Cooperative Regional Research Project

W-195 WATER QUALITY ISSUES IN POULTRY PRODUCTION AND PROCESSING

October 1, 2000 to September 31, 2005

TABLE OF CONTENTS

PROJECT NUMBER: **W-195**

TITLE: **Water Quality Issues in Poultry Production and Processing**

DURATION: **October 1, 2000 - September 31, 2005**

STATEMENT OF THE PROBLEM:

Water quality issues have received a lot of press coverage in recent years as contamination of ground and surface water sources have been brought before the US public. The importance of these issues will continue to escalate as our nation looks more critically at it's natural resource base. Water quality is an issue that will continue to be magnified and will not disappear or be played down in the near future. Water quality is a health issue in many parts of the US and world, and it is just as important to poultry production and processing, since water quality can affect poultry health and performance.

This new regional research project will be the only regional project dedicated to the role of water quality issues in poultry production. Water quality issues include the environmental, food safety, growth performance, and profitability of poultry and poultry products. The objective of this new project is to study the role of water used in poultry production and product processing and their effect on the environment, and food safety.

JUSTIFICATION:

<u>Importance in agriculture, rural life and consumer concerns</u>

Agriculture continues to be the dominant industry in rural communities; however, it is becoming more and more evident that stewardship of our natural resource base is not only the responsibility of farmers, but of all citizens. Consequently, society is demanding that agriculture implement environmentally sound sustainable systems of production that have low chemical usage, reduced movement of sediment and nutrients from the land, and have minimal or no off-site impacts. Components of these production systems must include reduction of waterborne pollutants into the environment, high-quality, healthy food products, and profitability. Management of pollutants released into the environment will insure a safe and healthy drinking water supply for humans and animals.

In 1990 and 1991, states throughout the U.S. assessed the surface water quality of this nation's rivers, streams, lakes and estuaries. According to EPA sources, agricultural non-point source pollution affected 72 percent of the river and stream miles, 56 percent of lake acres, and 43 percent of estuary acreage. The nation's groundwater quality was also assessed and found generally good; however, local areas have experienced significant contamination with agriculture implicated as one of the main sources of groundwater pollution. One-third of agricultural pollution originates from non-point sources, with causes which may include the mishandling of animal waste such as manure and dead birds, and poultry processing facilities.

Public concern over animal waste pollution of our water resources initiated several pieces of federal legislation. Agriculture was greatly affected by these federal laws such as the Coastal Zone Management Act, the Clean Water Act, and the Safe Drinking Water Act. Under the Coastal Zone Act Reauthorization Amendment, six management measures are used as a guide for agriculture to prevent non-point source pollution. They are: 1) sediment/erosion control; 2) confined animal facility; 3) nutrient management; 4) pesticide management; 5) livestock grazing; and 6) irrigation. Best management practices (BMP's) within these measures must be economically achievable and must represent the best means possible to reduce the discharge of non-point source pollutants. Manure, waste water, and runoff water that is utilized on agricultural land must be applied in accordance with an animal waste management or nutrient management plan. The Reauthorization Amendment is the foundation for controlling and preventing non-point sources of pollution. The re-authorization also encompasses the Clean Water Act which includes surface and groundwater protection from point and non-point sources of pollutants. Agriculture, in general, and the poultry industry, specifically, will most definitely be affected.

Maintaining profitability while protecting the environment has become a critical issue for the poultry producer. On many farms, traditional agricultural practices related to traditional crop and livestock production cannot provide adequate protection of the environment while sustaining agricultural profitability. To achieve this balance, agriculture must implement cost effective practices which invoke innovative approaches to marketing, production, management, and utilization. Such approaches include reducing total input costs, direct marketing, forward contracting, increasing efficiency through newly developed technologies, and identifying new uses for traditional agricultural products. All of this must be accomplished in harmony with the country's rich natural resource base.

Extent of the problem

Poultry production in the U.S. is an 18-billion-dollar-a-year industry which has grown dramatically since the 1950's. Increased concentration of poultry production has caused severe environmental problems such as odor, flies, dust and declining water quality. The poultry industry is faced with three major water quality and nonpoint source pollution issues. They are: 1) mortality management; 2) manure/litter management; and 3) processing plant waste. These issues must be addressed by the producers and managers of poultry companies. Water quality issues must be a normal business concern.

Non-point source pollution from animal waste runoff can reduce surface and groundwater quality by introducing excessive levels of nutrients such as nitrogen and phosphorus, organic matter, and pathogens into the environment. In 114 watersheds studied throughout the U.S., excessive levels of nitrogen and phosphorus were derived primarily from excessive or irresponsible manure applications. Detailed guidelines on manure-nutrient management programs must be developed for the poultry industry in order to avoid water pollution or improve water quality. Besides manure-nutrient management programs, mortality from poultry production units must be handled in such a way that disposing of the mortality does not pollute ground and surface waters. Alternative handling methods of daily mortality need to be developed that are economical and easily implemented by the industry.

One of the real challenges facing the poultry producer deals with the managing and handling of poultry waste products in ways that minimize adverse impacts, especially water quality impacts. Animal wastes contain materials which cause direct and indirect health problems in other animals and people. Health problems from water contact sports or drinking water always relate to the concentration of contaminants in the water. With more and larger poultry operations confined to smaller areas of land, the likelihood of water contamination increases. That is the single most important reason for concern of both ground and surface waters in areas where there are high numbers of animals producing large amounts of manure and associated by-products.

Water is vital to the poultry industry. Good quality water is necessary for poultry to grow, thrive and be profitable to the producer. On the other hand, the poultry industry must learn to prevent water pollution from large quantities of water discharged from meat and egg processing plants. Development of economical methods to clean up the large volume of discharged water from the processing plants is of high priority. Recycling of reclaimed water from processing plants to the production units is a possibility.

Poultry farms may use water from municipal sources (potable for humans), from wells, streams, ponds, lakes, rainfall catchments, and springs. Because of its very nature of potential hydrogen bonding, water is an excellent solvent for both inorganic and organic substances. For this reason, water is an ideal medium for the proliferation and distribution of harmful components such as chemical elements and microorganisms. Quality of surface and ground water depends upon naturally occurring inclusions such as cations, anions, heavy metals and inadvertent inclusions such as pesticides, herbicides and wash off of excessive organic or inorganic fertilizers, and microorganisms.

Drinking water is of concern to poultry producers due to its great variability in quality and its potential for contamination. Naturally occurring surface and ground waters always contain inclusions ranging from low to very high concentrations. Water quality is characterized by its taste, acidity, alkalinity, odor, color, turbidity, salinity, electrical conductivity, pH, biochemical oxygen demand, hardness, presence of anions, cations, herbicides, pesticides and bacteria. Water inclusions contribute to the diet of chickens, having either nutritional, anti-nutritional, toxic, or infectious properties. Dissolved inclusions and additives are generally considered to be more readily available for absorption. High quality drinking water may be defined as water which contains inclusions which promote vitality and lack inclusions causing morbidity and mortality. As the volume of non-drinkable water increases and the technology for measurement of inclusions improves, we are becoming increasingly aware of water inclusions and their effects on health and nutrition. It is important that we discover the effects of water inclusions, both naturally occurring and supplemental, on the performance of poultry and that we precisely define "high-quality" drinking water.

Drinking water inclusions can affect the quality of poultry meat and eggs. Water inclusions can discolor poultry products, particularly eggs. Toxic substances can build up in fat and muscle tissues and hens can export toxic substances into eggs. Variations in water quality and management practices (water treatments, additives, and delivery devices) have the potential to influence the health and productivity of poultry and the quality of processed poultry products. Poultry products are required by law to be washed or rinsed with potable water. Often cleaners and disinfectants are added to improve food safety. Wash and rise waters must be handled to avoid environmentally pollution.

Needs and advantages of a cooperative approach

It is important for the American poultry industry to strive toward the compliance of environmental policies and regulations and to exceed future expectations through the development and adoption of environmentally safe technologies. The development of these systems requires a multi-disciplinary approach that can only be accomplished through cooperation of various experimental stations to account for variations in climatic and environmental conditions in the US. Also, these issues must be examined regionally because of the enormous variation in forage and crop biology, soils type, and management systems employed across the US. No single station or investigator is likely to develop a single broad-based program to ensure the environmentally safe disposal of farm-generated poultry by-products or to ensure the safety of ground and surface waters. Unfortunately, local environmental conditions and local management practices vary across the country, so specific recommendations aimed at the poultry producers will have to be tailored for different geographic regions. Field testing and producer education programs must be addressed in different regions of the country to ensure that results of research trials and field tests are presented that pertain to the target audience. The need to refine information to fit local conditions mandates the need to develop an information base that involves researchers from diverse geographical regions and to include experts in nutrition, physiology, waste management, agronomy, horticulture, agricultural engineering, waste water management, and food safety.

Expected benefits

This formation of an interdisciplinary team will allow greater flexibility and innovation that dictates the need to solve non-point source problems for the poultry industry. Resources have been critically limited in recent years, and yet results have been forthcoming. By sharing the circumstances and approaches of several innovative programs, concepts and characteristics portrayed in other states can be tailored to fit the needs of other regions by saving time, money, and energy in solving related problems, as well as boosting programs that may need a new direction or approach.

The development of methods to ensure the environmentally safe disposal of poultry by-products and to ensure the quality of ground and surface waters requires a thorough understanding of scientific principles and their application to “real-world” situations. A more complete knowledge in these areas will allow for the development of sustainable agricultural systems that utilize science-based technologies to reduce environmental problems and will result in more appropriate management-based systems. The application and integration of these systems will result in improvements in the efficiency of poultry production by reducing costs, lessening the potential for the contamination of ground and surface waters, utilizing by-products in a more economical manner, and reducing the amount of non-point source pollutants being expelled into the environment.

Extension publications, videos, Experiment Station publications, popular articles in trade magazines, and refereed journal articles which discuss results from the project will be used to educate producers and managers of poultry companies on manure/nutrient management, waste water management and dead bird disposal. Through educational materials, producers and managers will further understand and appreciate the impact of various management schemes on water quality and poultry performance.

Oral presentations of the results will be presented at grower meetings, regional meetings, scientific meetings, international meetings, conferences, extension workshops, and the annual meetings of the Poultry Science Association, the Southern Poultry Science Association, the World's Poultry Science meeting, and Southeastern Poultry Association.

Coordination of the educational plan will be through the Chair of the committee. Richard Reynnells, USDA/CSREES/PAS liaison will be actively involved in assisting in national coordination and distribution of information. Coordination of an educational action plan will be discussed as part of meetings and conference calls. Personnel will have responsibilities related to their contributions on individual projects and team efforts.

How this project varies from past efforts

The new project varies from work done in the past by WCC-59 in that additional research emphasis is being placed upon the effects of non-point nutrient pollution associated with poultry production and slaughter. This has important ramifications upon environmental quality issues. Cooperative efforts to evaluate water quality and water deliver device effects on poultry performance will continue, but with added emphasis placed on the microbiologic environment within watering systems. This has an indirect impact on human heath and a direct effect on poultry productivity. Environmental issues, water quality, and food safety are critical public issues. This will be the only regional project that studies these issues specifically in the poultry production arena. The proposed research project is innovative and unique. It addresses the critical nature of environmental issues for the national poultry system in the absence of formal research programs.

RELATED CURRENT AND PREVIOUS WORK OF OTHER PROJECTS

An extensive search for related work was conducted in the Current Research Information System (CRIS) database in addition to a physical review of the USDA/CSREES list of Multi-State Research projects. The search found several Multi-State Projects fall within the scope of the new Project proposed by the WCC-59 participants. However, the new proposed project addresses a research problem not being addressed elsewhere. Most of the individual projects, within existing Multi-State Projects represent efforts of specific individuals and/or laboratories and do not duplicate WCC-59 efforts.

In addition, the new Project shares interests with other multi-state projects:

S-275	Animal Manure and Waste Utilization, Treatment, and Nuisance Avoidance for a Sustainable Agriculture
NC-183	Development of New Processes and Technologies for the Processing of Poultry Products (Terminated)
NE-127	Biophysical Models for Poultry Production Systems
S-291	Systems for Controlling Air Pollutant Emissions and Indoor Environments of Poultry, Swine, and Dairy Facilities
W-184	Chemistry and Engineering to Minimize Irrigated Agriculture's Effects on Water Quality
NRSP-3	The National Atmospheric Deposition Program
W-82	Pesticides & Other Toxic Organics in Soil & Their Potential for Ground & Surface Water Contamination

There is no overlap of the proposed New Project with any of the regional projects. However, methodologies generated by the New Project research will contribute to the goals of the related projects.

Project S-275 (Animal manure and waste utilization, treatment, and nuisance avoidance for a sustainable agriculture) shares similar goals to Objective 1 (Develop methods for proper management and recycling of poultry production and processing waste to improve water quality) in the proposed new project, but S-275 does not address any of the issues of Objective 2 (Determine water quality factors that affect poultry performance and market product quality).

The terminated Project NC-183 (Development of New Processes and Technologies for the Processing of Poultry Products) dealt exclusively with poultry, as does the new Project, but was focused on chemical, physical, and microbiological properties of poultry meat products as influenced by new processing techniques and technologies to improve and insure the safety and quality of processed poultry meat products. Two investigators participating on the new Project were formerly in Project NC-183.

The objective of Project NE-127 (Biophysical Models for Poultry Production Systems) are to develop, evaluate, and validate mathematical models appropriate for application to poultry production based on data generated in response to time-dependent changes of the environment with resulting economic implications. NE-127 utilizes poultry, as does the proposed new Project, however the goals of two projects are dissimilar. One investigator on NE-127 will also be included in the new Project.

Project S-291 (Systems for Controlling Air Pollutant Emissions and Indoor Environments of Poultry, Swine, and Dairy Facilities) includes poultry but the focus is on air pollution. For some potential pollutants, such as nitrogen, there are interrelationships between air and water contamination, but this is not the major focus of the new proposed project.

Projects W-184 (Chemistry and Engineering to Minimize Irrigated Agriculture's Effects on Water Quality), NRSP-3 (The National Atmospheric Deposition Program), and W-82 (Pesticides & Other Toxic Organics in Soil & Their Potential for Ground & Surface Water Contamination) are concerned with ground and surface water contamination. The focus of these Projects do not overlap with the new proposed project.

The new WCC-204, "Animal Bioethics" project may include the contemporary issue of water quantity and quality (WQ2) for all animals, but the focus and extent would not be a duplication of these proposed research efforts. Two other projects, S-289 (Factors Associated with Genetic and Phenotypic Variation in Poultry: Molecular to Populational), and S-285 (Reproductive Performance of Turkeys) contain little to no potential linkages to the proposed formalized research efforts.

Sera-ieg-17, "Minimizing Agricultural Phosphorus Losses for Protection of the Water Resources", focuses on phosphorus sensitive watersheds, the Phosphorus Index, use of BMP's to decrease agricultural phosphorus losses, and the development of soil phosphorus tests and animal manure application strategies. Again, there is little or no conflict with the proposed Water Quality Issues in Poultry Production and Processing project.

The Sera-ieg-24 deals with generic composting issues, but there has been little more than informal interaction. Little or no linkage is foreseen with the Water Quality Issues proposal.

The CRIS search strategy categorized projects as: poultry + water; water; manure; wastewater; NC-183/S-292; NE-127; and, S-275. There was significant overlap in these searches. The attempt was made to not summarize duplicate titles. For the search using the keyword "wastewater", six research projects were found to be terminated, four of which could have had application to the proposed project. Two new projects (DAF By-Products as Broiler Feed; and, HACCP Approach to Poultry Processing...") could have some linkage and could be placed within this project at some point. One project was a support center for manure management.

The "manure" keyword yielded information on three terminated projects and seven new projects. Of the seven, at least four could, or will, come under this project. Using "water" as the search strategy resulted in reports on nine terminated research efforts and three new research projects. The "poultry + water" keywords led to four terminated and five new research projects.

The conclusion can be clearly drawn that there are very few linkages between the proposed "Water Quality Issues in Poultry Production and Processing" Multi-State Research Project, and existing projects. There were no or very few projects discovered in these various search categories that addressed components of the proposed Water Quality Issues project section on Procedures intended to meet our Objectives. The proposed research project is innovative and unique. Given the critical nature of environmental issues dealing with WQ2, the absence of formal research programs to address these issues for the poultry system (with application to other species), and the willingness of many individuals to go to significant effort to submit this application and continue to develop significant cooperative programs, even with no formal recognition, it is very important that approval be provided this group of dedicated professionals.

RELATED CURRENT AND PREVIOUS WORK OF WCC-59:

The materials presented in this section demonstrate the productivity of the WCC-59 group. The participants in the Western Regional Coordinating Committee (WCC-59), "Poultry Production, Processing and Water Quality," have organized two symposia. The symposium "Water Quality and Poultry Production" was presented at the Annual Meeting of the Poultry Science Association in 1994.

The second symposium titled "Alliance for Environmental Stewardship: A Comprehensive Approach" was held in St. Louis, MO on September 27-29, 1999. The objective of the "Alliance" workshop was to create an opportunity for personnel representing the major sources of water pollution to define inhibitors to comprehensive nutrient evaluation and utilization programs, and to define ways they can cooperate to help develop science-based policy and regulations to reduce environmental pollution. Potential pollutant sources were defined as sectors of the industry which included: 1) agricultural nutrients which included commercial fertilizers, 2) animal production residuals and biosolids, 3) pollutants obtained from urban areas and on-site wastewater and sewage treatment facilities including biosolids. Working groups were formed among the 160 participants during the symposium developed a listing of Prioritized Recommendations were included , along with papers prepared by the 62 invited speakers in a proceedings publication (Blake and Kintzer, 2000).

The members of WCC-59 have created a poultry drinking water database by combining the results of their numerous studies. Most of the participants had their water samples analyzed at the University of Arkansas Water Quality Laboratory. Thus, the database is an accurate means of comparing water inclusion concentrations between geographic regions.

Other accomplishments from station-based members of the WCC-59 include, but are not limited to, the following extracts from meeting minutes. This effort clearly demonstrates the continued progress shown by the cooperative efforts of the technical committee.

The members of WCC-59 committee gathered data on water inclusions from commercial poultry farms in Washington, Oregon, Arkansas, Maryland, and Utah. The analyzed data on water inclusions in surface and ground water were correlated with poultry production parameters.

A. Washington (Zimmermann) analyzed drinking water samples from 71 broiler farms on Delmarva. The bacterial profile showed that 88% of the wells contained bacteria, 7% and 1% of these had coliform or E. coli bacteria, respectively. Nitrate (as N) exceeded 10 ppm in 27% of the wells. The growth performance variables from 49 farms, within one integrated company, from 190 flocks consuming the water were statistically related with all 20 measured water inclusions. Pearson correlation coefficient analysis suggested that elevated K, $CaCO_3$ and electrical conductivity (EC) in drinking water improved feed conversion. Mortality was reduced by high levels of Mg, K, $CaCO_3$, and EC. Condemnation was decreased by high levels Mg, Na, $CaCO_3$, HPO_4, and pH. Data were also analyzed by a rank multivariate procedure to evaluate effects of interactions among inclusions on broiler performance. Body weight was positively influenced by age, drinking water, $CaCO_3$, pH, dissolved oxygen, and was negatively effected by total aerobic plate bacteria (TAB); $r^2 = 0.912$). Feed conversion increased with age and drinking water TAB, but was reduced by K in the drinking water; $r^2 = 0.647$. Mortality increased with age and drinking water NO_3, but was improved by K; $r^2 = 0.175$. Condemnation was increased by age, HCO_3, and TAB; $r^2 = 0.153$. The results of the multivariate analysis suggest that bacteria in drinking water are reducing growth performance and that high nitrate level increase mortality on broiler farms on Delmarva. These results are not in agreement with those previously observed in WA or AR, likewise absolute concentration of inclusions varied greatly among the three regions. Interestingly, the bacteria causing morbidity are not Coliforms. Zimmermann's previously collected data has not yet been analyzed with the multivariate procedure.

B. Utah (Buchner) analyzed drinking water samples from 65 turkey farms but did not relate data to growth performance.

C. Washington (Zimmermann) surveyed 46 layer farms for water inclusions such as cations, anions, contaminants and bacteria in the drinking water and correlated the levels of water inclusions with layer performance. Of 46 layer farms, only 24 farms provided performance data. Water conductivity, iron, manganese, sodium, sulfate, chloride, and total bacteria were found not to correlate significantly with the data. The Pearson correlation coefficient and probability values for weeks with less than 90% egg production and chloride were r =.486, P =.0188; nitrate: r = .538, P = .0081; conductivity: r =.996, P =.0151; hardness: r =.552, P =.013, and magnesium: r = .528, P = .0095. The correlation between feed conversion (kg feed/dozen eggs) and hen-day egg production were negatively correlated r = -.437, P= .033). The correlation of hen-day egg production and pH was r =.495.

D. Arkansas (Barton) obtained and analyzed water samples of 120 Arkansas turkey farms from two companies. Little difference in water quality was observed. Water samples from 100-120 broiler breeder farms were also analyzed.

E. Utah (Warnick) tested soil samples for phosphates and nitrates where turkeys were raised. These nutrients were not pollutants in the water.

F. Oregon (Hermes and Holleman) surveyed all broiler farms in the state for 18 inclusions to determine background levels (performance data was not known).

G. Oregon (Nakaue) reported on a turkey farm that experienced 50% down grading due to crooked keel bones. After installation of a water softener, crooked keel bones were reduced by 2% but the rate of slipped hock tendon increased. Levels of Ca, Mg, Na, K and pH were higher on this farm than Corvallis drinking water. Toleration of Na may be high, but the role of Cl needs to be studied.

H. Washington (Zimmermann) analyzed drinking water samples from every broiler farm in Washington State and correlated 19 measured inclusion values with growth performance parameters of 210 flocks consuming the water. Bacteria were found in 41% of the water samples. In WA, broiler drinking water with high concentrations of sulfate or copper were associated with poor feed conversion whereas high levels of potassium, chloride, or calcium reduced mortality. None of the water inclusions was significantly related to body weight or condemnation. These results are in marked contrast with similar studies done in Arkansas. The results emphasize the differences in water inclusions between regions and suggest the mixture and interaction of inclusions in drinking water is as important as the absolute concentration.

Evaluation of the effectiveness of water additives, treatments, and delivery systems used in poultry production and processing facilities.

A. California (King) reported that vitamin C (1500 ppm) supplemented in the drinking water 24 hours prior to slaughter had no effect on lipid oxidation in the dressed poultry carcasses. Presence of iron, magnesium and copper in drinking water may affect lipid oxidation of dressed carcasses.

B. Oregon (Nakaue and Hermes) investigated four water delivery systems (trough, cups, Clark and Ziggity nipples) in broilers reared on a commercial broiler farm for five batches. Broilers provided water with trough waterers used more water than the two nipple types and cups. Growth rates of broilers on cups or Clark nipple waterers were the same, but slightly lower than the broilers provided water via the trough. Mortality was lower with broilers provided water via the Clark nipples than either the trough, cups or Ziggity nipples; however, broilers on Ziggity nipples had better feathering.

C. Washington (Zimmermann) supplemented drinking water with water additives such as electrolyte-vitamin-mineral, chlortetracycline, carnitine, lysine, and methionine during induced molt by fasting. Leghorn hens (65 to 108 wks of age) were not significantly affected with mortality or post-molt laying performance.

D. Washington (Zimmermann) reported that city water treated with electrolysis lowered broiler mortality and increased nickel and chromium levels compared to the untreated water. Broiler growth rate and feed conversion were not affected by water treatment.

E. The Western Regional Research Center, USDA, ARS (Stevens) investigated the formation of several compounds that may be mutagenic during chlorination of poultry processing water. The addition of S-9 liver enzymes to the Ames assay, which uses bacteria, destroys the mutagenicity of the compounds. Compound E, the major mutagen, was found to be structurally similar to MX, one of the most potent mutagens known.

F. The Western Regional Research Center, USDA, ARS (Tsai) reported that chlorine dioxide is used by many drinking water purification plants and in the disinfecting of fruits and vegetables during processing. Chlorine dioxide at 20 ppm had the same effectiveness in poultry chiller water as chlorine at 100 ppm. Chlorine dioxide is less corrosive and oxidative, and forms no THM (trihalomethanes) and mutagenic compounds. FDA has recently approved the use of chloride dioxide in poultry chiller water; FSIS must approve its use in the poultry processing plant.

G. Oregon (Nakaue and Hermes) reported that broiler reared on a commercial farm with Clark or Ziggity nipple drinkers out-performed broilers reared with either trough or cup waterers during a one year period.

H. California (King) researched dressed broiler carcasses for a dark and light muscle color condition which was observed by a commercial broiler processor. The problem was related to the length of time the dressed broiler carcasses were left submerged in the ice water. Light muscle color was related to carcasses being immersed in ice water for longer than 48 hours, due to tissue pigments leaching out of the muscle.

I. Utah (Warnick) reported market turkeys reared with Ziggity nipple drinkers were heavier than turkeys grown with dome-type waterers. One point better performance in market turkeys can have significant economic returns to the producers.

J. Oregon (Hermes and Nakaue) reported that four week broiler body weights were depressed by the highest level of nitrate in the drinking water (2000 ppm) compared to those given 0, 111, or 427 ppm nitrate from the sodium salt. Morphological changes in livers were also noted in the 2000 ppm nitrate group as well.

K. Washington (Zimmermann) reported that two strains of *Lactobacillus acidophilus,* selected for gut colonization, when added to drinking water (0, 10^4, 10^6, or 10^8 per day) failed to have a significant effect on broiler growth performance or carcass yield. Zinc bacitracin (20g/ton in feed) improved body weight gain and feed conversion, but had no effect on carcass yield.

L. Utah (Warnick) reported reduced water consumption by turkeys following cholera vaccination, via the water, and the reduced water consumption was not related to the powdered milk used in conjunction with the vaccine.

M. Utah (Warnick) reported water consumption by range reared turkeys correlated more with the time of day (ambient temperature) than to the temperature of the water.

N. Washington (Zimmermann) compared the effects of three electronic drinking water treatment devices to untreated water on broiler growth performance. Two of the devices increased dissolve oxygen content of the water and decreased conductivity and aerobic bacteria count. One of these reduced broiler mortality (P=.065), decreased pH (P= .062), and incresed Fe and Mn concentration in the water. The other increased temperature, Ti, and Mn, while reducing the concentration of chloride, Al, Ca, Cr, Mg, and Sr in the water. Neither the third device, an electrostatic water treatment, nor the other devices affected body weight or feed conversion. No treatment differences in hematocrit, bursa weight, or tibial ash weight were observed at 21 days of age.

O. Oregon (Hermes) reported on studies showing broilers prefer cup waterers to Swish™ water satellites. Studies were done in two commercial broiler houses with dimensions of 13.4 m x 116.4 m and 13.4 m x 125 m with broiler capacities of 27,500 and 25,830, respectively.

P. Arkansas (Andrews) presented data comparing broiler performance when drinking from cups, nipples, and bell waterers. Nipples reduced body weight, had no effect on feed conversion, but kept floors drier. Cups also kept litter dry. Newer nipples are being developed to increase water delivery to birds.

Selected Publications

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OVERVIEW OF OBJECTIVES:

OBJECTIVE 1: Develop Methods for Proper Management and Recycling of Poultry Production and Processing Waste to Improve Water Quality

1A. Evaluate management and recycling techniques for poultry waste as either a fertilizer, feed, or fuel to protect water quality.

1B. Evaluate management and recycling techniques for poultry mortalities to protect water quality.

1C. Evaluate management and recycling techniques for by-products of hatcheries, poultry meat processing and egg processing to reduce water usage and protect quality.

OBJECTIVE 2: Determine Water Quality Factors That Affect Poultry Performance and Market Product Quality

2A. Determine the effects of naturally occurring water inclusions on poultry performance, health, and product quality.

2B. Determine the effects of drinking water additives on poultry performance, health, and product quality.

2C. Identify additives or contaminants in processing water that affect poultry product quality.

OBJECTIVES

1: Develop Methods for Proper Management and Recycling of Poultry Production and Processing Waste to Improve Water Quality.

2: Determine Water Quality Factors That Affect Poultry Performance and Market Product Quality.

PROCEDURES:

Objective 1. **Develop Methods for Proper Management and Recycling of Poultry Production and Processing Waste to Improve Water Quality**
Coordinator: Blake (AL)

1A. Evaluate management and recycling techniques for poultry waste as either a fertilizer, feed, or fuel to protect water quality

1. Dietary and microbial strategies will be evaluated for their ability to reduce ammonia gas and fecal phosphorus from commercial egg-laying houses (Patterson-PA). First, antibodies to the uricase enzyme will be developed in an attempt to reduce the normal breakdown of uric acid that occurs in poultry manure. Another effort will evaluate several species of nitrogen-fixing bacteria (soil origin) for their ability to survive in hen manure and broiler litter and their efficacy in converting free ammonia to nitrate/nitrite. To reduce fecal phosphorus, dietary strategies along with control and Biomittent Lighting programs will be evaluated with post-peak laying hens to better utilize dietary calcium and phosphorus. Measures of hen productivity, egg quality, and fecal phosphorus concentration will be determined.

2. The USDA/ARS laboratory in Fayetteville, AR is involved in evaluating management and recycling techniques for poultry waste as either a fertilizer, feed or fuel to protect water quality. Dr. Moore is the lead scientist for the USDA/ARS CRIS “Poultry Manure Management to Reduce Non-point Source Phosphorus Pollution”. The three main objectives under this CRIS which relate to this project are to; (i) determine the factors that affect phosphorus chemistry and transport in soil, water, and manure, (ii) determine the long-term impacts of manure management strategies on soil, water, and air resources, and (iii) develop best management practices to reduce non-point source phosphorus runoff.

   In addition to the efforts of Moore (UDSA/ARS), others will investigate methods of improved poultry waste management and utilization which will provide poultry producers with a range of management options that will sustain productivity while protecting water quality (TN; VA; GA, WV).

In collaboration with the NRCS and other agricultural agencies, a phosphorus risk index will be developed as a tool for use by poultry producers and litter applicators to determine litter application rates on different fields and for different crop types (TN; VA; GA, WV). Evaluating changes in the solubility of the phosphorus component of the poultry litter when stored or when applied during house clean-out will also be evaluated. The evaluation of established Best Management Practices will also be an integral component of this process.

3. Recent changes in North Carolina laws regulating the land application of poultry litter require that litter be applied based on crop usage and litter nitrogen content. Levels of other nutrients such as phosphorus, copper, and zinc are also required to be monitored. The possibility that land application of litter will be based on phosphorus rather than nitrogen is quite distinct. Even though efforts are under way to decrease fecal nutrient excretion, there is also a need to extend the useful life of current bedding materials and to develop alternative uses of poultry litter once its usefulness as bedding has ceased. Current technology developed by Adherent Technologies, Inc., holds promise to both extend bedding life and to offer alternative uses of poultry litter. This process basically is a heat process which has the potential to both sterilize turkey litter and to change its form and, therefore, create a new product. This new product offers several potential advantages: 1) a product of greater value than litter, 2) a product that does not have to be land applied, which eliminates land application of excess nutrients, and 3) a product that will be moved out of the area where it is produced. This study will be conducted at North Carolina State University (Grimes) with the objective to determine if heat processed turkey litter can be reused as bedding for turkeys.

Pine shavings which have been used as turkey bedding for one growth period will be used in this study. Large White male turkeys will have been grown on the bedding for 20 weeks. This litter will be removed from the pens and heat processed for reuse as bedding material. Four treatment litters will be used: 1) control - new pine shavings, 2) turkey litter heat processed at low temperature (at least 250 F), 3) a mixture, 70:30 (w/w) of turkey litter heat processed at low and high temperatures (approximately 600 F), and 4) a mixture, 90:10 (w/w) of turkey litter heat processed at low and high temperatures (approximately 600 F). These bedding materials will be placed in 36 floor pens in a randomized block design to provide nine replicate pens per treatment. Thirty Large White hen poults will be placed in each pen on day of hatch. Typical rearing techniques will be applied to the birds for a 14 week growth period. During this period standard industry type rations will be provided. Feed consumption, by pen, and mortality will be monitored. Birds will be weighed individually at 6, 10, and 14, weeks of age. Period and cumulative feed conversion ratios will be calculated. Litter quality and nutrient content will be monitored. Nutrient content (N, P, Cu, and Zn) of the four treatment litters will be determined at the beginning of the study and at 6 and 14 weeks of age. Bacterial analysis for total heterotrophs, coliforms, staphylococcus and streptococcus sp. will also be determined at the beginning, and at 6 and 14 weeks of age. Analysis for campylobacter and salmonella sp. will be conducted at the beginning and at 14 weeks of age.

4. Malone (DE) plans a demonstration of sand as an alternative bedding in poultry houses will be implemented and market options for the litter will be identified. Four farms with paired houses will be used in this demonstration. Two broiler farms from one cooperating poultry company and two roaster farms from the other company will be monitored over a two-year period. On each farm, ~2 inches of masonry sand will be placed in one house and compared to ~ 3 inches of pine sawdust/shavings. Production cost per pound of live weight, body weight, feed conversion, mortality, fuel cost, and condemnation data will be determined each flock for a minimum of one year. In addition, litter temperature, gram negative bacteria, darkling beetle population, litter and intestinal cocci oocyst, and dust (total and respirable) will be monitored. Cost:benefit comparisons of the bedding treatments will take into account: production cost per pound of live weight; bedding, installation and crusting cost; volume of crust requiring storage, and estimated value of the litter for end-use markets. The cost:benefit estimates will be projected for both the poultry company and grower. Implications of any reductions in disease challenge and insecticide use for beetle control will be assessed. The physical and chemical characteristics of the sand base litter will be compared to the pine shavings/sawdust litter on each paired-house farm over a two-year period. Litter samples will analyzed for bulk density, particle size, moisture, ash, nitrogen, phosphorus and potassium. Both total and soluble concentrations of the following minerals will be determined; phosphorus, aluminum, iron, calcium, arsenic, copper, zinc and sulfur. The physical and chemical profile of each litter type will be plotted over time to establish predictions of the optimum composition for compatibility as an additive to a base soil amendment mixture. Based on survey of local turf and nursery industries, this information will be used to establish potential innovative markets for the sand litter.

   The use of sand or wheat chaff as a suitable bedding material will be investigated by researchers at the University of Tennessee (Burns, Goan, and Walker) and USDA (May, Lott, Miles) as management options that will contribute to productivity while protecting water quality. Their efforts will contribute to an informational base concerning the use of alternative litter materials within different regions of poultry production in the US.

5. The poultry industry is faced with increasing local, state, and federal legislation limiting the amount of nutrients applied to the land in the form of poultry manure, waste, or litter. Historically, these limits were based on nitrogen application. Recently, however, phosphorus has received a great deal of attention as being the rate limiting nutrient. In addition, future limits may be based on phosphorus, and possibly heavy metals, rather than nitrogen values. Therefore, all phases of the poultry production industry are concerned with limiting the amount of fecal nutrients excreted by poultry. These concerns and efforts should include the breeder phase of the turkey industry. Decreasing the dietary phosphorus levels in breeder feed would have both immediate and long term effects. The immediate effects would be to decrease the cost of breeder feed as well as poult costs, especially if the dietary phosphorus could be reduced without dietary phytase. Also, reducing fecal phosphorus would offer both immediate and long term relief from manure and litter use restrictions. In addition, the poultry industry would possibly receive positive

feedback from the public sector for being in a pro-active or progressive mode with respect to environmental awareness and concerns.

Five hundred parent stock Large White turkey breeder hen poults will be housed and reared according to standard industry methods including breeder and NRC recommended nutrition and feeding programs at North Carolina State University (Grimes). Sixty parent stock males will be placed and reared according to breeder and industry standards to provide semen for the hens. All hens will be weighed monthly until 18 weeks of age and then they will be weighed at time of photostimulation (30 weeks of age) and at the end of a 24 week lay period. At 18 weeks of age, the hens will be exposed to short day length to 30 weeks of age. At 30 weeks of age, one of three dietary phosphorus levels will be fed to the hens. The phosphorus treatments will be as follows: 1) industry standard level of .7% total phosphorus (.5% available), 2) .5% total phosphorus, and 3) .3% total phosphorus. At each dietary phosphorus level there will be two levels of phytase enzyme (0 and manufacturer's recommended level). This will provide for a 3 x 2 factorial design (3 levels of phosphorus and 2 levels of phytase) for a total of six treatments. At 30 weeks of age, turkey breeder hens will be assigned to pens with eight pens allotted to each of the six treatments. All other nutrients will be provided at breeder's recommended level and also to meet or exceed NRC recommended levels. The hens will be photostimulated at 30 weeks of age with 14.5-15.5 hours of light per day for a 24 week egg production period. Hens will be inseminated at approximately 14, 17, and 21 days post photostimulation and then weekly thereafter with at least 300 million sperm cells per hen. Eggs will be collected 5 times per day, stored for up to one week, and then set in incubators for 24 weekly hatches. At each setting, three eggs per pen will be used to determine percent shell, shell thickness (by direct measurement) and egg phosphorus content. Three additional eggs per pen will be weighed at setting and at transfer to hatcher; subsequent poults will be weighed. Any unhatched eggs will be broken and observed for fertility or day of embryo death. Apparent phosphorus digestibility will be determined at the beginning and at the end of the egg production period. Tibia P will be determined at the beginning of the experimental period and for 1 hen per pen at the conclusion on a 24 week lay period. Hen body weight, serum P, P retention, fecal P, tibia P, egg P, egg production, egg weight, egg shell thickness, percent shell, fertility, hatch of all eggs set, hatch of fertile eggs set, poult weight, poult yield per hen, and egg shell conductance will be determined.

6. Nutrient reallocation is also a concern with the disposition of poultry manures. Composting the poultry manure prior to land application may effectively alter the phosphorus loading rate upon application of the manure. In a series of experiments proposed by Carr (MD) and Burns, Goan, and Walker (TN) the soluble phosphorus and/or nitrogen in composted poultry litter and/or manure will be determined and compared to raw poultry litter and/or manure and poultry mortality compost. These processes will include various litter amendments added to the litter in the production environment and utilization of various recipes in the composting process. In Maryland (Carr), an agitated bed compost system will be used to make the litter compost and a two-stage poultry mortality compost system to make the poultry mortality compost. The

carbon:nitrogen (C:N) ratio will be varied from 15:1 to 30:1 using various feed stocks. Soluble phosphorus from the compost and the litter and/or manure will have an anticipated effect on water quality.

7. Methods for composting the manure and bedding material (litter) production from broiler houses is typically done exterior to the poultry house. However, there is research to indicate that litter can be composted in-house between flock placements to ensure improved bird health and performance when the next flock is reared on the old bedding (litter) material. Such methods will extend the useful life of the bedding materials (i.e. wood shavings, peanut or rice hulls, paper products) and result in a cost savings to the producer. Hermes (OR) proposes to identify methods of in-house composting of broiler litter and its effect on litter quality and broiler performance.

8. The employment of litter amendments to augment bird health and performance are becoming more widespread through the poultry industry. Economic advantages play a crucial role in the decision to use litter amendments. However, there is little information concerning their input to the manure product that will be eventually field applied. There is a need to determine the effects of litter amendments on soluble phosphorus in broiler chicken litter (Zimmermann-MD; Burns, Goan, and Walker-TN). The efficacy and economics of these amendments will be determined on litter samples that vary in age and number of flocks reared. Alum, a commonly applied litter amendment has been demonstrated to reduce in-house ammonia levels. Burns, Goan, and Walker (TN) propose to evaluate the real-time ammonia fluxes in alum treated and untreated broiler houses with the intent to develop a model of ammonia emissions on a regional scale to estimate the impact of these emissions on the environment.

   An alternative approach to the use of chemical additives is the enhancement of bacterial microorganisms that prevent or inhibit the conversion of the nitrogenous products of excretion to ammonia. May, Lott, and Miles (USDA) propose that naturally occurring microorganisms that do not favor the conversion of uric acid to ammonia exist in poultry excrement. Methods tailored at enhancing the natural populations of these microorganisms that are “anti-ammonia producers” may effectively reduce in-house ammonia levels and effectively improve the environment during rearing, impact overall emission levels, and reduce ammonia production from stored poultry litter.

9. An old concept with new application is the potential use of livestock wastes as a fuel source. The use of poultry litter as a biomass fuel source offers potential to the producer on a small-scale or for the generation of electricity or heat on a large-scale. Hulet and Patterson (PA) propose to evaluate the economics of a small litter-fueled boiler (Spinheat) that can produce both heat and electricity for a broiler production company. Also, in Minnesota, there is a new facility being constructed for the sole purpose of generating electrical energy from the combustion of poultry litter. There is a need to collect information from poultry producers in this state so that litter production can be collectively evaluated to determine the needs of this new burning facility (Noll-MN).

10. Research will be conducted to investigate the phosphorus requirement of male turkeys in the later stages of growth (Roberson-MI). Current research involves the evaluation of low-phytate corn in turkey diets and an estimation of phytase inclusion levels needed for optimum profitability, while reducing phosphorus output in the excreta. Various sources of phytase enzymes will be evaluated for their effectiveness in reducing phosphorus excretion while maintaining performance.

11. In Tennessee and Louisiana, waste disposal problems are on of the growing concerns to agriculture and the issue has become critical to municipal officials and corporate managers. Because of the concern about agricultural waste disposal problems, the LSU Agricultural Center's 8-acre Organic Recycling Facility was established and is equipped to conduct material processing and windrow composting. The facility offers a Compost Facility Operator Training Certification course which has attracted participants from 30 states and five foreign countries. Additions to the facility include the W. A. Callegari Environmental Center building. With this addition, the LSU AgCenter has a state-of-the art testing/research laboratory for evaluating the degradation of organic materials. The proposed research will encompass the use of the facilities available at the LSU AgCenter and Environmental Center to conduct training courses and research targeting the use of composted poultry by-products (manure, mortalities, processing wastes) as a soil amendment for crops such as sugarcane and cotton, for ornamental plants, and for fruit and vegetable production (Lavergne, Sanders, Carney, and Stephens–LA). In Tennessee (Burns, Goan, and Walker), a project is underway to develop an appropriate compost recipe that will enable the production of a litter-based product that is acceptable to the nursery industry. This will enable land-limited poultry producers to produce a low-input value-added product from their poultry litter.

12. Feed and feed additives not utilized by an animal for growth and development are excreted into the manure. However, if proper feed processing techniques are utilized, the amount of unused (non-digested) nutrients could be enhanced. Also, feed wastage could be minimized with proper processing techniques. Beyer (KS) proposes that proper processing techniques can be developed that improve feed form and reduce wastage. Conditioning time, heat, moisture, pressure and new processing equipment will be examined to determine what impact these variables have on eliminating feed wastage.

13. Frame (UT) will investigate the effects on turkey production parameters and bird health of recycled newspaper in different forms (chopped, ground, and pelleted) as an alternative bedding material. The cost effectiveness of these recycled newspaper products will also be compared to previous paper materials which proved superior to pine shavings but were prohibitively expensive. Local turkey producers raise about five million birds annually on wood shavings which are becoming more and more scarce and of poor quality while tons of newspaper are filling local landfills.

1B. Evaluate management and recycling techniques for poultry mortalities to protect water quality

The environmentally safe disposal of poultry carcasses, normal mortality that occurs during the growout period, has always been a concern to the poultry grower. Recent regulations in the state of Arkansas (July, 1994) and newly imposed regulations in the state of Alabama (July, 2000) prohibit the burial of carcasses. Other states will probably enact similar legislation to prohibit the use of burial as a method for carcass disposal. Concerns with groundwater contamination and the residue remaining in the ground have been the primary concerns.

Methods for the disposal of poultry carcasses include incineration, composting, and conversion into a usable feed ingredient. Due to the emergence of newer incineration technologies there is a need to investigate the economics and efficiencies of new equipment presently on the market (Blake-AL). Also, composting has been adopted in many of the poultry producing states, but there is a need to consider techniques that will define the process and the use of the composted material for its full value as a fertilizer. Previous research has been conducted at various Experiment Station locations. There are several participants in the project that continue to investigate the use of composting as a method for the disposal of poultry carcasses and evaluate the composted product for its fertilizer and soil amendment properties. Several participants have proposed to consider various aspects related to poultry carcass composting (Watkins and Moore-AR; Carr-MD; Blake and Hess-AL; Carey-TX; Noll-MN; Ritz-GA). Other methods that offer the pickup of dead birds and the transport of the carcasses to a rendering facility in an environmentally friendly manner are also worthy of further investigations (Blake and Hess-AL; Noll-MN; Carey-TX; Ritz-GA).

The recycling of poultry carcasses into a usable feed ingredient also offers potential. Methods for the pickup and transportation of the dead birds requires consideration from a disease and economic viewpoint. Also, a thorough microbiological and nutritional evaluation of the product must be completed to determine its value as a feed ingredient. Methods for the preservation of poultry carcasses prior to processing, as well as methods for processing require further investigation (Blake and Hess-AL; Carey-TX; Noll-MN). Methods for the large-scale processing of daily mortalities from several integrated companies are being employed in Alabama and the companies involved need Experiment Station expertise.

1C. Evaluate management and recycling techniques for by-products of hatcheries, poultry meat processing and egg processing to reduce water usage and protect quality

The disposal or utilization of hatchery wastes and inedible egg by-products has proven difficult in recent years. This may be because these byproducts tend to be seasonal or are isolated geographically and have yet to be completely addressed as sources of potential water quality concerns. Innovative research needs to be conducted to evaluate different techniques and methods to utilize hatchery waste at the least cost and greatest long-term viability (Hulet and Patterson-PA; Beyer-KS) and also to develop a practical on-site composting system for hatchery waste disposal (Hermes-OR). The results should provide valuable information which will contribute to the improved income of producers and will eliminate this waste stream from the environment.

Objective 2. Determine Water Quality Factors That Affect Poultry Performance and Market Product Quality Coordinator: Zimmermann (MD)

2A. Survey drinking water quality on poultry farms and relate water inclusions to poultry performance, health, and product quality

Poultry farms may use water from municipal sources (potable for humans), from wells, streams, ponds, lakes, rainfall catchments, and springs. Because of its very nature of potential hydrogen bonding, water is an excellent solvent for both inorganic and organic substances. For this reason, water is an ideal medium for the proliferation and distribution of harmful components such as chemical elements and microorganisms. Quality of surface and ground water depends upon the naturally occurring inclusions such as cations, anions, heavy metals and inadvertent inclusions such as pesticides, herbicides and wash off of excessive organic or inorganic fertilizers, and microorganisms.

Drinking water is of concern to poultry producers due to its great variability in quality and its potential for contamination. Naturally occurring surface and ground waters always contain inclusions ranging from low to very high concentrations. Water quality is characterized by its taste, acidity, alkalinity, odor, color, turbidity, salinity, electrical conductivity, pH, biochemical oxygen demand, hardness, presence of anions, cations, herbicides, pesticides and bacteria. Water inclusions contribute to the diet of chickens, with either nutritional, anti-nutritional, toxic, or infectious properties. Dissolved inclusions and additives are generally considered to be more readily available for absorption. High quality drinking water may be defined as water which contains inclusions which promote vitality and lack inclusions causing morbidity and mortality. As the volume of non-drinkable water increases and the technology for measurement of inclusions improves, we are becoming increasingly aware of water inclusions and their effects on health and nutrition. It is important that we discover the effects of water inclusions, both naturally occurring and supplemental, on the performance of poultry and that we precisely define "high-quality" drinking water.

Drinking water inclusions can affect the quality of poultry meat and eggs. Water inclusions can discolor poultry products, particularly eggs. Toxic substances can build up in fat and muscle tissues and hens can export toxic substances into eggs. Variations in water quality and management practices (water treatments, additives, and delivery devices) have the potential to influence the heath and productivity of poultry and the quality of retailed poultry products.

Since geographic differences in water quality may exist, research to quantify the effect of water inclusions on poultry health and performance will be conducted in several locations. In Arkansas, research and field trials will be conducted to evaluate the effect of weight gain, feed conversion and yield of different levels of bacteria in the drinking water of broiler chickens (Watkins). In Maryland (Zimmermann), Alabama (Hess and Blake), and Oregon (Hermes) researchers will determine the effects of naturally occurring water inclusions on poultry performance, health, and product quality. Well water samples will continue to be collected from broiler and layer houses, analyzed, and correlated with growth performance of broilers consuming water. Also, a survey to determine the quality of drinking water on broiler breeder farms will be initiated in Maryland.

Studies will correlate laying hen performance and egg quality in Pennsylvania flocks with drinking water inclusions and other parameters of water quality (Patterson). Flocks will be identified as being either normal or problem flocks based on bird health, egg grade out, or flock performance. Egg quality will be commercial grade out reports including percentage grade A, dirties, cracks, and leakers. Water samples will be taken quarterly at the well head to correspond with seasons of the year the flocks are in production.

All results will be correlated with poultry production parameters from the participating states that will be surveyed.

2B. Evaluate the effect of drinking water additives on poultry performance, health, and product quality

Drinking water is often treated (filtered, softened, acidified, neutralized, disinfected, magnetized, etc.) to improve bird growth performance and to maximize the efficacy of additives. Drinking water is commonly used to deliver additives such as vaccine, medication, and other nutrients. A rule of thumb is that poultry drink twice as much water, by weight, as feed consumed, thus the quickest method of administering medication is via drinking water. All commercial poultry farms are equipped with proportioners capable of delivering additives into the drinking water delivery system at precise dosages.

Drinking water treatment or additives are done to correct perceived and real problems. Water softening is used to reduce hardness (calcium and magnesium salts) and iron. These can interfere with water delivery systems causing water restriction or flooded houses. Hard water also reduces the effectiveness of some cleansers. Many water treatments and additives may alleviate environmental stressors. Broilers provided carbonated drinking water show improved livability and feed conversion.

Several stations, located in geographically different climatic areas will conduct research and field trials to evaluate the effect of different water treatments on the performance of broiler chickens (Watkins-AR; Zimmermann-MD; Carr-MD; Hess and Blake-AL). Also, Zimmermann (MD), Noll (MN), and Ritz (GA) will investigate the effects of drinking water treatments, additives, and delivery systems on poultry performance, health, and product quality. Many products and water treatment systems are being marketed without supporting research or field data to support their efficacy. Additives will be examined for their efficacy in improving poultry performance through the drinking water. Research programs will be initiated to determine the effectiveness of drinking water disinfection systems and to monitor biofilm development in broiler drinking water systems and investigate cleaning and prevention methods (MD). A process employing ozonation will be evaluated for its effect on animal performance and reduction in pathogenic microorganisms (GA).

At the University of Maryland, Carr will determine the effects of carbonated drinking water on the livability of broilers as a heat stress intervention in warmer months of the year as compared to tap water. The greater the livability, the less mortality to be treated by composting. This research will be conducted in the University of Maryland Broiler Environmental Research Facility which has 18 - 500 bird independent chambers. Each chamber has nipple drinkers, a water measuring system and a piping distribution system to accommodate carbonated drinking water and tap water sources.

2C. Identify additives or contaminants in processing water that affect poultry product quality

Occasionally, iron or rust in pipes can cause surface discoloration on poultry products. The HACCP food safety system, mandatory in large processing facilities, requires that carcasses be free of fecal material. Rust particles on poultry carcasses have been mistaken for fecal material and condemned, which results in product and economic loss. Dietary nitrate may also affect the concentration of nitrate in meat and eggs, as well as affect on meat color. Limited information exists concerning the effects of water quality on product quality and consumer preferences. Watkins (AR) proposes to conduct research and field trials to determine the impact of minerals such as iron, manganese, sodium, chloride, sulfate, and calcium on the growth and performance and meat quality of broiler chickens. King (CA) will conduct research to determine how high levels of selected minerals (manganese, copper, and iron) in the water supply affect deterioration of unsaturated fatty acids in stored poultry meat.

EXPECTED OUTCOME:

Completion of the objectives as outlined in this research project proposal will not only increase our understanding of the relationship of water quality in poultry production but will bring us the opportunity to apply innovative methods that will ensure the environmentally safe disposal of poultry by-products and will ensure the quality of ground and surface waters. A more complete knowledge in these areas will allow for the development of sustainable agricultural systems that utilize science-based technologies to reduce environmental problems which will enhance management-based systems for the poultry industry.

The formation of this interdisciplinary team will allow cooperating members of this research project proposal to recommend the most efficient and economical methods for water quality management in poultry production systems. This water quality program is uniquely situated and information gained from this project will be presented to industry and producer groups around the country by committee members. Members of this research project are located in various regions and have been actively involved in outreach or continuing education programs in the past. Potential also exists to place this information on a variety of internet sites, which would provide interested individuals or groups "state of the art" information. All forms of technology transfer are expected to be used to effectively reach target audiences

ORGANIZATION:

Regional Technical Committee: The Technical Committee shall consist of the Administrative Advisor (non-voting), CSRS representative (non-voting), a technical representative from each participating SAES appointed by the director, and a technical representative of each cooperating USDA research laboratory named by the appropriate administrator. The responsibility of the Technical Committee shall be to coordinate research activities of the participants and to carry out such other functions as outlined in the Manual for Cooperative Regional Research SEA-CR/OD-1082.

Officers: These shall consist of a Chair, a Secretary, and a Member-at-Large. The Secretary will assume the office of the Chair and the Member-at-Large will assume the office of secretary.

Executive Committee: This subcommittee, consisting of the Chair, Secretary, Member-at-Large, and the Administrative Advisor will act as directed by, and for, the Technical Committee between meetings.

The time and place of the annual meetings will be decided by vote of the members after consultation with the Administrative Advisor or by the Executive Committee when so directed.

Coordination of the educational plan will be through the Chair of the committee. Richard Reynnells, USDA/CSREES liaison will be actively involved in assisting in national coordination and distribution of information. Coordination of an educational action plan will be discussed as part of meetings and conference calls. Personnel will have responsibilities related to their contributions on individual projects and team efforts.

W- Water Quality Issues in Poultry Production and Processing

SIGNATURES:

Administrative Advisor

8/15/00
Date

Chairman, Regional Association of Directors

8/15/00
Date

Administrator, Cooperative State Research, Education and Extension Service

9-20-00
Date

ATTACHMENTS:

Project Leaders
Resources
Critical Review
References
Appendix D

PROJECT LEADERS:

State, Laboratory	Participant(s)	Specialization
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Crop and Soil Environmental Sciences 424 Smyth Hall Virginia Tech Blacksburg, VA 24061	Greg L. Mullins	Nutrient Management
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West Virginia University Extension Service Center for Agricultural and Natural Resources 1058 Agricultural Sciences Building P. O. Box 6108 Morgantown, WV 26506	Thomas J. Basden	Nutrient Management

RESOURCES:

PARTICIPANT	OBJECTIVE 1 A	OBJECTIVE 1 B	OBJECTIVE 1 C	OBJECTIVE 2 A	OBJECTIVE 2 B	OBJECTIVE 2 C	RESOURCES SY	R/E/T*	PY	TY
Alabama										
John P. Blake	X	X		X	X		0.1	0/100/0	0.0	0.1
Joseph B. Hess		X		X	X		0.2	0/100/0	0.0	0.1
Arkansas										
Susan A. Watkins	X	X		X	X	X	0.2	0/100/0	0.1	0.0
Phillip D. Moore	X	X					1.0	100/0/0	0.0	0.0
California										
Annie King						X	0.1	10/0/0	0.0	0.1
Delaware										
George W. Malone	X						0.2	30/70/0	0.0	0.2
Georgia										
Casey W. Ritz	X	X			X		0.1	0/100/0	0.0	0.0
Kansas										
R. Scott Beyer	X		X				0.1	30/50/20	0.0	0.02
Louisiana										
Theresia Lavergne	X						0.1	0/100/0	0.0	0.0
Fred Sanders	X						0.1	0/100/0	0.0	0.0
Bill Carney	X						0.1	0/100/0	0.0	0.0
Matthew Stephens	X						0.1	0/100/0	0.0	0.0
Maryland										
Lewis E. Carr	X	X			X		0.1	45/55/0	0.0	0.3
Nickolas G. Zimmermann	X			X	X		0.2	30/70/0	0.0	0.1
Michigan										
Kevin Roberson	X						0.25	35/65/0	0.5	0.0
Minnesota										
Sally L. Noll	X	X			X		0.1	20/80/0	0.0	0.0

Mississippi									
James D. May	X					0.3	100/0/0	0.0	0.0
Berry D. Lott	X					0.2	100/0/0	0.0	0.0
Dana M. Miles	X					0.5	100/0/0	0.0	0.0
North Carolina									
Jesse L. Grimes	X					0.2	85/15/0	0.0	0.1
Oregon									
James C. Hermes	X		X	X		0.2	25/75/0	0.1	0.0
Pennsylvania									
R. Michael Hulet	X		X			0.1	70/30/0	0.0	0.0
Paul H. Patterson	X		X	X		0.1	70/30/0	0.0	0.0
Tennessee									
Robert Burns	X					0.2	0/100/0	0.1	0.0
Charles Goan	X					0.1	0/100/0	0.2	0.0
Forbes Walker	X					0.2	30/70/0	0.1	0.0
Texas									
John B. Carey		X				0.1	0/100/0	0.0	0.0
Utah									
David D. Frame	X					0.2	50/50/0	0.0	0.0
Virginia									
Paul L. Ruszler	X	X	X	X	X	0.1	0/85/15	0.0	0.0
Greg L. Mullins	X					0.1	25/75/0	0.0	0.0
West Virginia									
Thomas J. Basden	X					0.25	0/100/0	0.0	0.0
TOTALS						**5.90**		**1.1**	**1.02**

*Percentage of appointment **R**esearch/**E**xtension/**T**eaching

CRITICAL REVIEW:

Objective 1. Develop methods for proper management and recycling of poultry production and processing waste to improve water quality.

Poultry Waste and Land Management

Poultry waste and land management options to mitigate the impact on the environment and water quality are numerous. Yet the three main options for using these wastes are as a fertilizer, feed or fuel. Recycling the nutrients to either plant or animal systems is an appealing solution, although capturing the energy contained in poultry waste to do other useful work is another option.

Fertilizer

Crops

While most of the broiler litter produced annually is applied to pastures and hayfields (90%) new and alternative uses for poultry manure and litter have been demonstrated in recent years. Poultry litter applied to pansy and snapdragons demonstrated a positive growth response according to Erbach *et al.* (1997). Hall (1997) demonstrated soil plots fertilized with chicken litter as the N source generally showed greater levels of P, K, Ca and Fe and lower pH than plots fertilized with equivalent N from chemical fertilizer. Soil nutrient levels were influence similarly by different types of chicken litter (non-composted broiler, composted broiler, non-composted breeder, and composted breeder). Corn and snap bean leaf samples from the plots showed all elements were sufficient regardless of fertilizer source, and yields were similar between the chicken litter and chemical fertilizers. Cabbage head weight, head diameter and total weight were increased in fine sandy loam soil when poultry litter applications were compared with commercial fertilizer or composted trash according to Cooper et al. (1997). Other efforts will focus on the possible link of using poultry litter as a soil amendment to foodborne disease organisms associated with tomatoes and strawberries (Morant and Ekperigin, 1998). A study was designed to evaluate whether tomato growth in Fusarium species infested soil can be enhanced when poultry litter is used as an amendment and impact the efficacy of biological control agents. The fungus Trichoderma virens applied as a biocontrol agent actually reduced tomato yield while poultry litter increase yield. Neither treatment had an impact on fruit quality according to the authors (Morant and Evert, 1998). Field studies of Readdy (1996) were conducted to determine the N and P availability from broiler litter and quantify litter rates in vegetable crops. Litter treatments included 0, 12.5, 25, 50 and 100% of the recommended N fertilizer rate for cabbage and sweet corn and the same recommended N rate of chemical fertilizer. Cabbage yield increased with up to 50% of N supplied through litter then leveled off. Sweet corn yield at 25% N from litter was similar to chemical fertilizer treatment. Both N and P availability increased up to the 50% litter N rate and was similar to the chemical fertilizer.

For more than 250,000 acres of cotton grown in the Tennessee Valley region, poultry litter represents an affordable and readily available source of nutrients. In studies carried by Readdy (1996) sources of N including fresh poultry litter, composted litter and urea significantly increased cotton lint yield. Nitrate leaching to deep soil levels and surface organic matter accumulation will be investigated in coming years. Best management practices are being developed for stacked broiler litter (SBL) use on Bermuda grass meadows (Eichhorn *et al.*, 1998). Field plots fitted with equipment to measure rainfall runoff, infiltrate flow rate and collection of water samples were studied during three hay harvests in the presence of a control a commercial fertilizer (CF) at .7 Mg/ha (N-P-K = 17-2.1-21) SBL at 4.5, 9.0 and 18 Mg/ha. Forage yield, crude protein and digestible dry matter were maximized and most cost effective at the 18 Mg/ha SBL. Forage quality ranked from highest to lowest on the basis of crude protein, fiber, and digestibility with CF = SBL at 18 Mg/ha, greater than SBL at 9.0 and greater than SBL at 4.5 which was equal to the control. Plant tissue analysis indicated the yield of lower SBL and control plots was limited by N and K deficiency across harvests. Other nutrients were in adequate supply for Bermuda grass and provided most nutrients in sufficient quantities required by most classes of cattle, although Cu and Zn were at lower than required levels. Preliminary data on concentrations and loads of total bacteria and fecal coliforms were not significantly different among treatments with runoff waters exceeding, and leachate water meeting safe levels of fecal coliforms for livestock but not human consumption.

Nitrogen fluxes were studied in fescue pastures amended with broiler litter in the Coastal Plain, Piedmont and Appalachian Plateau of the Southeast (Marshall *et al.*, 1998). Ammonia flux was generally less than 10 kg/ha, representing a loss of <6% of applied N. De-nitrification flux ranged from -20 to 2500 g N_2O-N/m^2/hr, but was always <5% of applied N. Plant uptake was the largest flux of applied N averaging 59.5 kg N/hr or 43% of applied N. Nitrogen budgets indicated a substantial surplus of N at all sites.

In a novel study Fontenot and Kornegay (1998) evaluated the relative efficiency of recycling nutrients in broiler litter by soil application to pastures or feeding directly to grazing steers. Broiler litter was applied to pastures at the rate of 2223 kg/ha and compared to an equal amount fed to cattle. Forage P and Cu tended to be higher for pastures on which litter was fed or applied to the soil compared to control pastures. Serum P and Cu tended to be higher from steers fed the broiler litter. Dietary P affected steer daily gain, while dietary N had no affect on performance. The authors concluded that utilization of poultry litter by direct feeding is an effective means of broadcasting pasture nutrients and avoiding excessive application to the soil.

Poultry litter and commercial fertilizer treatments were applied to both newly planted pine seedlings and recently thinned mid-rotation age pine trees (Wilhoit, 1997). Seedling growth response from the poultry litter that included intensive weed control was better than other treatments, while growth on litter without weed control was less than that from the commercial fertilizer treatment. Higher litter application rates of 4 and 8 t/ac had growth responses comparable to commercial treatments in mid-rotation age trees. Groundwater nitrate levels were high in all other the seedling litter and fertilizer plots during the first couple months following application, then decreased substantially. Further research with specialized spreading equipment for organic solids in forest settings indicated that narrow swath width (28 ft) was more uniform than that recommended by most spreader manufacturers (approximately 40 ft) (Ling, 1997).

Land Management

Utilizing poultry litter and manure for agronomic crops requires proper manure and land management techniques to minimize environmental impact. Considerable investigation has addressed phosphorus run off, ammonia losses, and microbial and steroid contamination of surface water. Land management strategies include wetlands, riparian zones, and vegetative strips.

NH_3 losses and P runoff

Estimated nitrogen losses as ammonia from commercial pullet and layer manure and broiler litter as a percentage of feed nitrogen were 32, 40 and 18% respectively (Patterson and Lorenz 1996, 1997; Patterson *et al.*, 1998). Hill *et al.* (1996) demonstrated that gaseous losses of N following poultry litter application were small (<10 kg/ha) during the first 7 days and essentially ceased after 1 week. However, immediately after a rainfall event ammonia volatilization increased. Phosphorus runoff in small watersheds was decreased approximately 70% when poultry litter was treated with aluminum sulfate (alum) before spreading to pastures (Moore *et al.*, 1997). Further more ammonia volatilization from the litter was reduced 99% for the first 4 weeks of growout. Studies aimed at reducing ammonia losses from composting poultry litter treated with phosphoric acid, alum and a microbial mixture indicated both alum and phosphoric acid greatly reduced ammonia volatilized (Moore and Sauer, 1997). Alum treatments also reduced soluble P in the composted litter. In a runoff study, P losses were lowest for the control plots and plots fertilized with alum-treated compost. Concentrations of P were highest in plots fertilized with phosphoric acid and compost treated with the microbial amendment.

When commercial fertilizer and litter were applied at the same N and P rates, runoff from the fertilizer plots had higher concentrations of NO_2-N, NH_4-N, TKN, PO_4-P and TP, whereas litter plots had higher COD and TSS concentrations according to Edwards and Daniel (1996). Vadose water at 120 cm contained NO_3-N as high as 8, 24, and 37 mg/l following litter applications of 10 and 20 Mg/ha and manure at 17.7 Mg/ha. Alum reduced the runoff of P by 87 and 63% of that from litter alone in first and second runoff events. Three and 21 m buffer strips were shown to remove 65 and 87% of incoming TKN, 71 and 99% of incoming NH_4-N, 65 and 94% of incoming PO_4-P and 67 and 92% of incoming TP, respectively. In other work by Costelo and Vories (1998) treating broiler litter with alum suppressed ammonia flux due to a lowering of litter pH and shifting ammonia-ammonium equilibrium toward the non-volatile ionic form. Furthermore they deduced that alum treatment would reduce the ventilation and space-heating requirements for broiler rearing by 40 % compared to untreated control birds.

Bacteria

Recent efforts have addressed potential pathogens in poultry and livestock waste, their management and survival in the environment. McCaskey and Gurung, (1998) studied manure management to control E. coli 0157:H7 and Salmonella on the farm. McCaskey *et al.* (1998) specifically look at the impact of constructed wetlands on these organisms as a means of odor control. Postharvest control of microorganisms in minimally processed fruit and vegetables including tomato, pepper and melon was studied by Suslow (1998). Research demonstrated that residual populations of E. coli and Salmonella species are detectable in stacked dairy and mixed poultry/dairy compost intended for vegetable soil application. In a survey over several months detectable populations were recovered from piles at dairies, composting facilities and in windrows adjacent to fields. E. coli was recovered from compost with temperatures as high as 135 F and from waster sources used to irrigate the compost suggesting recontamination on the site and the opportunity for disinfectants to reduce the load with water treatment.

New and proposed work in this field will address antibiotic resistance in selected organisms found in poultry and swine manure, their movement in the environment and methods to minimize transmission. DNA fingerprinting will be used by Morant and Ekperigin (1998) to tract microorganisms found in poultry litter, their survival in untreated and composted litter and their recovery from tomatoes and strawberries grown with organic and inorganic soil amendments.

Hormones

Broiler litter was found to contain 65 ng of 17-beta-estradiol and 133 ng of testosterone per g of dry weight according to Hartel (1997). When background levels were measured from edge of the pasture plots, testosterone and estradiol ranged from 14 -19 and 40 -50 ng/l of runoff. When cattle were placed in these plots levels increased to 18-36 and 100-140 ng/l, respectively. When the plots were amended with 9000-kg broiler litter/ ha and a runoff event occurred one day after applications estradiol levels increased to 150-2300 ng/l and 63-1000 ng/l for testosterone. By 200 days after litter application levels of the two hormones were essentially at background levels again.

Wetlands, riparian zones, vegetative strips

Numerous management opportunities including wetlands, riparian zones, and vegetative strips exist to reduce the losses of nutrients from fields fertilized with both inorganic and organic products. Fescue grass vegetative filter strips have the potential to remove metals of concern in the runoff from poultry litter according to Edwards *et al.* (1997). Two wet land cells planted with arrowhead and pickerelweed are being evaluated on a commercial dairy in Central Florida (Nordstedt *et al.*, 1998). The primary goal of the system is to minimize surface water discharge from the farm and to remove phosphorus. Other constructed wetland work has attempted to determine the contribution of the plants, the seasonal effects of temperature on treatment efficiency, and evaluate groundwater quality of seepage below the cell bottom. Hill *et al.* (1996) indicated that live plants contributed more to water treatment than just wooden rods as a control barrier. Nitrate levels are a concern in the deep seepage below the plant cell bottom, however data collected over a 55-month period indicated that wetlands were effective in reducing TKN 83.4%, NH_3 84.5% and P, BOD5, COD, and TSS were reduced by 76.1, 89.7, 79.6 and 88.6% respectively.

Watershed based management of the land could contribute to greater resource sustainability. Work by D'Souza *et al.* (1998) and Collins *et al.* (1998) suggests geographic information systems coupled with improved land use decisions are possible. As an example litter transporters and applicators might more effectively target litter nutrients where soil N and P are in short supply in order to manage around potential water contamination.

Poultry Nutrition and Management

Nitrogen

Strategies for reducing the nitrogen concentration in poultry manure fall into four main categories including: better feed formulation, lower protein diets, using feed additives and manure management. Better feed formulation can include having a better handle on the protein and amino acid concentration of feed ingredients and a better understanding of birds requirements. More precision feeding is possible with a better handle on either concentration or requirements so as not to oversupply dietary protein or amino acids. Simply feeding synthetic amino acids (methionine, lysine, tryptophan and isoleucine) in place of protein can reduce the crude protein level of laying hens diets by as much as 4% while still maintaining egg production and weight (Keshavarz and Jackson, 1992).

Feed additives include enzymes such as hemicellulases, beta-glucanases and others that free up the carbohydrate portion of cereal grains to allow for better utilization of carbohydrates as well as proteins. These can lead to as much as a 20% reduction in fecal volume and nitrogen excretion. Studies with Leghorn pullets aimed at reducing N and P intake while maintaining performance indicated that both dietary enzymes and feed formulation strategies can make significant improvements (Deshmukh, 1997). Low protein diets with or without a dietary enzyme reduced N intake by 12%. Pullet body weight was significantly lower than the control but met breeder standards for weight for age. Diets with enzymes added to make phytic acid P more available to the birds reduced P intake by 15% while dietary formulations with more highly available P ingredients plus the enzyme reduced total dietary P by 25%. The birds performed equal to or better than the control fed pullets suggesting performance can be maintained while reducing dietary crude protein, N and P.

Lastly, broiler and layer management techniques that keep free water away from manure and litter can reduce gaseous ammonia emissions and prevent leaching of nutrients from the manure. Good ventilation in the manure pit will assist drying and better hold nitrogen that might otherwise escape. Composting allows the growth of good bacteria and fungi that hold manure nitrogen in a stable form that won't volatilize as ammonia or leach away from the pile. The heat generated (110-150 F) during the composting process will further dry manure. New cage equipment for layers and trampoline floors for meat birds can rapidly dry manure thereby minimizing environmental contamination. Several commercial litter and manure amendments are available on the market to either chelate ammonia N or reduce the pH thereby keeping nitrogen with the litter rather than in the bird's environment.

Phosphorus

Strategies for minimizing P levels in the manure are numerous but a major impact can be made by selecting ingredients with highly available phosphorus. Phytate P found in many cereals is in a form that is not well absorbed by the bird. The P in corn and grain sorghum for example is only about 20% bioavailable because of the large phytate P content. While the P in meat and fish meals are 81 and almost 100% bioavailable (Patterson, 1996). Calcium added to the diets of broilers and laying hens as well as the calcium bound in di- and tricalcium phosphates can reduce the utilization of P and allow it to pass through the bird's digestive system unabsorbed. Phytate breakdown and P absorption was reduced 24% in laying hens when calcium levels were increased from 30 to 40 g Ca/kg diet (Klis and Versteegh, 1991). In experiments designed to influence dietary P using phytase with commercial laying hens in a factorial design, Bryant and Roland (1998) fed 0.1, .02, .03 and .04% available P (AP) and three levels of phytase 0, 300, and 600 units/kg. Results suggested that .1% AP is adequate for phase 1 hens, and with the addition of phytase is adequate in phases 2 and 3. However when one looks at first cycle hen performance there was a significant linear increase in egg production with increasing AP levels and increasing levels of phytase.

The impact of high available P (HAP) corn and phytase on P uptake and excretion by young pigs during a 7-day digestibility trial was evaluated (Baxter *et al.*, 1998). Manure P was reduced 21, 23, and 41% below the control diet for the phytase, HAP corn, and HAP corn + phytase diets, respectively.

Better feed manufacturing with specialized equipment can improve pellet durability index values (>90%) compared to commonly manufactured feeds with PDI values of 50-70% (Beyer, 1998). Work with broilers and turkeys has shown high quality pellets to improve production parameters compared to feed that had lost its form do to transport handling. Furthermore when enzymes such as phytase or beta glucanase are added to diets undergoing more rigorous manufacturing procedures, it appears enzyme efficiency and feed efficiency is improved with a corresponding decrease in N and total fecal excretions.

Two genetically engineered fungal and plant phytases were equally effective in enhancing utilization of phytate P in poultry and swine (Fontenot and Kornegay, 1998). Feeding microbial phytase increased utilization of protein and amino acids in pigs and broilers fed low-protein diets.

Broilers fed diets containing either low phytic acid corn, phytase enzyme or a combination of the two ingredients were evaluated for the impact on P runoff from small plots fertilized with these litters (Moore and Sauer, 1997). Data from this study indicated the dietary modifications had no significant impact on P runoff from the plots.

In studies utilizing ruminant-derived rendered byproducts Drewyor and Waldroup (1998) determined broilers could use meat and bone meal at levels up to 20% of the diet with no adverse effects, however, fecal P output was greatly increased. In other studies undertaken to evaluate the P needs of broilers at different ages in the presence or absence of phytase for birds up to six weeks of age, the recommendations of the NRC appear adequate in the absence of phytase, and can be reduced approximately 0.1% with phytase supplementation.

Recent studies by Denbow *et al.* (1998) have characterized the recombinant phytase produced from soybean tissue culture cells and found the biochemical characteristics were similar to fungal phytase. Soybeans expressing the recombinant phytase were used as a supplement in poultry diets to compare with commercial fungal phytase (Natuphos) in feeding trials. Both sources of enzyme were equally effective as supplements based on body weight gain, P availability and excretion.

Feed

Many good studies have concluded that properly treated poultry litter and manure nutrients can be recycled into the livestock feed chain. While the cattle industry has adopted this technique in some areas it remains an under utilized opportunity for many ruminant producers. Recent research with weanling goats has demonstrated the feeding of broiler litter as the forage component of their daily ration (Solaiman *et al.*, 1996). Moss (1998) backgrounded Holstein heifers on isocaloric diets based on corn silage or coastal Bermuda grass hay with either broiler litter (BL) or soybean meal to supply 14.5% CP. Including BL with hay depressed dry matter intake, but did not affect intake on the corn silage diets. Daily gain of heifers on corn silage with or without BL were 1.21 and .88 kg; corresponding values for heifers on grass hay were .65 and .94 kg. Neither heart girth or wither height was affected by BL additions to the diet.

In a study aimed at increasing the feeding value of broiler litter for ruminants Park *et al.* (1997) mixed sugars and proteins before deep-stacking. Molasses additions improved the digestible energy concentration of moderate to high fiber litter that otherwise might limit dietary levels of litter and animal production. There also appears to be considerable potential to reduce the condensed tannin concentration in feedstuffs by the addition of broiler litter before deep stacking. Typically condensed tannins limit feedstuff utilization because of protein binding and precipitation that interferes with digestion and palatability.

Another option for using hen manure as a feed stock for conversion into earthworm biomass was recently reported by Ndegwa *et al.* (1998). First high-rise manure was composted with wood chips and mechanically turned on a two-week basis. Composting reduced the manure weight 24% and volume 34% compared with deep stacked raw manure over an 8-month period. The ideal stocking density for producing worm biomass was 1.6 kg worm/m^2 at a feeding rate of 1.25 kg compost/kg worm/day, while for the production of vermicompost the same stocking density at a feeding rate of .75 kg compost/kg worm/day was ideal.

Fuel

An old concept with a new application is the use of poultry and livestock wastes as a fuel source. Studies have shown chicken manure to have a fuel value (4,400 BTU/lb) about one third the value of coal (12,800 BTU/lb) and about 2/3 the value of cord wood (6,700 BTU/lb). Government subsidized incineration plants that burn poultry litter are in operation in other parts of the world and are being proposed in the United States as well. Costello and Vories (1998) recently installed a biomass furnace in a broiler house to evaluate different feed stocks for their thermal performance and costs. Pelleted wood, pelleted litter will be assessed as potential fuel sources, while another furnace, which handles loose biomass such as sawdust, or poultry litter will be evaluated in the near future. Another means of harnessing the energy held in poultry wastes is through anaerobic digestion and methane production. Work by Hill *et al.* (1996) indicated the fermentation of livestock waste was improved when a mathematical model of the process included a term for the nitrogen ratio of the feedstocks.

Poultry Mortalities

The volume of poultry mortalities taken collectively from the broiler, turkey and egg industries are significant despite improved health and bird management. Options for coping with these mortalities in a biosecure manner are numerous, yet some have no place in our modern paradigm of recycle without pollution. For these reasons burial and incineration of poultry mortalities will not be considered. However other strategies that seek to return carcass nutrients to either plant or animal systems have a future.

Composting

Composting of dead birds has been a modern revelation that has been widely accepted by poultry companies and growers. Advantages are numerous and pioneering work by Murphy (1988), Malone (1988), Dobbins (1988) and others demonstrated the process.

Recent work by Keener (1997) studied composting of poultry, dairy and swine mortalities to determine the effect of body size on composting time. An equation using body weight to the ½ power was found to estimate required composting time. Results have led to a “unification” theory on design and operation of facilities for composting animal mortality.

Feed Ingredients

Both chemical (NaOH) and enzymatic methods were evaluated to remove feathers from hen carcasses and combined with fermentation as a means of chemically preserving the carcasses and feathers without refrigeration (Kim and Patterson, 1999). Results indicated both NaOH and enzyme treatments were capable of solubilizing feathers and improving pepsin digestibility. Protein and amino acid concentration was diluted compared to conventional poultry byproduct meal because of carcass fat that is normally rendered off separately. Estimated annual cost savings were greater compared to conventional carcass storage, pickup and rendering.

Phosphoric acid preserved mortalities are being explored for biological safety and nutrient quality. Processing options include rendering, extrusion and fluidized-bed cooking/dehydration (Beasley and Classen, 1998).

In an economic evaluation of dead-bird disposal systems Crews *et al.* (1994) compared existing and emerging technologies. Existing technologies included disposal pits, incineration and large-bin composting. Among these disposal pits were the least expensive per lb of carcass, followed by composting then incineration. Flock size had little impact on pit disposal costs (approximately $0.04/lb) but composting costs dropped considerably when flock size reached 200,000 ($0.0392/lb). Emerging Technologies included small bin composters, fermentation and refrigeration. Among these composting was the least expensive followed by fermentation and refrigeration. Fermentation cost was greatly influenced by flock size dropping to only $0.0340/lb with a flock of 200,000 birds.

Poultry Processing Waste Management and Recyling

Although many byproducts of poultry processing have been effectively recycled to livestock and poultry feeds, others either remain to be recycled or conventional options are not as practical as they once were because of socio/economic forces.

Feathers

New and alternative uses for poultry feathers are imperative to effectively utilize the more than two billion tons of feathers generated annually. Options include a patented separation process that generates feather fibers that can be utilized for multiple purposes (Wright, 1997). Thick (felt) and thin filter papers generated from feathers could be used to filter air, certain metals, and as decorative paper. Quill fractions can be mixed with resins to make a fiberboard. Baby diapers generated from feathers appear to have equal absorbency with less weight than existing diapers.

Better utilization of feather keratin has been demonstrated with a keratinase from Bacillus licheniformis (Carter and Shih, 1997). Scaled-up fermentation to maximize enzyme production resulted in a 10-fold increase in keratinase production (Shih and Miller, 1997).

Feather meal and various other protein supplements have been compared as feed supplements for dairy calves. Holstein heifers fed starter diets with either soybean meal or feather meal plus soybean meal with or without a yeast culture had the equal gain (0.72 - 0.78 kg/d) from birth to 14 wk of age (Moss, 1998). Studies such as this demonstrate the merits of recycling byproduct feeds into livestock rations.

Dissolved Air Flotation (DAF) Biosolids

Strategies for DAF biosolids management are numerous and include composting (Carr, 1994) and land application (Freiss and Beetschen, 1994). Biosolids from poultry processing including DAF have potential as feed ingredients based on chemical analysis of their nutrients. Maurice (1998) evaluated the non-fat fraction of poultry processing solids precipitated with iron at 0, 2 and 4% in the diet of breeder hens over a 4-month period. Hen egg production and hatchability was not impaired by these diets. Broiler chicks hatched from eggs produced by the same breeders were grown to market age on diets of 0, 2, 4, and 8% non-fat DAF biosolids. Broiler performance at 7 weeks was slightly depressed at the highest 8% level. However, serum and organ minerals were not impacted by the dietary treatments. Others have also demonstrated that DAF byproducts can be included in broiler diets at levels less than 7% to enhance dietary nutrients while serving as an avenue to recycle these processing byproducts (Smith *et al.* 1997).

Hatchery Waste

Composting of hatchery waste has been demonstrated by Malone (1988) and Carr (1992). Fermentation technologies were utilized by Deshmukh and Patterson (1997 a,b) with hatchery waste to preserve the nutrients and generate two potential feed ingredients. Crude protein (CP) and energy concentrations of tray waste and a combination of tray waste/cull chicks from a Leghorn hatchery were 29.8% CP, 2696 kcal/kg and 41.5% CP and 3520 kcal/kg respectively. The two ingredients were extruded and dried, then mixed into the diets of broiler chickens at 2.5, 5.0 and 10%. Broiler performance and parts yield on the diets with hatchery by-products was equal or greater than the control fed.

Shell Waste

Egg processors are challenged to dispose of 120,000 tons of eggshell annually in the US, while some companies are spending more than $100,000 per year to move the waste to landfills. This is not a sound or long-term solution. A new patent pending process that cuts the shells and membranes at tremendous speed creates two useful products that can be sold instead of hauled away for trash (MacNeil, 1999). The shell membranes contain 10% collagen. As a biomedical product raw collagen has excellent demand in the production of skin graft and tissue replacement products, dental implants, angioplasty sleeves and for cornea repair. Purified collagen is now selling for up to $1000 per gram. The clean eggshells can be used as a paper pulp substitute, or as a feed supplement for livestock.

CRITICAL REVIEW:

Objective 2: Determine Water Quality Factors That Affect Poultry Performance and Market Product Quality

Overview

Poultry farms may use water from municipal sources (potable for humans), from wells, streams, ponds, lakes, rainfall catchments, and springs. Because of its very nature of potential hydrogen bonding, water is an excellent solvent for both inorganic and organic substances. For this reason, water is an ideal medium for the proliferation and distribution of harmful components such as chemical elements and microorganisms. Quality of surface and ground water depends upon the naturally occurring inclusions such as cations, anions, heavy metals and inadvertent inclusions such as pesticides, herbicides and wash off of excessive organic or inorganic fertilizers, and microorganisms.

Drinking water is of concern to poultry producers due to its great variability in quality and its potential for contamination. Naturally occurring surface and ground waters always contain inclusions ranging from low to very high concentrations. Water quality is characterized by its taste, acidity, alkalinity, odor, color, turbidity, salinity, electrical conductivity, pH, biochemical oxygen demand, hardness, presence of anions, cations, herbicides, pesticides and bacteria. Water inclusions contribute to the diet of chickens, having either nutritional, anti-nutritional, toxic, or infectious properties. Dissolved inclusions and additives are generally considered to be more readily available for absorption. High quality drinking water may be defined as water which contains inclusions which promote vitality and lack inclusions causing morbidity and mortality. As the volume of non-drinkable water increases and the technology for measurement of inclusions improves, we are becoming increasingly aware of water inclusions and their effects on health and nutrition. It is important that we discover the effects of water inclusions, both naturally occurring and supplemental, on the performance of poultry and that we precisely define “high-quality” drinking water.

Drinking water inclusions can affect the quality of poultry meat and eggs. Water inclusions can discolor poultry products, particularly eggs. Toxic substances can build up in fat and muscle tissues and hens can export toxic substances into eggs. Variations in water quality and management practices (water treatments, additives, and delivery devices) have the potential to influence the health and productivity of poultry and the quality of retailed poultry products. Poultry products are required by law to be washed or rinsed with potable water. Often cleaners and disinfectants are added to improve food safety. Wash and rise waters must be handled to avoid environmental pollution.

Effects of naturally occurring water inclusions on poultry performance, health, and product quality

Water is an essential nutrient required for the absorption of food nutrients, nutrient transport, waste excretion and thermal regulation (Scott *et al.*, 1982). Chickens obtain water through ingestion of drinking water, from moisture in their feed and from biochemical reactions during utilization of carbohydrates, fats and proteins. Chickens require a constant supply of high quality water for optimum growth, production and efficiency of feed utilization (Scott *et al.*, 1982). It is usually concluded that the best water is pure water, however, the best tasting water for birds, man and other animals often contains small amounts of carbon dioxide dissolved in the water (Dawes, 1968). Water and feed consumption patterns are closely related with a much reduced feed intake during water abstinence (Sykes, 1983; Savory, 1978; Duke, 1986). This relationship deteriorates during high ambient temperature when additional water is needed for thermal regulation (Scott, 1982; Duke, 1986).

Poultry producers are interested in the beneficial effects of inclusion in water as well as detrimental effects. Many times, birds of the same genetic stock consuming the same batch of feed under the same management conditions have markedly different production results (Zimmermann, unpublished data). This has led to the speculation that the production of poultry is also associated with the quality of water.

Early drinking water research utilizing poultry (reviewed by National Academy of Sciences, 1974; Council for Agricultural Science and Technology, 1974; Coulston and Mrak, 1977; Roland, 1977) was concerned with inadvertent contamination, total dissolved solids (TDS), pH, and nitrate. Salinity and conductivity are used synonymously with TDS. An upper level of 3,000 ppm TDS was suggested NRC (1984) but Mulhearn (1957) and Olson *et al.* (1959) suggested 4,000 ppm TDS as the upper safe limit.

Hardness is a tendency to precipitate soap and form scales on heated surfaces. Temporary hardness is due to presence of calcium and magnesium bicarbonates. Permanent hardness is caused by calcium and magnesium sulfate. Hardness is a problem in plugging up watering devices. Sodium and potassium produce no hardness. Water softeners remove hardness but not TDS. The suggested association of hardness with fatty liver syndrome in laying hens could not established experimentally (Jensen *et al.*, 1977). Gardiner and Chernos (1981) observed increased watery droppings, leg deformities and poor egg shell quality on farms with exceptionally hard waters. Atteh and Leeson (1983) supplied calcium or magnesium carbonates (up to 100 ppm) to broiler chicks for 3 weeks and found magnesium to improve feed efficiency but increased leg abnormalities. Calcium had no such effect.

Natural waters have a pH of 4 to 9. Water intake of poultry is not influenced in a pH range of 2 to 10 (Fuerst and Kare, 1962). However, waters beyond a pH range of 6 to 9 can be corrosive for metallic equipment.

The effects of nitrate nitrogen on poultry health are not well defined. Ten ppm nitrate nitrogen is the highest level allowed in human drinking water, but poultry may have a higher tolerance. Chickens, turkeys (Adams et al., 1966), and Japanese quail (Adams, 1974) can tolerate 300 ppm nitrate nitrogen in water. In presence of 9,500 IU vitamins A/kg diet, chicks tolerated 200 ppm nitrite nitrogen (Adams *et al.*, 1966). Littlefield (1977) reported that 233 ppm nitrate nitrogen was tolerated by broilers, a level of 466 to 933 ppm caused a growth depression, and 1,867 ppm was lethal.

A number of reports are available on the effect of salt (NaCl) solutions on production parameters of poultry. With the normal amount of salt present in diet, a level of 4,000 ppm salt in water caused watery droppings in chicks, turkey poults and ducklings (Krista *et al.*, 1961). It also decreased feed intake, growth rate, and increased mortality. Connor et al, (1969) observed reduced growth of chicks at 0.56% salt in water. Sherwood (1975) and Wideman and Nessley (1992) suggested differences in strains of laying hens to tolerance of salt in water. Supplementing the drinking water of laying hens with sodium chloride significantly increased egg shell defects, and reduced shell quality. Hens receiving 0.05% to 0.5% salt in water for 7 weeks had a very poor shell quality, but dietary levels of 2 g salt per kg diet had little effect (Balnave and Scott, 1986; Balnave and Yoselewitz, 1987; Yoselewitz and Balnave, 1989a, 1989b; Balnave, 1993; Moreng, 1992).

More research is needed to evaluate relative uptake of nutrients in the water vs. in the feed. Sodium dissolved in water is better utilized than from solid feed (Ross, 1979). Ward *et al.* (1994, 1995) reported that some forms of copper were more available when delivered in water and feed in turkeys. Damron and Flunker (1995) added calcium lactate in the drinking water of laying hens to increase total dietary calcium by 0.2% and reported improved egg shell quality.

A solution containing 1,000 ppm sodium bicarbonate was not toxic to turkey poults, but on containing 3,000 ppm did cause edema and death. Solutions containing 7,500 ppm sodium citrate, iodide, carbonate and sulfate caused edema and death in poults (Scrivner, 1946).

Sulfate solutions with less than 18,000 ppm magnesium sulfate had no adverse effects on turkeys (Kienholz, 1966). A solution containing 12,000 ppm sodium sulfate reduced egg production of chickens to about the same extent as one containing 10,000 ppm magnesium sulfate (Krista *et al.*, 1961). Solutions containing 1,000 ppm of sodium or magnesium sulfate are well tolerated by hens. Magnesium sulfate (4,000 ppm) solution reduced egg production to about 15% and decreased water intake, but an equivalent concentration of sodium sulfate reduced egg production to about 76% and increased water intake (Adams *et al.*, 1975).

Barton *et al.* (1986) analyzed drinking water samples from 300 broiler farms in Arkansas and correlated the results with broiler growth performance parameters reared on those farms. Their results demonstrated that elements in the water had significant ($P < .05$) correlation (r) to feed conversion (magnesium positive r; calcium negative r), body weight (dissolved oxygen, bicarbonate, hardness, and magnesium positive r; nitrate negative r), livability (calcium and potassium negative r), and condemnation (calcium and nitrate negative r). Barton *et al.* (1986)

suggested growth performance was related to the aggregate of elements in the water as well as high or low levels of specific elements. This was supported by Zimmermann *et al.* (1991) when an experiment with elevated dissolved oxygen in the water failed to improve broiler body weight.

Zimmermann *et al.* (1993) conducted a study similar to Barton *et al.* (1986) using data from 60 broiler farms in Washington state. The water inclusion profiles from Arkansas and Washington farms had major differences. These differences resulted in different elements affecting broiler performance parameters. The results from Washington state indicated that feed conversion was positively correlated with sulfate and copper concentration in the drinking water while livability was positively correlated with potassium, chloride, and calcium. In this study the measured water inclusions had no effect on body weight or percentage condemnation. The effects of water inclusions on broiler performance variables in Arkansas did not agree with the results from Washington.

Zimmermann and Douglass (1998) evaluated the effect of drinking water inclusions from 49 wells on broilers performance parameters on Delmarva. Elevated potassium, hardness, and conductivity in drinking water improved feed conversion (negative r); mortality decreased as magnesium, potassium, hardness and conductivity of broiler drinking water increased; postmortem condemnation was decreased with increased magnesium, sodium, potassium, hardness, conductivity, phosphate, pH, and conductivity.

The effects of water quality on growth performance probably are not caused by single elements but rather by a combination of elements (Barton *et al.*, 1986; Zimmermann *et al.*, 1991, 1995, 1998; Grizzle *et al.*, 1996, 1997a, 1997b). Grizzle *et al.* (1996) demonstrated the combined effects of drinking water nitrate-N (3.55 or 5.19 ppm) and low pH (5.75) adversely affected broiler performance. Grizzle *et al.* (1997a) presented data showing that low levels of nitrate or coliform bacteria did not affect broiler performance but when combined broiler performance was impaired. Zimmermann (unpublished data) observed that when toxic levels of nickel and chromium were both present in broiler drinking water, growth performance equaled that of untreated control birds. El-Begearmi *et al.* (1977) observed a mutual protective effect of mercury and selenium when fed to Japanese Quail. Jensen (1975) reported that selenium toxicity in chicks could be alleviated with silver. These examples suggest that combinations of inclusions in drinking water can affect broiler performance.

Zimmermann and Douglass (1998) used SAS®, Inc. (1988) rank regression analysis (Proc min) to evaluated the relationships between multiple inclusions in addition to simple correlation analysis used in prior research (Barton *et al.*, 1986; Zimmermann *et al.*, 1993, 1995). Body weight was positively influenced by age, drinking water hardness, pH, dissolved oxygen, and was negatively influenced by total aerobic bacteria number (TB). Feed conversion increased with age and TB, but was reduced by higher potassium levels in the drinking water. Mortality increased with age and drinking water nitrate but potassium decreased mortality. Post mortem condemnation was increased with age and drinking water TB, but was reduced with elevated potassium and pH. The results of the multi-element regression analysis indicated that TB had an influence on growth performance parameters, in contrast to the individual element correlation analysis where TB did not have significant effects.

Because the levels of water inclusions between Arkansas, Washington, and Delmarva were different, Zimmermann and Douglass (1998) concluded that water quality is unique within regions and that a survey of water quality in each region would be necessary determine the effect of water inclusions upon broiler performance. This conclusion was supported by Hermes and Holleman (1992). They found regional differences in the types and levels of inclusions present in water samples from Oregon broiler, layer, turkey, hatchery, and processing facilities.

Zimmermann and Douglass (1998) suggested that water quality information from many regions, when compiled into a single large database could make it be possible to identify mutual properties in water inclusion profiles. This would enable prediction of broiler performance potential in regard to water quality.

Among 71 Delmarva drinking water samples, 88% were found to contain aerobic bacteria, less than 2% had coliform bacteria present, and E. coli was absent from all but one sample (Zimmermann and Douglass,1998). This compares with 41 and 97% bacterial presence in drinking water on broiler farms in Washington (Zimmermann *et al.*, 1993) and Tennessee (Goan *et al.*, 1992), respectively. Zimmermann *et al.* (1993) also reported 11% of broiler drinking water samples contained coliform bacteria in Washington state.

Effects of drinking water treatment, additives, and delivery systems on poultry performance, health, and product quality

Drinking water is often treated (filtered, softened, acidified, neutralized, disinfected, magnetized, etc.) to improve bird growth performance and to maximize the efficacy of additives. Drinking water is commonly used to deliver additives such as vaccine, medication, and other nutrients. Poultry tend to drink twice as much water, by weight, as feed consumed, thus the quickest method of administering medication is via drinking water. All commercial poultry farms are equipped with proportioners capable of delivering additives into the drinking water delivery system at precise dosages.

Drinking water treatment or additives are done to correct perceived and real problems. Water softening is used to reduce hardness (calcium and magnesium salts) and iron. These elements can interfere with water delivery systems causing water restriction or flooded houses. Hard water reduces the effectiveness of some cleansers and medications. Zimmermann *et al.* (1991) reported that a magnetic water treatment device reputed to prevent scale and improve broiler performance was ineffective.

Many water treatments and additives may alleviate environmental stressors. Dameron (1991) found that cooled drinking water improved performance of laying hens during heat stress. Similar finding were reported for broilers (Beker and Teeter, 1994; Okelo *et al.*, 1998). Bottje and

Harrison (1985) found infusion of carbonated water into the crop of cockerels produced a favorable acid-base balance during heat stress. Odom *et al.* (1985) and Koelkebeck *et al.* (1992, 1993) observed a favorable effect on egg shell quality by providing laying hens with carbonated water during heat stress. Broilers provided carbonated drinking water had improved livability and feed conversion (Smith and Teeter, 1993; Okelo *et al.*, 1998). Iwasaki *et al*. (1997) reported broilers that consumed a solution *ad libitum* from 35 d of age, had significantly lower mortality due to heat stress and higher live weight gain than birds drinking tap water. The 4% glucose-water treatment reduced rectal temperature, and prevented the decrease in whole blood viscosity, and plasma osmolality associated with high temperature stress in broilers (Zhoa *et al*., 1998)

There is increasing interest in disinfection of drinking water delivered to chickens. Disinfection of drinking water would be a critical control point for control of human pathogens in an on-farm Hazard Analysis Critical Control Point (HACCP) food safety program. Drinking water is readily disinfected by chlorination, iodination, ultraviolet light, and ozone treatments (Wagenet *et al.*, 1995). Chlorination and iodination are commonly used to disinfect drinking water on poultry farms. Dameron and Flunker (1980) reported sodium hypochlorite reduced of water consumption in hens and broiler chicks at 40 and 100 ppm, respectively. Murphy *et al.* (1987) reported that 2 ppm sodium hypochlorite would reduce water intake in broilers.

Drinking water systems are of great interest because they deliver the most important nutrient, water, to the birds. Water systems have evolved from jugs to troughs to hanging bell-shaped drinkers to cup drinkers to enclosed nipple drinking systems. Wabeck *et a*l. (1994) reviewed the development of nipple drinker systems and reports a potential for lower carcass weight during Summer months. May *et a*l. (1997) reported water consumption from nipples was often similar to that from bell waterers during the low temperature but was less during the periods of high temperature largely because panting broilers have difficulty drinking from high nipple waterers. All systems are subject to clogging, dripping, and microbial contamination, all of great economic importance. Much research will be performed to identify superior water systems as they continue to evolve.

Additives or contaminants in drinking or processing water that affect poultry product quality

Water additives used during growout and processing can affect nutritional quality, safety, and shelf life of meat and egg products. In some instances these additives and processing residues become part of the waste stream. Hauser and Hill (1981) showed that some egg washing soaps were more biodegradable than others. Shih and Kozink (1980) were able to recover and recycle protein by filtration of processing waste water.

The HACCP food safety system is mandatory in processing facilities and requires that carcasses be free of fecal material. Rust particles on poultry carcasses have been mistaken for fecal material and condemned (Hess, personal communication). Occasionally iron or rust in pipes can cause surface discoloration on poultry products. HACCP programs have greatly increased the volume of fresh water that must be used during slaughter and research is needed to identify methods to reduce water use.

The HACCP inspection system will drive much research in the future and potable water will be a key factor in this research. The timing of feed withdrawal prior to slaughter is important to prevent fecal contamination and many reports have focused on the issue in both broilers and turkeys (Wabeck, 1972; Summers and Leeson, 1979; Duke *et a*l., 1997). Several reports have indicated that addition of lactose to the diet or drinking water reduces *Salmonella* colonization in the lower intestine of chicks, molting laying hens (Corrier *et a*l., 1991, 1992; Hinton *et a*l., 1990; Ziprin *et a*l., 1990). However, Barnhart *et a*l. (1999) reported lactose had little effect on crop and cecal *Salmonella* in broilers following feed withdrawal.

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