.5 g (1:20 ratio), 0.33 g (1:30 ratio), 0.25 g (1:40 ratio), 0.2 g (1:50 ratio) and 0.17 g (1:60 ration) of ESM were respectively added to one of the flasks. The seventh flask (without membrane) served as the control. Bacterial suspensions were incubated with agitation (150 rpm) at 37° for 30 minutes. Following incubation, all suspensions were poured into a sterile filtering-stomacher bag, and bacterial suspensions were removed with a sterile pipette and aseptically transferred to a sterile test tube. Samples were placed on ice until transferred to capillary tubes for D-value determination as described above.

Trypsin and immobilized trypsin treated ESM. Nine samples of 1.5 grams of ESM were placed in sterile 50-ml polypropylene graduated tubes. Three tubes each received one of the following treatments in 46 mM Tris buffer (pH 8.1) with 12 mM $CaCl_2$: (1) 20 ml of trypsin (200 units/ml) in the Tris buffer;

(2) 20 ml of Tris buffer with 3 ml immobilized trypsin (97.8 units/ml); (3) 20 ml of Tris buffer as a control. Tubes were laid horizontally in a controlled environment incubator/shaker and incubated (37°C, 100 rpm) for 3 hours. Samples were removed and membranes were rinsed 5 times in sterile, ddH_2O to remove any residual trypsin from the membranes. One gram was removed from each sample and added to 20 ml of the previously described bacterial suspension. Bacterial suspensions were incubated with agitation (150 rpm) at 37° for 30 minutes. Following incubation, all suspensions were poured into a sterile filtering-stomacher bag and bacterial suspensions removed with a sterile pipette and aseptically transferred to a sterile test tube. Remaining ESM fragments were evaluated for enzymatic activity as previously described.

Heat inactivation of ESM proteins. Shell membranes were placed in sterile, deionized water and heated to either 80 or 100°C for 15 minutes after which membranes were rinsed with sterile water and excess water removed. One gram from each sample was added to 20 ml of the bacterial suspension, incubated, and treated as previously described for D-value determination and enzymatic activity.

Treatment of ESM with lipase. Three treatments consisting of either (1) a buffer control, (2) porcine lipase (4,000 units), or (3) a combination of porcine lipase (2,000 units), wheat germ lipase (300 units), *Thermomyces lanuginosus* lipase (5,000 units) and *Candida albicans* lipase (300 units) were added to 100 ml of 50 mM sodium phosphate buffer (pH 7.0) and placed in a sterile 120 ml beaker containing five grams of ESM from a common pool and a Teflon stirbar. Membrane treatments were incubated (4 hours, 37°C) with mild stirring (100 rpm) and stored (4°C) overnight. Following incubation, membranes were removed from the treatments and rinsed with sterile ddH_2O. One gram ESM samples were removed, added to 20 ml of the bacterial suspension, and D-values and enzyme activities were determined as described.

Layer breed and age trials. Fifty eggs per group were collected from White Leghorn (WL) and Rhode Island Red (RIR) layers at 25 to 27 weeks and 78 to 80 weeks of age. Birds were housed at Carolina Eggs and the North Carolina Department of Agriculture and Consumer Services Piedmont Research Station and fed standard corn and soybean layer rations under a 16 hour light, 8 hour dark cycle. Membranes were extracted and prepared as described above with subsequent analysis of the enzymatic activities of lysozyme and β-NAGase.

Enzymatic versus biological activity. Fifty fresh eggs from WL layers at 33 weeks, 50 weeks and 81 weeks of age were collected and their membranes were extracted using the more commercial-like methods described below. Lysozyme and β-NAGase activity were measured and heat inactivation $D_{54°C}$-values determined for each group of membranes.

Results and Discussion

MICs. Figure 1 shows the effects of various concentrations of ESM on the D_{54}-values for *Salmonella* Typhimurium. At 54°C, the control treatment (no added ESM) required over 5 minutes of heating time (5.34) to yield a 1 log reduction in bacterial population. When eggshell membranes were added at a ratio of 1 g of membrane to 10 ml of the *S.* Typhimurium suspension, the $D_{54°C}$-value was significantly reduced over 7-fold (to 0.69 min). Significant increases in the $D_{54°C}$-values were detected as the concentration of ESM to cell population decreased. At a ratio of 1 g to 60 ml of the bacterial suspension, there was no significant difference in the heat resistance of *S.* Typhimurium compared to the ESM-free control treatment (5.02 min vs 5.34 min).

Treatment of ESM with trypsin, heat, and lipase. Due to the difficulty in extracting and purifying the components comprising ESM, an indirect approach was first taken to access the impact of individual components on the observed antimicrobial activity of ESM. The biological activities (reduction in $D_{54°C}$-values) of ESM following exposure to various treatments are shown in Table 1. Subjecting the ESM to

suspended or immobilized trypsin resulted in all loss of antimicrobial activity as depicted by significant increases in $D_{54°C}$-values (5.38 min and 5.12 min respectively) compared to the 1:20 ESM treatment (1.65 min). Although loss of the biological activity was not surprising, it was interesting to note that when ESM was exposed to either solubilized or immobilized trypsin, there were no significant reductions in β-NAGase activity and a slight decrease in lysozyme activity. This finding may be related to several possibilities: 1) the active sites responsible for enzymatic activity lack lysine-arginine bonds and are therefore unaffected by trypsin; 2) the active sites are partially protected by membrane components; or 3) trypsin is able to cleave specific sites in the enzyme yielding peptide fragments adhered to the ESM that work cooperatively to produce the specific enzymatic activity. Unlike the enzyme activities, the iron-binding capabilities of membrane-bound ovotransferrin were significantly reduced by exposure to trypsin.

Membranes subjected to heat treatments (80 and 100°C for 15 min) prior to exposure to *S.* Typhimurium cells lost significant biological activity (i.e., from 1.65 min to 3.99 and 4.43 min respectively, Table 1). Although the heat 'inactivated' membranes retained some biological activity, it was greatly diminished. If protein components of ESM were primarily responsible for the reduction in D-values, heat denaturation of these proteins would occur to varying degrees with exposure to heat. Membrane-bound β-NAGase was more susceptible to heat degradation, with no activity detected following the 15-min heat treatments. Membrane-bound ovotransferrin retained some activity while lysozyme retained up to a third of its activity (14.0 ± 4.8 U/mg at 80°C; 4.3 ± 2.3 U/mg at 100°C) (Table 1). ESM biological activity was not affected by treatment with the lipases (D_{54}-values of 1.54 and 1.18 min respectively) demonstrating that lipid components are not probable contributors to the ESM biological activity. Furthermore, these two lipase treatments also did not affect ovotransferrin, lysozyme and β-NAGase activities (Table 1).

Breed and age trial. Figure 2 shows the enzymatic activity of lysozyme and β-NAGase as influenced by layer breed and age. Shell membrane lysozyme activity (43.4 U/mg) was greatest in the WL layers at 25 to 27 weeks of age. ESM from 78 to 80 week old WL layers had significantly lower lysozyme activities (17.1%) than ESM from the younger birds. Contrary to the differences observed in WL layers, no difference in ESM lysozyme activity was detected between young and old RIR layers. ESM lysozyme activity from 25 to 27 week old WL layers was 28% greater than the RIR counterparts, however no significant breed difference was observed for membranes extracted from the 78 to 80 week old layers. β-N-acetylglucosaminidase activity was highest in the ESM extracted from 25 to 27 week old WL and RIR layers (13.2 and 12.6 U/mg respectively). A significant reduction in β-NAGase activity within the WL breed was observed in ESM extracted from the older birds (14.4%).

Comparison of enzymatic and biological activity. Figure 3 depicts the enzymatic and biological ($D_{54°C}$-values) activity of lysozyme and β-NAGase detected in ESM from WL layers at three different ages (33, 50, and 81 weeks.). Lysozyme and β-NAGase activity was greatest in the ESM from 33 week old layers. A significant reduction in both ESM enzyme activities was found in the 50 week old layers. At 81 weeks, a slight numerical increase in both lysozyme and β-NAGase activity was observed in the ESM, although not significantly different than membranes from 50 week old layers. Shell membranes from 33 week old layers (having the highest lysozyme and β-NAGase activity) produced the lowest D-value (1.9 min). However, no significant differences in D-values were observed across hen age groups. After molting, the 81 week old layers produced similar lysozyme and β-NAGase ESM activities as the 33 (lysozyme) and 50 week old layers (lysozyme and β-NAGase). Despite significant decreases in lysozyme and β-NAGase between layers at 33 and 50 weeks, the lack of significant differences in D-values may indicate that ovotransferrin, the third component responsible for the observed antibacterial properties, may have a greater role than the two enzymes and perhaps be key to the antimicrobial activity of the ESM. Layer breeds within age groups did not influence D-values (unpublished data). Thus, age and breed apparently do not adversely affect the biological activity of ESM. The findings of these studies indicate that ESM, a significant waste disposal problem for the egg industry, may have significant value-added properties making it a useful by-product.

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Table 1. Enzymatic and biological activities of ESM components

ESM treatment	Biological (D_{54}-value) activity (minutes)	Lysozyme Activity (U/mg)	β-NAGase activity (U/mg)	Ovotransferrin activity (μg iron/g ESM)
Control	1.65 [c]	41.4 ± 3.9 [a]	12.2 ± 1.6 [a]	110.2 ± 10.6 [a]
Immobilized trypsin	5.12 [a]	36.7 ± 4.2 [a]	11.3 ± 1.1 [a]	45.7 ± 8.4 [b]
Trypsin (suspended)	5.38 [a]	37.8 ± 2.2 [a]	9.7 ± 1.8 [a]	39.7 ± 11.7 [b]
80°C for 15 min	3.99 [b]	14.0 ± 4.8 [b]	0 [b]	31.7 ± 12.0 [bc]
100°C for 15 min	4.43 [b]	4.3 ± 2.3 [c]	0 [b]	17.1 ± 4.3 [c]
Porcine lipase	1.54 [c]	42.8 ± 4.5 [a]	11.8 ± 1.4 [a]	100.1 ± 9.5 [a]
Lipase cocktail	1.18 [c]	40.6 ± 5.2 [a]	10.9 ± 1.7 [a]	104.7 ± 16.5 [a]

[a-c]Mean values (n=3) within D-values and protein/enzyme activity values with different letter superscripts are significantly different ($\alpha \leq 0.05$).

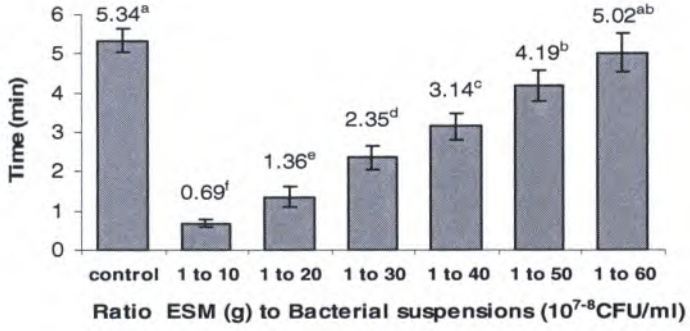

Figure 1. Mean $D_{54°C}$-values (minutes) (n=3) for Salmonella Typhimurium following treatment (incubation at 37°C for 30 min) with various concentrations of egg shell membranes (grams) to bacterial suspensions (ml). [a-f]Mean D-values with different letter superscripts are significantly different ($\alpha \leq 0.05$).

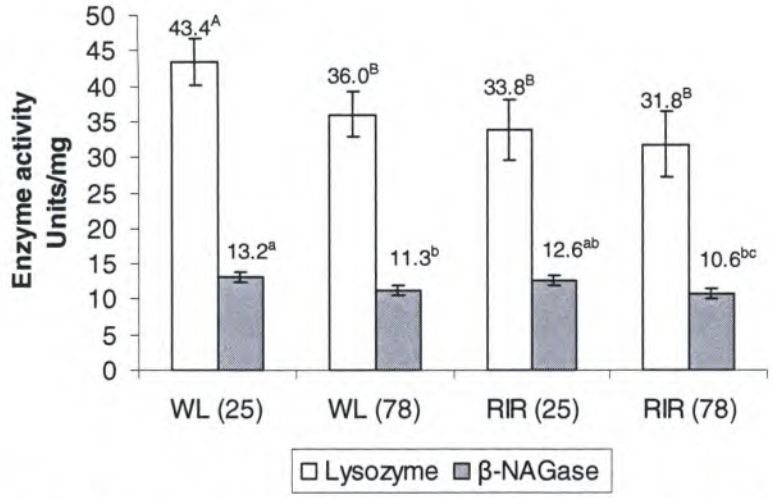

Figure 2. Comparison of the enzymatic activity of lysozyme and β-N-acetylglucosaminidase in eggshell membranes from White Leghorn (WL) and Rhode Island Red (RIR) layers at 25 to 27 and 78 to 80 weeks of age. [ABabc]Means with different letter superscripts within enzyme types differ significantly ($P \leq 0.05$) (n=3).

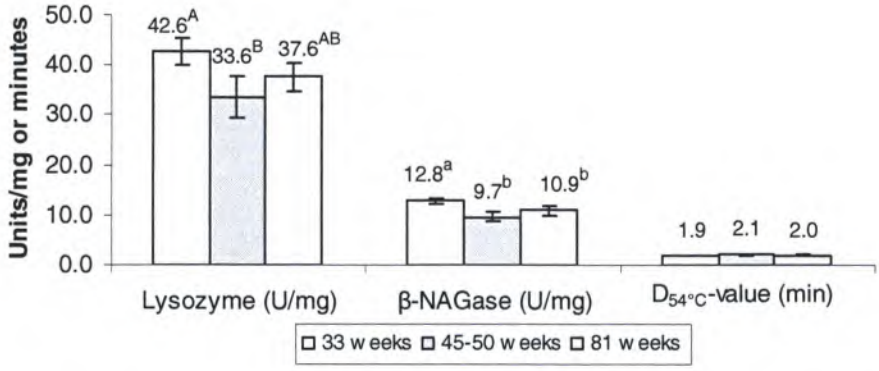

Figure 3. Comparison of the enzymatic activity of lysozyme and β-N-acetylglucosaminidase versus biological activity [D-values (min) of ESM treated *Salmonella* Typhimurium (37°C, 30 min) followed by heat inactivation (54°C)] of eggshell membranes from White Leghorn layers at 33, 50 and 81 weeks of age. [ABab]Means with different letter superscripts within enzyme types differ significantly ($P \leq 0.05$) (n=3).

ARSENIC IN POULTRY LITTER: REEVALUATING ITS WASTE MANAGEMENT IMPLICATIONS

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Overview of Arsenic

Arsenic (As) was isolated in 1250 A.D. by German-born Dominican friar Albertus Magnus. It is a ubiquitous element whose abundance is pervasive, as it ranks 12th in the human body, 14th in seawater and 20th in the earth's crust. Its discovery has been mired with controversy throughout human history; not only has it been used for medical purposes but also in various fields such as chemistry, electronics, agriculture, metallurgy and industrial applications (Badal and Suzuki, 2002).

Arsenic, with atomic number 33, is a notoriously potent poisonous metalloid that has many allotropic forms and it is used as a component of various alloys, pesticides, herbicides and insecticides. It has chemical similarity to its predecessor phosphorus, so much so that it will partly substitute phosphorus in biochemical reactions and is thus noxious. When heated it oxidizes to arsenic trioxide; this reaction is rapidly noticeable as it emits fumes whose foul odor resembles rotten garlic (ATSDR, 2005).

Arsenic derivatives, especially arsenic trioxide, have been used in a variety of ways over the past two centuries, paradoxically in medicine, most commonly in the treatment of some cancers. In 2000 the Food and Drug Administration approved this compound for the selective treatment of terminal patients with acute promyelocytic leukemia (APML) that are resistant to all-trans retinoic acid (Antman, 2001). Moreover, it was given for 12 years as a component of Fowler's solution in the treatment of psoriasis to a patient with bleeding esophageal varices, as reviewed by Huet *et al.* (1975).

Elemental arsenic and arsenic compounds are classified as toxic and dangerous for the environment in the United States (EPA, 2001) and the European Union (TDDS, 1967). Additionally, the International Agency for Research in Cancer (IARC) recognizes arsenic and its structural derivatives as group 1 carcinogens, and the EU lists arsenic trioxide, arsenic pentoxide and arsenate salts as category 1 carcinogens (IARC, 2004). It is not surprising then that ingestion of arsenic, both from water supplies and living tissues, has been scientifically linked as a cause of skin, liver, lung, kidney, breast and bladder cancer (Chen *et al.*, 1992; Jackson and Grainge, 1975; Schrauzer *et al.*, 1978). Moreover, it forms inhibitory organometallic complexes with plasmin enzyme in humans and leghemoglobin reductase in soy.

Most importantly, arsenic perniciousness lies on the fact that it can kill by allosteric inhibition of an important metabolic enzyme (lipothiamide pyrophosphatase) leading to multi-system organ failure as revealed post mortem by red colored mucosa due to severe hemorrhage. In poultry, the safety usage and toxicity levels of arsanilic acid, sodium arsanilate, carbasone, nitarsone, and roxarsone have been investigated in turkeys (Sullivan and Al Timimi, 1972a-d) and in Japanese quails (El Begearmi *et al.*, 1982); whereas the responses of organic arsenicals alone or in combination with antibiotics has been studied in broiler chickens by Waldroup *et al.*(1986).

Arsenic in Poultry Litter

The poultry industry is currently one of the fastest growing livestock production systems in the world; however, management of poultry waste has become a challenging environmental problem. Poultry feedstuffs, mainly broilers, can contain trace amounts of arsenic in the form of organoarsenical feed additives such as Roxarsone (3-nitro-4-hydroxyphenylarsonic acid) for its growth-promoting and disease-controlling properties, especially to combat coccidiosis. It is added at concentrations of 22.5 to 45.5 g/ton according to manufacturer suggested inclusion rates. Roxarsone is not absorbed by the feathers or tissues (Morrison, 1969); hence it is not considered a nutritious ingredient, which passes unchanged as part of the mixed digesta through the gastrointestinal tract of birds and ends up in fecal outputs. Poultry litter, a combination of poultry manure and bedding material, can contain arsenic at concentrations of 10-50 mg/kg. Garbarino *et al.* (2003) shows that although Roxarsone is stable in fresh poultry litter, it is rapidly converted to arsenic (V) when poultry litter is composted under aerobic conditions.

Disposal of the resulting arsenic-bearing poultry litter is currently unregulated, and it is frequently used to fertilize croplands. One possible retention mechanism for arsenic in soils and aquifers is adsorption to mineral surfaces. Arai *et al.* (2003) found that arsenic (II/III and V) was almost always concentrated in abundant needle-shaped microscopic particles associated with Ca, Cu, and Fe, and to a lesser extent with S, Cl, and Zn regardless of soil type. Excessive manure applications as an alternative organic fertilizer coupled with abundant irrigation or torrential rains can lead to arsenic leaching; resulting in contamination of soils and waterways that are deleterious to human health.

Arsenic-Induced Immune Impairment and Metabolic Disruptions

Toxic metals are antagonistic to other minerals necessary for growth, reproduction and well being of poultry (Moxon and Wilson, 1944) and plants in the environment (Frei and Hutzinger, 1985). Vodela *et al.* (1997) found that increasing levels of drinking water contaminants and decreasing levels of vitamins and minerals in diets resulted in significantly ($p<0.05$) decreased feed and water intake, decreased weight gain, and suppression of cell-mediated, natural, and humoral immune response in male broiler chickens. In avian species, arsenic is not only considered an immunosuppressant agent but also a disruptive one as regards to B vitamins and selenium (Se) metabolism (Carlson *et al.*, 1954; Stanley *et al.*, 1994), reproductive performance (Lillie *et al.*, 1957), developmental maturity (Wharton and Fritz, 1953), chicken egg Se content and lay (Krista *et al.*, 1961), and chick tissue Se contents (Carlson *et al.*, 1962).

Santra and collaborators (2000) demonstrated arsenic-induced hepatic fibrosis due to long-term exposure in a murine model. Within 6 months, initial biochemical evidence of hepatic membrane damage, probably due to reduction of glutathione and antioxidant enzymes, was evident. Fatty livers with serum aminotransferase and alanine aminotransferase were significantly elevated by 12 months and hepatic fibrosis by 15 months after continued arsenic feeding. Moreover, from a pharmacokinetic standpoint, dimethylated and methylated arsenicals that contain arsenic in the trivalent oxidation state are more cytotoxic, more genotoxic, and more potent inhibitors of the activities of some enzymes than are inorganic arsenicals that contain arsenic in the trivalent oxidation state (Thomas *et al.*, 2001). These finding have been corroborated by Mass et al. (2001).

Waste Management Implications

Contaminations of soils and water with arsenic are widespread (Nriagu, 1994). The extent of arsenic desorption (release) from litter materials increases with increasing time and pH from 4.5 to 7, but at most, 15% of the total arsenic was released after five days at pH 7, indicating the presence of insoluble phases and strongly retained soluble compounds (roughly 85%), suggesting that arsenic in poultry litter undergoes surface and subsurface transport processes (Arai *et al.*, 2003).

On January 22, 2001 the U. S. Environmental Protection Agency adopted a new standard for arsenic in drinking water at 10 ppb, replacing the old standard of 50 ppb, which all production systems must comply with by January 23, 2006 (EPA, 2001). Faced with stricter federal regulations and an increasingly demanding customer base, the poultry industry must reassess the implications of managing arsenic levels in poultry wastes. Recently, six poultry companies were acquitted from a lawsuit alleging that arsenic use as a feed additive resulted in cancer among individuals in Arkansas, which is just one example of how consumer awareness can prove menacing to the industry.

Commercial poultry operations are rife with logistical and production issues to be solved on a day-to-day basis. Indirect arsenic contamination of soils and water bodies is not a chief concern amongst chicken and turkey producers, and it should not be if arsenic was not fed in the first place. Technological advancements in toxic metal analysis are still in an experimental development phase, as current detection and determination of arsenic in poultry waste samples through capillary electrophoresis (CE), microscale-high performance liquid chromatography (μHPLC) and inductively coupled plasma mass spectrometry (ICPMS) proves to be non-selective, logistically unfeasible, time consuming and most importantly, cost prohibitive (Michalke, 2005).

Poultry Industry Challenges and Alternatives

Europe's ban on antibiotics -fully enforced by the beginning of 2006- and current discussions of adding more feed additives that would be faced out by 2016 places increasing pressures on poultry operators desiring to further penetrate foreign markets. In the case for organoarsenical feed additives -regarding reductions on carcinogen contamination of soils and waters- it has been suggested that poultry farms can adopt any combination of these three alternatives: 1) completely eliminate organoarsenical dietary inclusion and replace it with a natural non-toxic alternative, 2) drastically reduce its inclusion rate in diets coupled with improved sanitary practices, and/or 3) creatively devise another use for poultry wastes instead of land mass applications coupled with phytoremediation. The biological remediation of environmental problems using plants has been scientifically demonstrated with success by planting and growth of Brake fern *Pteris vittata*, which efficiently removes arsenic from the soil (Lena *et al.*, 2001).

There are more elaborate methods for removing inorganic arsenic from water. Many take advantage of the strong bond that forms between As and Fe. Arsenic in drinking water can be removed through co-precipitation of iron minerals by oxidation and filtering. If this treatment results are unacceptable, adsorptive arsenic removal media may be utilized. Several adsorptive media systems have been approved for use in a study funded by the U.S. Environmental Protection Agency, U.S. Air Force, the National Institute of Environmental Health Sciences, and the National Science Foundation.

Venture capital environmental firms capitalize on this characteristic with a new class of amended silicate adsorbent that removes more arsenic from water than traditional ways, and do it more easily and more cheaply. An overlooked contamination source is that of widespread burning and landfill disposal of timber treated with chromated copper arsenate (CCA-timber) that was used as a structural and building material in rural areas.

With regards to applications in human health, an *in vivo* experiment in mice showed that sodium selenite administration 1-h before sodium arsenite exposure resulted in reduced cytotoxicity, thus exemplifying the significant importance of Se-enhanced foods in protecting against widespread toxic maladies, as observed in Bangladesh's human population exposed to arsenic-contaminated drinking water (Biswas *et al.*, 1999).

Goals for the future include the replacement of coccidiostats with a vaccine. A vaccine is currently available but is relatively expensive. Vaccines against coccidiosis are used in pullets and more rarely in laying hens. In the future, these vaccines can be of preeminent importance for broiler production.

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