Poultry Manure: The New Frontier for Anaerobic Digestion

by

Sumesh M. Arora*
Director of Strategic Biomass Initiative
Mississippi Technology Alliance
134 Market Ridge Drive
Ridgeland, MS 39157
601-260-2107
sarora@technologyalliance.ms
www.technologyalliance.ms

Mark E. Zappi, Ph.D., P.E.
Dean of College of Engineering
University of Louisiana
Lafayette, LA

John W. Logan
Chairman, Eagle Green Energy
Jackson, MS

Richard L. Vetter, Ph.D., PAS, ACAN
President, Agri-Bio Systems
Elgin, IL

* Author to whom correspondence should be addressed

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Abstract

The science of anaerobic digestion is well understood, but practical applications in animal agriculture are still limited in the United States. Small-scale "gobar-gas" units have been in operation in rural India for several decades and primarily generate gas that can be used for cooking and lighting. Along with hundreds of on-farm systems in Europe, Denmark and Germany also have some very large centralized digesters that take manure from multiple farms. The common thread between most digesters, large or small, is that they use dairy manure, or in some cases swine manure, as the substrate for digestion. A new on-farm digester that came on-line in Spring 2007 uses broiler poultry litter to generate methane that is used to heat the chicken houses and generate electricity. The farmer has an interconnect agreement with the local utility to sell the excess electricity. This digester is located in south-central Mississippi and is considered to be the first on-farm unit of its kind in North America.

Digester developers have largely ignored poultry litter, especially from broiler chickens, as a viable substrate for digestion. However, data show that biogas generation potential from litter is comparable to that of dairy manure, if not better. Broiler litter also poses a significant environmental challenge for U.S. poultry producers in areas ranging from Arkansas – Oklahoma to Maryland – Delaware. Using anaerobic digestion to process litter provides numerous benefits that include energy generation, environmental hazards mitigation, liquid fertilizer generation, and marketable soil amendment solids. Another potentially lucrative revenue stream for the digester owners is the ability to qualify for carbon credits since each ton of methane generated qualifies for 18 tons of carbon credits as per data available through the Chicago Climate Exchange. A cash flow model has been developed that includes various revenue streams and credits and capital and O&M costs that shows a simple payback of less than five years for an on-farm poultry litter digester system.

There is also a growing interest in integrating large-scale digesters with ethanol plants as evidenced by a recent project in Nebraska. This is a highly symbiotic relationship where the digester supplies utility-scale gas and electricity to the ethanol plant and receives ethanol process byproducts that serve as co-digestion feedstocks along with the dairy manure. Given the spatial concentration of poultry farms and the relative ease of transporting broiler litter, utility-scale poultry litter digesters will be well suited for such integrated operations.

Introduction

As experts predict that mankind is quickly approaching an age where the production yield and overall inventory of fossil fuels, particularly petroleum and natural gas, have reached a point where they are no longer be a viable energetic resource for meeting societal needs, society must strive to develop an “energetic portfolio” of numerous contributing alternative energetic sources. This need for finding alternative energetic sources actually lies amongst three drivers: home-front economics, national strategic independence, and simple resource availability. Clearly, the time is at hand when development of promising alternative energy sources must be accelerated and the most promising options fully commercialized.

The tide began to turn in favor of anaerobic digesters in early to mid-1990 after a long lull in the 1980s. According to a report published by John Martin (2004) there were three key factors that led to the renewal of this interest in AD technology. It should be noted that all three were primarily environmental drivers as a barrel of crude oil in the late 90’s was less than $20 on average. The shrinking distance between suburbia and farmland meant that the farmers needed cost-effective strategies for reducing manure-related odors from storage facilities, including anaerobic lagoons and land application sites. Another environmental factor was the concern of negative impacts on surface and ground water quality due to livestock and poultry manure runoff. The third and final environmental driver was increasing awareness and concern about global climate change. Methane gas is considered to be 21 times as potent as carbon dioxide in terms of green house gas emissions.

The rising environmental concerns and need for waste stabilization along with the interest in alternative energy sources led to the creation of the United States Environmental Protection Agency’s AgSTAR Program in the 1994. AgSTAR is cosponsored by the US Department of Agriculture (USDA) and the Department of Energy (DOE). Under the leadership of Kurt Roos, the AgSTAR Program has been very successful in encouraging the development and adoption of anaerobic digestion technology. Data from 2002 showed that the number of operational digester systems in the US doubled in the program’s eight years of existence. The fruits of the AgSTAR program produced significant environmental and energy benefits, including methane emission reductions of approximately 124,000 metric tons of carbon equivalent and annual energy generation of about 30 million kWh. Figure 1 shows the status of farm scale digesters in the US as of 2002 (AgSTAR Digest, 2003).

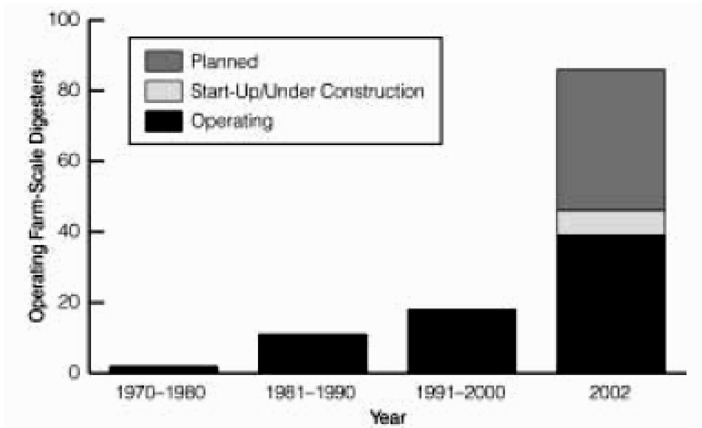

Figure 1: Anaerobic Digester Status in the U.S. as of 2002
(Source: AgSTAR Digest, Winter 2003)

The farming community is feeling the weight of the energetic issues discussed above because they have become manifested in the form of increasing energy costs. Broiler farms in South Mississippi are continuously struggling to remain economically viable within a relatively unstable market due to those economic factors. Traditionally, these farms were receiving minimal profits from the sale of the litter produced that historically approached $10 per ton. Changes in this market associated with the greatly reduced feeding of this material to cattle and increased restrictions associated with regional river-shed nutrient inputs have all but eliminated this small profit line from broiler production income streams. Given the very minimal margin of profitability sometimes experienced by broil farmers, even the loss of this additional profit line may drive the farmers into a negative profitability mode.

Brinson Farms, located near Prentiss, Mississippi, has undertaken a pioneering initiative to convert the litter produced from their broiler raising operations into a feedstock for supporting a profitable “biorefinery” operation to be constructed on-site. This biorefinery will be centered with an anaerobic digester that will produce biogas that will be used to produce electricity using an on-site genset system. This study was performed to evaluate if the residuals exiting the digester could be used to provide additional profit lines. This additional processing and hopefully additional income is targeted to position the proposed system as a true biorefinery producing numerous value-added products.

Production and Characteristics of Broiler Litter

Poultry production in the United States is a multi-billion dollar enterprise, and Mississippi is the fourth largest broiler producing state in the country. Commercial poultry production in Mississippi is the largest agricultural enterprise, producing 850,000,000 broilers per year and over $3 billion in annual sales. The amount of litter produced is also significant, 3.2 billion pounds per year. There is a large potential for commercialization of value added products from broiler litter, especially in the major poultry producing states such as Mississippi, Alabama, Georgia, and Arkansas

Before any real assessment of the potential value of the litter for producing biogas could be performed, a complete evaluation of several samples of litter collected at Brinson Farms was performed by Mississippi State University in partnership with Mississippi Technology Alliance (MTA). It must be noted that Brinson Farms during the time of this analytical characterization had previously initiated a new policy of not adding bedding (historically bedding materials such as primarily wood-based products such as wood chips, sawdust, or used newspaper was added). Brinson Farms in collaboration with Tyson determined that the broilers produced were of acceptable quality (in fact, healthwise they appeared to be raised with less disease problems). Of prime benefit was the lack of bedding amendments which reduced the volume of litter to be disposed. The lack of bedding also reduced bulking within digesters with material that does not digest very well.

The results of this analysis is listed below – note that comments concerning how these data compare to litter traditionally produced with bedding amending are provided as well:

> *Moisture Content: 23% (about the same as most litters)*
> *Ash Content: 22% (this is 40% higher than most litters)*
> *Nitrogen Content: 3% (about the same as most litters)*
> *Phosphorous Content: 1.2% (about half compared to most litters)*
> *Potassium Content: 3% (slightly higher than most litters)*
> *pH: 9.1 (about the same as other litters)*
> *Thermal Value: 5,400 BTUs/# (about 15% less than most litters)*
> *Protein Content: 35% (about the same as most litters)*

The two most intriguing data generated from these analyses are the numbers for ash content and thermal value. Both essentially relate to the potential of using this litter as feedstock for thermal conversion systems, such as combustion or gasification. In the case of the ash content, the increase in ash is believed to be due to the lack of cellulose (wood product) associated with the ceasing of bedding addition to the houses. Hence, the concentration of minerals within the poultry feed is not diluted to produce less ash on a per weight basis (wood products have less ash than feed). Similarly, the thermal energy content of the litter (BTUs/pound) is also reduced over litter having bedding present. Albeit, these data are not dramatically different from traditional litters, they do represent a lesser quality feed for potential input into thermal conversion units.

This difference does not change the potential for digestion. Wood products are composed primarily of lignocellulosic materials, which are not degraded very easily within the deep anaerobic conditions within these units. The lack of bedding only reduces bulking within the digester. By reducing bulk, the mass transfer within the digester will increase and required mixing energies reduced – both of which improves the overall performance of the digester. In laboratory studies conducted at Mississippi State University, which lasted several days, multiple samples of poultry litter from Brinson Farms showed very good biogas yield and activity. Other published data (as shown in Figure 2) also indicate a slightly better biogas potential from chicken slurry compared to cow and pig slurries that are basis for most existing digesters around the world.

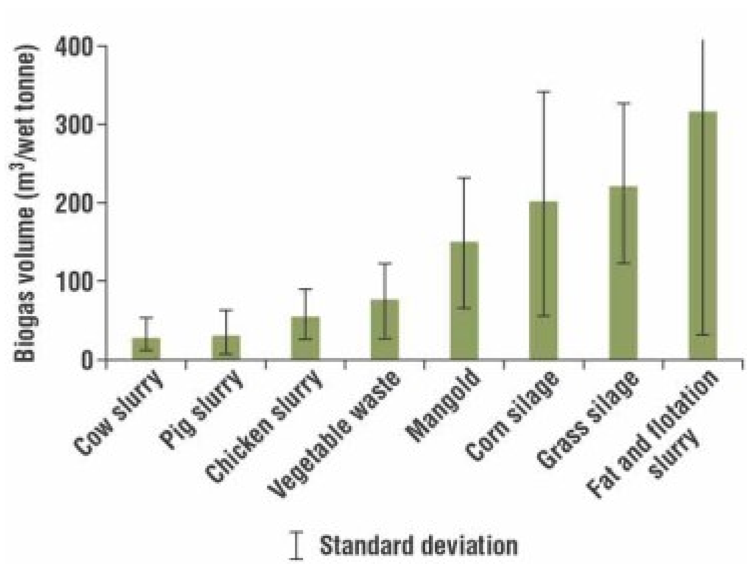

Figure 2: Average biogas yield per metric ton of wet waste for some possible substrates (data shown with margin of error bars) (Source: van den Broek)

Introduction to Digestion Technology

In order to fully understand and appreciate the materials entering and exiting a digester treating litter, the following brief overview of digester operations is presented.

Digester Microbial Processes

The microorganisms within a digester and the organics in the influent are the two main components used in the production of biogas. This gas is primarily a combination of methane and carbon dioxide. This section will focus on the microbiology of these key microorganisms with particular emphasis placed on the biogas-producing organisms.

The degradation of the organic materials within the waste slurries fed into a digester is performed by anaerobic microorganisms. This type of biodegradation process is responsible for many natural processes including the degradation of detritus in swamps and bogs and the digestive systems of termites and large animals. Anaerobic biotreatment is a very popular waste treatment process particularly for high strength wastewaters and some complex organic pollutant of xenobiotic origin. The use of anaerobic organisms, or anaerobes, is popular because they produce little biomass per unit pollutant removed, require small amounts of nutrients, and do not use oxygen as their terminal electron acceptor, which eliminates the need for aeration. These benefits generally all result in pollutant removal costs that are lower than aerobic techniques (biotreatment processes that use microorganisms that do require oxygen). The negative aspects of anaerobic treatment are relatively slow degradation rates and the potential for production of odors via the formation of volatile fatty acids or the conversion of inorganics to volatile by-products, such as nitrogen to ammonia and sulfates to sulfides.

The anaerobic conversion of the waste into biogas is actually performed over a series of biochemical reactions that occurs within microorganisms. Additionally, these biochemical reactions are not performed within only one micro-organisms, but actually many types that combine to formulate the three overall steps of digestion process: Hydrolysis, Acetogenesis, and Methanogensis. During the hydrolysis or liquefaction stage, the complex organic wastes (proteins, lipids, and complex carbohydrates) are broken down into smaller compounds, or in other words, organic chemicals with lower molecular weights, primarily sugars. The acetogenic stage involves conversion of the hydrolytic by-products into simple organic acids, carbon dioxide, and hydrogen. Example simple organic acids include acetic and proprionic acids. Finally, the methanogenic stage involves conversion of the simple organic acids into inorganic gases, primarily methane and carbon dioxide. Of the three conversion steps of the biogas production process, the methanogenic step is the most difficult and often problematic. Digester systems can easily produce too many organic acids upsetting the equilibrium of the reactor system, often observed by declining pH, which in turn, inhibits methanogenic activity and finally shutting the overall process down. An improperly operating digester is easy to detect in that the build-up of organic acids (which are volatile and quite odorous) becomes apparent with the dramatic increase in odors emitting from the digester.

In terms of temperature, two operating temperatures can be utilized that actually impacts the types of functioning organisms. The first is referred to as mesophilic biotreatment which in terms of biogas production operates best around 95^{o} F. The second temperature regime is thermophilic which operates in the 130^{o} F range. Mesophilic biological activity is the most commonly used for biogas generation for several reasons which includes the ease at maintaining this temperature and most known biogas producing microbial consortia operate within this range. Quite frankly, there continues to be discussion among experts on the merits of thermophilic digesters in terms of the cost-benefit ratio of this approach. From an overall biological process perspective when considering many other types of biological processes (other than biogas production), thermophilic system tend to yield a higher rate and extent of product conversion. In fact, digesters used to degrade waste secondary sludge at wastewater treatment plants often operate at or near the thermophilic regime (sludge digestion is a biogas producing process almost identical to animal waste to biogas systems). Therefore, several biogas production experts do favor the use of thermophilic conditions if maintaining this temperature is reasonable for a given facility/design. It is important to note that transitioning back and forth between mesophilic and thermophilic regimes is not recommended. DOE reports that microbial activity drops off significantly between 103^{o} F and 125^{o} F. They also point out that temperatures less than 75^{o} F also have adverse impacts on biogas production.

The optimal pH used for biogas system is far less controversial in that the commonly used range is between 6.5 and 7.5. Recent research by the primary author's research team does present convincing evidence that lower pH conditions may provide a reactor system capable of high methane production yields within the produced biogas (this is discussed later in this section in more detail), thus increasing the energetic value of the gas. This concept is "researchy", and as such, it is suggested that neutral pH conditions be maintained until much more development on acidophilic (acid tolerant) systems is accomplished.

Digester Process Operations

The operation of a digester is targeted toward optimizing the degradation of the inputted waste into more environmental stable post-treatment residuals and biogas. The biogas is composed of primarily methane (CH_4) and carbon dioxide (CO_2) – typically in approximate molar ratios ranging from 40% methane and 60% carbon dioxide for poor performing units to as high as 80% methane and 20% carbon dioxide for highly optimized units. Actually, if the digester is performing reasonably well, biogas does also contain numerous other gases at much lower levels (again, if the digester is operating okay). Example minority gases found in the biogas produced from decently operating digesters include ammonia, hydrogen sulfide, phenolics, and mercaptans – all by-products of anaerobic decomposition of organic wastes. Many of these chemicals are considered culprit compounds responsible for causing odors at animal raising facilities. Additionally, some of these chemicals, specifically hydrogen sulfide and ammonia, can be highly corrosive and thus damage process components constructed from metals.

The operation of a digester involves four main stages that are listed below:

1 – Raw waste collection

2 – Raw waste pre-digestion preparation

3 – Digestion of wastes

4 – Collection of biogas

5 – Post-digestion residuals preparation

6 – Post-digestion residuals disposal (or utilization)

A brief summary of each process step is presented in the subsequent paragraphs.

Raw waste collection – This step involves collection of the feedstock and placing in position to be prepared for treatment. Within agricultural activities, this stage is often one of the most time consuming and expensive operations. Yet, from a feasibility assessment of implementing digestion one that does not impact this decision since waste removal must be done in almost all cases, regardless of waste management technique employed.

In the case of Brinson Farms, collection of the raw waste involves the use of heaving equipment to literally scrape the caked waste materials from the house floor (a front-end loader is typically used for cake removal). This operation is done between each growth cycle (which lasts approximately 30 to 50 days depending on the farm). Unlike other confined animal raising facilities, broiler raising operations produces a waste product (litter) that is very dry compared to dairy and swine operations (approximately 20% water content). Brinson Farms has 10 houses holding about 20,000 birds per house. The farm is capable of running five to six growth cycles per year through its operation. Approximately 250 tons of waste material is generated per cycle (~1,500 tons per year generated). Every year each house is "cleaned out" to remove all built up materials down to the base flooring of the house. This is done by cleaning out one to two houses per growth cycle. Clean out adds about another 50 tons per cycle to the collected material to be digested. In total, approximately 1,600 tons of litter is produced per year.

Raw waste pre-digestion preparation – The preparation of the raw waste or feedstock is dependent on the condition of the material to be treated. In the case of wet feeds, such as most dairy and swine operations, no water is added – in fact, in some cases, some water may be removed via settling or screw pressing. Since most digesters operate at system water contents less than 12%, then water addition is a must for poultry litter treatment. Often times, the source of the water is recycled water collected from dewatering operations after treatment within the digester. As a point of note, if the assessment performed within this report finds that water generated from the digester is of market value, then Brinson Farms must determine the economics of using the water for supporting a market(s) or return it back for re-slurrying of in-coming raw litter feed. This decision should be based on life-cycle analysis that considers the market use and associated value added income streams as opposed to the cost of water input.

Some interesting research is on going concerning more elaborate pretreatment techniques prior to inputting the raw feed into the digester. Techniques such as oxidation of the feed are showing fairly convincing evidence of both increased rate and extent of digestion. However, if ozone or hydrogen peroxide is used, this can add a considerable cost to the overall economics of the system. It is suggested that these techniques are too "researchy" at this time for use at Brinson Farms. It may be of value to keep abreast with these developments as they are reported in the literature. Eventually, these developing techniques may of value for implementing at Brinson Farms.

Digestion of wastes – This step involves input of prepared feed into the digester. Typically, digester units are operating with a solids loading ranging from 1% to 14% - most often with complete mix units tending toward the lower end and plug flow units being at the upper range bound listed. The designed solids concentration at the Brinson Farms system is 5% (w/w). Retention times are dependent on the type of waste being degraded. In the case of the Brinson Farm litter, bench studies at Mississippi State University indicated that retention times in excess of 30 days should suffice. The resulting biochemical reactions performed by the microbes result in the production of microbial cell mass and biogas (approximately 65% methane when properly operating). It is expected that degradation yields in excess of 70% of the non-fixed solids should occur (discussed in more detail later in this report). Hence, the three products or residuals expected to exit the digester are biogas and the slurry – which is composed of water and undigested solids. The bulk of the undigested solids should actually be non-digestible solids that are recalcitrant to the biochemical reactions.

Collection of biogas – The biogas is typically dehumidified as it is cooled via weep-water production. Biogas produced in virtually all anaerobic digestion systems requires removal of sulfur compounds to prevent down-stream corrosion problems (as sulfuric acid is formed) by passage of the gas through iron sponge. Since biogas is not very compressible, it is almost always utilized within the short time after production. Note that the thermal value of biogas is usually about 70% that of natural gas due to carbon dioxide dilution.

Post-digestion residuals preparation – As discussed above, two primary non-gaseous residuals will be produced from a digester treating animal wastes. These are liquids and solids. The options available for disposal or utilization of these residuals will be discussed later in this report. Separation can be performed using a variety of techniques including screw pressing, gravity separation, drying beds, or thermal drying.

Evaluation of the Characteristics of Post-Digester Residuals

The key components of digester slurry to be considered within this report that are considered of value are nutrients, organic matter, and inorganic matter. This section will detail the estimated condition of the solids and liquid existing the digester in the form of the effluent slurry.

Expected Solids Within the Slurry

Brinson Farms has 10 poultry houses with each one containing 22,000 birds per cycle. With six cycles processed each year this yields a total of 1,320,000 broilers produced each year. As per Brinson Farms personnel, each house will produce an estimated 15 tons per house/cycle which comes to 275 tons per cycle or approximately 1,600 tons per year of total litter.

In terms of solids balance, most digesters should achieve greater than 60% reduction of total non-fixed solids with removals in excess of 70% not uncommon. In terms of volatile solids degradation, many systems achieve removals in the 70% to 90% range. A conservative estimate is that 60% of the litter will be digested thus meaning that on an annual basis the system will produce 640 tons per year of residual solids existing the digester (or 1,280,000 lbs. per year of residual solids).

Any use of the solids exiting the digester would most likely involve dewatering and maybe even drying of the solids. As discussed above, numerous dewatering equipment types are available for use at biogas to power facilities. Most often screw, screens, or drying beds are used for dewatering. There are also a variety of drying unit processes that may be applied within a farm setting; however, the cost benefits of adding a drying step should be carefully studied with operations costs and known markets providing key insight as to the economic feasibility of this option. Hence, dewatering via screw presses possibly followed by open air drying are the only likely two water reduction processes to be employed upon operation of the system at Brinson Farms. The estimated water content of the final dewatered solids is expected to be in the 20% to 40% range.

Of the chemicals postulated to be found within the residual slurry exiting the digester, the solids are expected to be composed of primarily nutrients and minerals. It should be pointed out that some digester systems treating animal wastes from agricultural activities report a significant market for the fibers within residual digester solids. However, the vast majority of these are diary operations that do have significant bedding ending up within the digester inputs. However, since the broiler operations at Brinson Farms do not involve bedding or any other form of fiber (lignocellulosic materials), then the residual solids exiting the Brinson Farms system are not expected to have a marketable volume of digester fibers. The primary value of these solids is believed to be the nutritional component for use as fertilizer.

No biological process on a practical scale performs 100% conversion if operated within a realistic amount of time. Hence, the solids are expected to contain both untreated or partially treated solids and digester microorganisms – the actual amount is difficult to predict but based on observations with sewage sludge, it is estimated that approximately 30% of the solids will still be unstable. The unstable component of the solids may very likely have potential to have a remaining BOD and the potential to produce odors and attract flies. Both of which may pose handling and environmental problems.

The nutrients are of prime interest because they likely are of the highest value in terms of a potentially marketable material as they can be possibly used as a fertilizer source. Nutrients include compounds containing appreciable amounts of nitrogen, phosphorous, and potassium (or N:P:K). The organic matter may also serve as an additional value component in that this fraction may be used to increase soil organic content – however, it will be of much lower value and very likely must be tied to the nutrient fraction to be of any value. The organic fraction is likely made up of undigested proteins, carbohydrates, organic acids, phenolics, and bacteria.

Most of the nutrients entering the digester are converted into reduced forms of the inorganic constituents. Hence, nitrogen goes to ammonia, phosphorous is liberated from organically bonded forms into inorganic phosphate or lower molecular, more soluble organics forms, with potassium also following the same fate as phosphorous in terms of likely being liberated from organic sources. DOE reports that solids produced by digesters handling animal wastes often contain ammonium, phosphate, potassium, and more than a dozen other minerals that make this product of value as a soil conditioner.

A review of literature indicates that the digestion process will reduce very little of the nutrients originally found in the litter. The Oregon Department of Energy reports that digesters are reported to reduce the nutritional content of the incoming waste slurries by approximately 25%; thus, indicating that the nutrients within litter entering a digester for a large part will remain as viable nutrient sources – albeit some of this fraction may be converted into a more reduced form, such as nitrate to ammonia (and sulfate to reduced sulfur compounds, such as hydrogen sulfide). This level of nutrients remaining within the post-digested residuals should be of potential agrarian value for its fertilizer content. Therefore, the NPK value of the solids is estimated to be approximately 2.5:1.5:2.5 based on the initial concentrations found in the raw litter.

Expected Water Quantity and Quality Post-Digestion

Poultry litter contains low amounts of free water (about 20% water by weight) as compared to other animal raising wastes, such as dairy (contains ~95% water) or swine (contains ~98% water). Therefore, to reach the low solids content within digesters considerable amounts of water must be added to achieve this goal. Assuming a 5% solids concentration is used within the digester(s), then for every ton of litter to be added into the digester approximately 4,300 gallons of water must be added. This represents an annual volume of water to be added to the litter for the digestion system (assuming a target of 5% w/w solids concentration) of 6,880,000 gallons. When considering evaporation and other water losses, 7 Mgal per year of water will be needed. This is not a particularly large water demand – in fact, it represents about the same amount of water that 130 people would use on an annual basis within the US (average American uses between 150 to 200 gallons per day of water).

A key aspect of the water produced within digester from a value-added perspective will be the fertilizer value of the liquid. A review of the minimal amount of information available in the open literature coupled with some estimates of concentrations based from past experience with bioreactors, the following nutrient concentrations are estimated to be found in the liquid residual: 5,000 mg/kg of total N; 3,000 mg/kg of total phosphorous; and 6,000 mg/kg of total potassium (note that 1 mg/kg = 1 mg/l). In other terminology, this represents the following nutrient levels as presented from a total weight percentage basis of 0.5% as N, 0.3% as P, and 0.6% as K. The expected pH values are expected to be within the neutral range. This liquid is also expected to contain appreciable amounts of organic materials – likely in the form of traditional reduced organics (phenolics, mercaptans, and low molecular weight organic acids) and residual manure, carbohydrates, and proteins that escaped degradation within the digester. An estimate of the organic fraction in the form of total organic carbon is very difficult to make. However, based on a review of reported COD values for liquid effluents exiting the digesters tend to range from several hundred mg/l to several thousand mg/l. However, given the apparent high level of degradation expected from the organics within poultry litter, it is expected that the COD should fall within the several hundred mg/l range. The expected TOC or total organic content of this liquid based on observed comparison of COD to TOC concentrations seen in similar studies is roughly estimated to be that TOC concentration will be 1/10 the concentration of COD. Hence, the TOC of the liquid is expected to be in the tens of mg/l.

Biogas Production

Biogas as a Gaseous Energy Source

Based on the 10 houses operating at Brinson Farms, it is estimated that approximately 1,875,000 cubic feet (cf) of biogas will be produced per cycle of birds. Assuming six cycles per year, this equates to 11,250,000 cf per year of biogas being produced. At 700 BTUs/cf of biogas (or 70% methane - CH_4), a total of 7,875,000,000 BTUs of energy is produced from the digester operations on an annual basis. The value of this level of biogas production using a $6.00/cubic yard of natural gas is worth approximately $68,000 per year. This yields approximately $40 per ton of inputted litter into the overall system. The digester system on Brinson Farms is supporting a 65 KW dual fuel genset which is capable of operating on as much as 90% methane (from biogas) and 10% diesel fuel. Typical operating range is closer to 80% methane and 20% diesel. The genset has been selected to support primarily the needs of the farming operation. Even though Brinson Farms has interconnect agreements with the local rural power generation (South Mississippi Electric Power Association) and distribution (Southern Pine Power Association) entities, the farm expects to put very little energy on the grid. The gas is also intended to be used for heating the 10 poultry houses in the winter time and a gas compressor is available to compress the gas up to 150 psi to store excess methane in a 30,000 gallon bullet tank. Gas going to the genset is scrubbed prior to usage. Electricity produced from this system is currently qualifying for a 1.8 cent per kilowatt-hour (KwHr) Production Tax Credit (PTC) from the Internal Revenue Service. It appears that PTC on new poultry litter digester installations may only be half that.

Using the Biogas Produced for Making Biofuels

The DOE estimates that 30,000 BTUs of thermal energy as natural gas are needed to produce one gallon of biodiesel. At 30,000 BTUs per gallon for biodiesel production, enough thermal energy is produced in the form of biogas at Brinson Farms to provide enough natural gas displacement to directly make approximately 250,000 gallons of biodiesel per year. The concept of using biogas derived from an anaerobic digester to produce ethanol has been demonstrated at the commercial scale refinery in Mead, Nebraska. The federal Environmental Protection Agency selected a model ethanol plant developed by E3 Biofuels near Mead as the backdrop for a national announcement in September 2006 to propose a Renewable Fuels Standard program projecting annual cuts up to 3.9 billion gallons in petroleum use and 14 million tons in greenhouse gas emissions. The objective is to reduce the nation's dependence on foreign oil by doubling the use of renewable fuels such as ethanol and biodiesel. The E3 plant was chosen because the plant combines a large feedlot with an ethanol plant that uses manure from the feedlot to power the ethanol plant. One of the by-products from the production of ethanol, wet distillers grains, can be fed to the cattle, eliminating drying and transportation of the feed by-product. This closed-loop system will significantly reduce the fossil fuel used in the production of ethanol.

Performance Metrics for AD Projects

Any engineering project is only as good as that level of its utilization and resulting profits. Unfortunately, the review of literature on manure to biogas projects indicates that inadequate planning appears to have been done prior to and during system operation. Many digester systems have been built and many have been abandoned for a variety of reasons with poor economic returns being by far the primary reason for project failure. This section presents some suggested metrics that may be applied to digester projects as a means of evaluating project success from a variety of perspectives. The reader must realize that "success" can be very different from a project by project basis. It is realized that in many cases, success is often dictated by the power pay-back prices provided by the regional power provider and on-farm energy offset yielded from on-farm power production and usage (Zappi, et al.)

The following list provided below is presented as suggested parameters that may provide key performance data that can be used to fully assess all aspects of what can be considered a "successful" application. This list addresses both environmental and economic performance specs. The anaerobic digester system on Brinson Farms contains a sophisticated computer controlled monitoring and tracking system. The programmable logic controller (PLC) interfaced to a PC running under the Windows® operating system is gathering operational data and is also capable of producing alarms when values of certain parameters exceed specified limits in either direction. It is also capable of maintaining flow rates and temperature of the make-up water for the system and the volume and quality of biogas produced. Based on the total investment of the current system on Brinson Farms, which is really a commercial scale pilot unit, the return on investment (ROI) is around seven years. It is expected that two additional digesters that are being constructed on broiler operations in Mississippi will have simple paybacks of less that five years.

<u>Technical/Environmental Metrics</u>

Gas Quality and Quantity:
Methane, carbon dioxide, ammonia, hydrogen sulfide, biogas production rate and volume

Influent and Effluents:
NPK, COD, BOD5, total solids, volatile solids, fixed solids, pH, alkalinity, volatile fatty acid (VFA) concentrations

Digester Parameters:
pH, temperature, ammonia, conductivity

<u>Economic Performance Metrics</u>

Net worth of power produced
Energy input into farm system
Energy input into the grid
Energy bill reduction
Gross and Net Profit
Return on Investment

Summary

During initial discussions with poultry farmers raising broilers in South Mississippi during the early 2,000's, these groups felt that at least $10 per ton of litter must be recovered from litter management activities to keep current farming operations economically attractive. The amount of natural gas equivalents estimated to be produced at Brinson Farms is estimated to return a profit of about $40 per ton. If a reasonable profit is returned on the sale of the fertilizer value of the digester, then approximately $5 more per ton may be added to the value of the untreated litter produced at Brinson Farms. This positions Brinson Farms to potentially yield a profit on each ton of litter produced approaching $50 per ton.

Additional study of the profitability of the system at Brinson Farms is underway; however, this preliminary assessment does indicate that at least a three-fold profit will be returned to the farm over the minimal amount stated by the regional farmers as their goal to remain economically viable.

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