Converting Food-Animal By-Products into Value-Added Products: The Animal and Poultry Waste Management Center at North Carolina State University

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INTRODUCTION

Food-animal related agribusiness in the United States has for several years accounted for annual revenues exceeding $80 billion. In North Carolina, food-animal industries represent a critical component of agribusiness accounting, in 1993, for approximately $3.5 billion, or nearly 60 percent of the state's farm-gate income. Both nationally and in North Carolina, food-animal related industries have grown tremendously during the past two decades, and they are expected to continue to grow at a rapid rate in coming years. The size and magnitude of these industries results in the production of tremendous quantities of by-products or what are often referred to as wastes. These by-products include: manures and litters, hatchery by-products, feathers and hair, animal mortalities, processing offal and processing waters containing environmental compounds of regulatory concern. When not properly managed, these by-products can potentially result in odor problems and/or the the contamination of ground and surface waters by nutrients, other compounds, and pathogens. These environmental concerns have resulted in various federal, state, and local regulations that focus on waste minimization, on-site waste recovery and recycling to replace land application as the predominant method of waste disposal. Considering the current regulatory focus on agriculture, there is little doubt that the future growth and economic stability of the agricultural food-animal industries will be affected by their waste management and co-product utilization practices.

The College of Agriculture and Life Sciences (CALS) at North Carolina State University (NCSU) has initiated a "Center" to expand on research needs for improved treatment and management procedures for converting manures, litters, and processing wastes into aesthetically acceptable and economically valuable products. This program, currently under establishment as the Animal and Poultry Waste Management (A&PWM) Center, provides the infrastructure to evaluate alternative waste management procedures and the development of co-products. The A&PWM Center provides the means to evaluate waste management technologies beyond the laboratory bench on a pilot or commercial-scale basis. Interdisciplinary, broad based, and cooperative research by industry, universities, and government agencies to address short and long term waste management needs of the food-animal agriculture industry is the primary focus of this program.

ANIMAL AND POULTRY WASTE MANAGEMENT - AN OVERVIEW

An overview of current waste management practices utilized by agricultural food-animal industries illustrates the need for alternative waste management technologies. Most manures and litters are currently being applied either in the raw form or as compost to crop and pasture land in the areas where they are being produced. In some cases, concentrated animal units now produce more nutrients than can possibly be utilized by the crops being grown in the local area. Over application of such materials can result in the contamination of ground and/or surface waters by nitrates, phosphates, other chemicals and pathogens. In other cases, manure is collected in lagoons where naturally occurring bacteria, primarily anaerobic species, are used to break down and reduce the

amount of waste produced. The liquid from these lagoons is often pumped onto nearby land for potential fertilizer value.

Most hatchery by-products (shells and unhatched eggs) and animal mortalities (especially for poultry and young swine) are currently buried in pits onsite or are disposed of in sanitary landfills. Both practices are likely to be banned or heavily regulated in the near future. Therefore alternatives must be developed to manage and beneficially use these valuable by-products.

Over the past few years, some poultry enterprises have begun utilizing the natural biological process of composting to handle their animal mortalities. Mortality composting utilizes a mixture of the dead animals, manure and materials such as straw, sawdust, leaves, grass, corn stover, peanut hulls etc., to provide the carbon and nitrogen needed to allow the bacteria to grow, utilize and break down the animal carcasses. This process provides an effective low-cost alternative for disposing of animal mortalities in an environmentally safe manner. However, the product is almost always land applied.

Carcasses from large animals (beef, dairy, swine, horses, etc.) have for many years been rendered and returned to the animal food chain. Due to the small amount of mortality which generally occurs on a daily basis on poultry operations, it is often not economically feasible for those operations to transport their mortalities to the renderer. Thus, alternative systems need to be developed and demonstrated which will allow on-farm preservation and storage of the preserved carcasses so that larger quantities can be collected and transported to rendering, drying and/or extrusion facilities for conversion into animal feed-grade meals.

Offal from food-animal processing plants has for many years been sold to rendering plants for conversion into feed-grade meat, bone and blood meals. Feathers, another major by-product of poultry processing plants, are often hydrolyzed and converted into feed grade feather meals. Research has identified other processes which appear to be economically viable and better alternatives such as acid fermentation, fluidized bed drying, extrusion, and treatment with newly developed enzymes. These alternatives have been introduced over the past few years, but they need to be scaled up and possibly modified so they can be demonstrated to be economically feasible and viable, if they are to become adopted by the animal industries.

Tremendous amounts of water (500,000 to 1 million gallons/plant/day are not uncommon) are used in food-animal processing plants. The waste water from these plants must be treated and purified before being released. Such waste waters contain large quantities of blood, fat and protein. Dissolved air flotation (DAF) is a common process which is used to remove these materials as sludge, with the aid of flocculants. The DAF sludge is extremely difficult to handle with little nutritive value. Therefore, it is often dried in a press and land applied. Improved and economically-viable methods for separating these materials from processing waste waters need to be developed to enhance purification and recovery of these by-products.

THE ANIMAL AND POULTRY WASTE MANAGEMENT CENTER FACILITIES

The A&PWM Center facilities are to be housed on approximately five acres at the NCSU's Agricultural Field Laboratory, located south of the NCSU Campus on Lake Wheeler Road. Two buildings (a 70 feet X 100 feet waste processing equipment building and a 36 feet X 140 feet composting building) will house the equipment necessary for research, development, and demonstration of advanced waste management technologies. Capital waste conversion equipment available for research utilization includes extruders, a fluidized bed dryer, cooler, roaster, mixer, screw press, and pellet mill. In addition, NCSU's poultry, swine and cattle research units, located on adjacent property, will supplement the A&PWM Center facilities. These units are equipped with grow out facilities and standard feed mill equipment such as ribbon mixers, pellet mills, scales, bagging equipment, and meat grinders. Collectively, these facilities will provide the infrastructure for the continued evaluation of innovative alternatives for animal waste management.

The design of the waste processing building and the compost building incorporate some unique aspects that are not encountered in similar facilities. Because the facilites are designed for pilot scale research, the facilities must be dynamic to accommodate process modifications. Therefore, the facilities had to be designed in such a

way that equipment could be added or deleted for different operations or experiments. Some of the unique features of these facilites are presented below.

The waste processing building is sized for additional equipment and overhead doors are provided for replacing or adding equipment. A laboratory within the waste processing building is designed to be a functional analytical laboratory but serve as a field classroom for students or visiting groups of professionals. Because of potential pathogens and odors associated with the animal wastes, the waste receiving portion of the building is segregated from the process portion. The existing topography of the site was used in providing access to two levels. The building frame also had to be sized to accommodate proposed equipment to be mounted on the roof and suspended from the frame. Trench drains that drain to an onsite lagoon provide a means of collecting wash down water for anaerobic treatment prior to spray irrigation at the site. These are some of the unique features built into the design of the waste processing building.

The compost building is designed to accommodate various types of wastes and processes. It is essentially a pole building with a concrete slab. Researchers will be able to utlize various sizes of bins, piles, or rows with various by-products targeted for composting. This flexibility allows for a much broader range of research to be conducted. This facility can also be expanded by adding similar structures adjacent to the planned building.

ANIMAL & POULTRY WASTE MANAGEMENT OBJECTIVES

The A&PWM Center will be addressing all aspects of food-animal waste management including manures and litters, hatchery wastes, processing wastes, and other related by-products. The primary goal will be to convert food-animal industry by-products, which have normally been considered wastes, into value-added products. The specific objectives for the A&PWM Center are:

1. To provide a modern facility and associated equipment (i.e., the infrastructure) for carrying out research and extension educational activities on the management and utilization of food animal waste products; and, for the development of economically and environmentally acceptable procedures for conversion of these wastes into value added products for the food producing animal industries. Once developed, many of these procedures will undoubtedly be adopted by the food animal industries nationwide and around the world.

2. To provide personnel to operate the facility and its equipment on a daily basis and to work with the faculty and industry groups in carrying out the research and extension educational activities.

3. To provide the infrastructure which will allow participating scientists to be successfully competitive for individual and multi-disciplinary research funding on a national basis in the waste management arena.

4. To provide the national and world food animal-producing industries with economically feasible and safe alternatives for handling and recycling by-products produced by these industries in the course of food production.

5. To facilitate in-service training in new technologies for waste management for extension agents, agricultural agencies, waste management system operators, agribusiness, and other technology-user groups.

It is anticipated that this overall project will result, over time, in the development of new and innovative environmental resource technologies. The approach is multidisciplinary and will include not only research and development but a broad and varied education and training program.

THE ANIMAL AND POULTRY WASTE MANAGEMENT CENTER CONCEPT

The A&PWM Center is more an organizational concept than a facility. To efficiently and effectively address the waste management requirements of the various food-animal industries, a broad based and

interdisciplinary participation into the A&PWM Center activities is needed. The A&PWM Center has, therefore, established an operational structure in which NCSU, industry, commodity groups, other universities and government agencies may form a partnership to address the agricultural food-animal waste.management research area.

RESEARCH UNDERWAY AT THE ANIMAL & POULTRY WASTE MANAGEMENT CENTER

To illustrate the types of projects that are currently supported by the A&PWM Center, research projects that are under way are summarized below. Researchers and their affiliations are provided to illustrate the multi-disciplinary approach.

Development and Demonstration of a Fermentation Preservation System for Converting Poultry Mortality and Sweet Potatoes Into Added Value Products. P. R. Ferket (Poultry Science), L. F. Stikeleather (Biological & Agricultural Engineering), J. L. Grimes (Poultry Science).

The poultry and sweet potato industries currently produce wastes or co-products that are not recycled and/or have the potential of contributing to environmental pollution, public nuisance odors, or the spread of diseases. The objective of this project is to further delineate recycling pathways for waste or co-products of these two industries. Through this investigation, the use of fermentation and extrusion technologies will be developed to reduce the potential waste stream into the environment, further delineate recycle pathways for poultry and crop co-product material, develop alternative feed ingredients for the poultry industries, and provide an alternative on-farm system for handling poultry mortality.

Separation of Turkey Litter to Enhance its Value as a Cattle Feed Ingredient. J. L. Grimes (Poultry Science), R. W. Harvey (Animal Science), M. H. Poore (Animal Science), B. A. Hopkins (Animal Science), J. T. Parsons (Duplin County Extension), J. M. Rice (Biological & Agricultural Engineering), R. V. Melton (Sampson County Extension), M. E. Regans (Wayne County Extension).

Research has indicated that turkey litter may be inferior as a cattle feed supplement when compared to broiler litter which has been utilized successfully as a cattle feed supplement. However, it has been demonstrated that broiler litter can be separated into fractions with some fractions having increased nutrient content which may enhance poultry litter value as a cattle feed supplement or plant fertilizer. During this project, turkey litter will be separated into fractions in order to enhance its value as a cattle feed supplement. Subsequently, pilot litter separators will be utilized to determine the best method and type of unit for separating turkey litter. These units include a shaker unit, a rotary drum unit, and a fluidized bed unit. A working model is planned for construction to generate enhanced litter fractions for a cattle feeding trial. This unit will also serve as a unit for on-farm demonstrations for the turkey industry.

Biofilter for Removing Odorous Compounds in Exhaust from Swine Buildings. P. W. Westerman (Biological & Agricultural Engineering), J. C. Barker (Biological & Agricultural Engineering), R. W. Bottcher (Biological & Agricultural Engineering), J. J. Perry (Microbiology), L. F Stikeleather (Biological & Agricultural Engineering).

Odor from swine production facilities has become a critical factor in the continued production of swine in large confinement facilities. A technology that may be economically adapted to many swine buildings is the use of biological filters to microbially oxidize odorous compounds. This research is an evaluation of pilot-scale peat biofilters to treat exhaust air from a swine building (finishing floor with pits) at typical ventilation rates for North Carolina swine houses. Initial treatments are various inoculants for the biofilter: (1) bacteria from soil near a swine building, (2) cultured *Thiobacillus thioparus* bacterium, and (3) no inoculation, with two replications each. After the initial inoculant evaluation, the best inoculant treatment will be used for evaluating two or three different residue times (air flow rates). Removal of odorous compounds would be evaluated by: (1) taking air samples for analysis by gas chromatography, and (2) taking quantitative readings with an "Odor Monitor" (commercial sensor of "relative odor").

Development and Demonstration of an Integrated Wastewater and Processing Waste Management System for Trout Production. J. E. Shelton (Soil Science), J. M. Hinshaw (Zoology).

Existing and impending regulations for discharge water from trout producing farms, the handling of processing waste, and morts require the development of systems of waste management for this unique industry. This project is an endeavor to develop a system for removal of trout manures from raceway waters to assure compliance with regulations for discharge waters, and to manage processing waste. The first and second phase of the project involves the development and evaluation of a research filter/composting system and the construction of a commercial system on an existing trout farm in Transylvania County. The chemical and physical properties of the compost will be studied and crop response to media using the generated compost will be evaluated. This is a cooperative project with NCSU personnel and the Departments of Soil Science and Zoology and the Tennessee Valley Authority.

A System for Development of Value-Added Products from Swine Manure and Peanut Shells. E. E. Jones (Animal Science), J. C. Barker (Biological & Agricultural Engineering), P. W. Westerman (Biological & Agricultural Engineering), J. J. Perry (Microbiology), J. 0. Garlich (Poultry Science), E. V. Caruolo (Animal Science), S. L. Warren (Horticultural Science), W. C. Fonteno (Horticultural Science)

The swine industry in North Carolina has grown continuously in the past two decades, and many changes in production facilities and methods have taken place. With the development of large corporate organizations and contract grower facilities at multi-site locations, there has been a simultaneous increase in production of swine manure and high-nitrogen or high-nutrient content lagoon water. Another agricultural commodity in eastern North Carolina which generates a very large amount of waste material is peanuts. This crop yields several hundred thousand tons of peanut shells which are a waste product that is high in carbon content. A very small percentage of these shells is used for ruminant feedstuffs, and some shells are being used as a source of fuel for electricity generating plants. Neither of these uses of peanut shells is entirely satisfactory as a solution for disposal of this by-product material. The availability of swine manure with its high organic nitrogen content and the availability of peanut shells with high carbohydrate content provide two agricultural by-products which have potential of being mixed together to develop a consistent mixture for a composting process that would product a value-added product for animal nutrition in the form of an alternative source of protein and energy for animal feeds as well as a fertilizer or soil amendments for horticultural and crop production. This multi-year project involves the development of a system which can produce consistent materials to be used in value-added products for animal feeding and horticultural purposes. The first year focuses on development of a system to compost swine manure and peanut shells to a consistent product, and testing the physical and chemical properties of these materials for animal feeds and horticultural uses. The second year will take materials produced under different formulations and test them as value-added products in feeding and plant growth trials. The third year will study the feasibility of transferring the technology and composting protocol of the proposed in-vessel system to alternative systems, such as windrows, static piles, etc. for on-farm or co-op use without sacrificing product quality.

Deep-Stacked Broiler Li tter as a Protein Supplement for Dairy Replacement Hei fers. B. A. Hopkins (Animal Science), M. H. Poore (Animal Science)

Broiler litter has been successfully used in rations for beef cattle for many years. Although there has been concern in the past about heavy metal and drug residues as a result of feeding litter, research has shown that this is of little concern. More recently, there have been questions about the possible presence of pesticide residues in litter as a result of darkling beetle control programs. This project will evaluate the pesticide usage practices of the broiler industry and evaluate litter for the presence of residues. Once the residue potential is better understood, representative litter will be obtained and analyzed for residues. The litter will be evaluated in a feeding trial with dairy heifers during a 112 day growing trial. Econcmic value of the deep stacked litter will be determined in the various diets studied. The information from this project will be used to develop better recommendations for dairy producers desiring to feed deep stacked litter to growing heifers.

Optimizing the Proteolytic Degradation of Animal By-Products. E. S. Miller (Microbiology), J. C. H. Shih (Poultry Science).

Keratin is the principal constituent of feathers, wool, and hair and is refractory to proteolysis by most of the well-studied proteolytic enzymes (proteases). The amino acids in these stable, animal structural proteins comprise a significant mass of the by-products generated through intensive animal industries. Proteinaceous wastes represent both potential environmental pollutants and potential value-added products. When properly treated, hydrolyzed protein by-products can be used for nutritional supplements in animal feeds. The bacterial strain *Bacillus licheniformis* PWD-1 was isolated by NCSU researchers from a poultry waste digester and shown to hydrolyze feather keratin. A keratinolytic serine protease ("keratinase) secreted by the bacterium has since been isolated and the gene sequenced. Current efforts are focused on understanding and enhancing the enzymatic mechanism of feather keratin degradation, and on the pattern of enzyme synthesis during bacterial fermentation on proteinaceous wastes. This project involves the use of purified keratinase from *B. licheniformis* PWD-1 to study substrate specificity and catalytic parameters in keratin, collagen, and synthetic peptide hydrolysis. Secondly, bacterial fermentations will be carried out on specific animal proteins under various nitrogen, oxygen, and temperature conditions to quantify protease synthesis and release of amino acids into the fermentation broth. Enzyme and gene transcriptional activity will be monitored. These approaches will facilitate genetic modification of protease activity for optimal hydrolysis of animal by-products, for optimal fermentation conditions, and for increased recovery of value-added products from intensive animal husbandry practices.

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