Colorado State University
Extension

Anaerobic Digestion of Animal Wastes in Colorado

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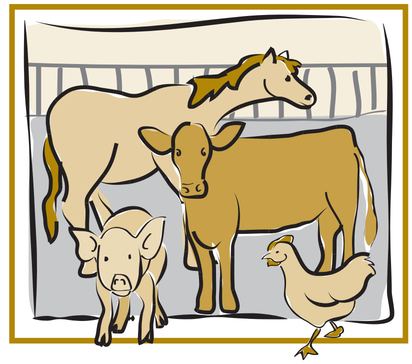

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The demand for clean energy, coupled with concern for management of livestock wastes, has revived an interest in generating methane from livestock manures. The most widely accepted technology currently available for converting organic wastes present in livestock manure is anaerobic digestion (AD). AD is a biological process by which microorganisms convert organic material into biogas, containing methane and carbon dioxide. Biogas produced by this process can be utilized to generate electricity or can be cleaned up and supplied to natural gas lines. Collection and utilization of methane generated from livestock manure offers the potential to reduce global emissions of methane (a greenhouse gas), reduce CO_2 released from fossil fuels, diminish odor from agricultural facilities, and improve water quality. In many cases, anaerobic digestion either decreases on-farm energy costs or increases revenues from energy resale. However, installation of an anaerobic digester will result in increased maintenance and is not a good fit with all livestock operations. Care should be taken to ensure that installation of anaerobic digestion technology is appropriate.

Anaerobic Digestion Process

Anaerobic digestion requires that feed material be of low solids content, less than 15% solids by weight. Typically, manure collected on a dry lot has a much higher solids content than 15%. The microorganisms that convert organic materials into methane are very sensitive, requiring a pH near 7. In addition, the organisms work best at high temperature, around 35°C (95°F). For each 11°C (20°F) decrease, gas production will be cut approximately one half or will take twice as long. While volume reduction of waste does not occur during the digestion process, 50-60% solids reduction can be expected and nutrients are conserved, adding value to the end product for crop use. An advantage of AD is that nearly 95% pathogen inactivation occurs. In the digester, organics are removed as they are converted to methane while nutrients (nitrogen and phosphorus) are conserved. The end product is a low odor, high nutrient, stabilized waste suitable for land application (see section on *Land Application of Anaerobic Digestion End Products* below).

Energy Generation from Anaerobic Digestion

Biogas generated by anaerobic digestion typically contains between 60-70% methane. Other constituents include carbon dioxide, hydrogen sulfide, ammonia, and other trace organics. The predicted energy production for different types of animal wastes is shown in Table 1. To put the energy value of animal waste into perspective, a well-insulated, three-bedroom home takes about 900,000 BTU per day for heating during cold weather. Because 50 percent of the biogas goes back into maintaining the necessary temperature of the digester, it would take the manure from approximately 50 cows to produce enough biogas to heat an average home.

Anaerobic Digestion System Configuration

Anaerobic digesters are typically large reactors constructed of either concrete or steel. The volume of the reactor depends on the volume of wastes to be processed in the

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Quick Facts

- Anaerobic digestion is a waste management solution that has the potential to provide a source of renewable energy. Anaerobic digestion technology converts animal waste to methane biogas, which can be utilized as a renewable source of energy. The end product is a low odor, high nutrient, stabilized waste which is suitable for land application.
- One cow can produce roughly 14,000 BTU per day. It would take manure from approximately 50 cows to produce enough biogas for heating a typical home. A 5000 head dairy, which would be a large sized dairy in Colorado, can produce enough energy to heat 100 homes.
- Feasibility of anaerobic digester installation in Colorado should be carefully considered. Cattle are often kept on dry lots resulting in a waste high in solids and inorganic material (rocks and soil particles). These challenges can be overcome, but there are increased complexity, capital cost, and maintenance requirements for successful installation and operation of an anaerobic digester.

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Table 1. Energy value for various animal wastes based on a 1000 lb animal.

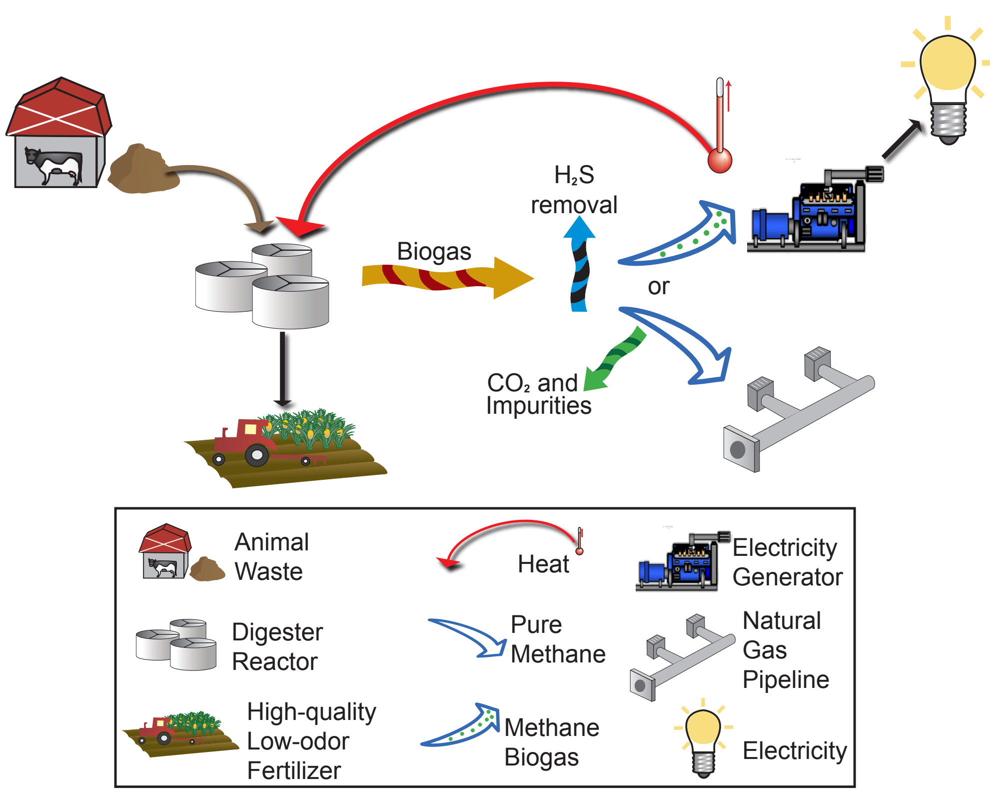
	Volatile Solids (lb/day/1000 lb)	Methane Production (ft^3/animal/day)	Energy Value (BTU/animal/day)
Dairy cattle	8	17	16,000
Beef cattle	6	13	12,000
Swine	5	18	17,000

system. With most conventional digesters, a holding time of 20 - 30 days is required to convert manure solids into methane. Methane gas can be utilized onsite, serve as fuel for an electricity generator, or be purified and supplied to natural gas lines (Figure 1). Through cogeneration, heat produced by the electricity generator is captured and utilized to meet digester heating requirements to 35°C. Cogeneration has been the most common use for methane produced by anaerobic digestion. Recently, there is a growing interest in purification of biogas for resupply to natural gas lines due to high maintenance requirements for generators. This requires that all gas components aside from methane are removed. Of note is that hydrogen sulfide should be removed from biogas for cogeneration due to its corrosive nature. This can be done by passing the biogas through iron filings.

Land Application of Anaerobic Digestion End Products

The end product of AD will contain 5-15% solids, depending on the solids content of the waste which is input to the system. Either the processed material containing solids can be applied by a honey wagon, or solids can be separated for land application of solids separately from liquids. When solids are separated, the liquid end product can be used as a fertilizer and solids can be composted and land applied by a manure spreader. Solids separation in combination with composting can result in a lower weight product which can be transported for land application, while the weight of the processed material containing liquid and solids (5-15% solids) may be too difficult to transport over large distances. Utilizing the liquid fertilizer for irrigation is referred to as fertigation or chemigation and is regulated by the Colorado Department of Agriculture. When fertigation systems are connected to a freshwater source, appropriate measures must be taken to avoid contamination of the freshwater source such as inclusion of a backflow preventer and shutoff valve. Fertigation systems must adhere to Colorado Department of Agriculture regulations.

Figure 1. Typical Anaerobic Digester Configurations.



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Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Center for Environmental Science.

Anaerobic Digestion Technology Selection

Several technologies can be applied for anaerobic digestion including covered lagoons, plug flow, complete mix, upflow sludge blanket, and fixed film reactors. Technology selection is highly dependent on solids content (Table 2). Of note is that swine waste is generally in the form of a slurry (<15% solids) and thus amenable to AD conventional technology while cattle waste collected from dry lots can be very high in solids content (>50%). Dairy manure collected on concrete (by scraping) generally has a total solids content between 10-16%, while flushed manure can have a solids content less than 3%, but can vary substantially depending on the amount of water used for flushing manure.

Covered Lagoons

Covered lagoons are one of the cheapest and simplest anaerobic digestion technologies available. Anaerobic digestion and subsequent production of methane takes place naturally in wastewater lagoons which contain high strength wastewater. A synthetic cover, typically plastic or rubber is used to trap and store the biogas. Because covered lagoons are difficult to heat, they are only recommended in warm climates.

Table 2. Recommended Waste Solids Content for AD Technologies.

Technology	Recommended Waste Solids Content
Covered Lagoon	<3%
Plug Flow	11 - 14%
Complete Mix	5 - 10%
Upflow Sludge Blanket	3 - 7%
Fixed Film	<3%

Too little methane is generated by covered lagoons in Colorado's cold winter climate to justify installation of biogas capture and use equipment.

Plug Flow

Plug flow digesters are a low tech AD technology for treatment of high solids content waste (Table 2). The thick, high solids content waste travels down the digester in a "plug," as a continuous mass. Plug flow digesters can be a good fit with the often high solids content waste generated at animal feeding operations in Colorado.

Complete Mix

Complete mix reactors are large, often cylindrical, tanks which have a mechanism to keep the reactor completely stirred. This mechanism can be injected biogas, or a motorized paddle. Mixing produces an ideal environment for anaerobic microorganisms by spreading the nutrients evenly throughout the reactor, while simultaneously helping to dampen shock loads of toxins which may enter the system since influent is instantaneously diluted through mixing. Complete mix reactors operate best when solids content is between 5-10% (Table 2). Because solids content of waste produced at most Colorado cattle feeding operations is higher than 5-10%, complete mix reactors are often not a good fit unless an external source of water or wastewater is readily available.

Upflow Sludge Blanket

Upflow sludge blanket reactors are similar in design to a complete mix reactor, except that there is no integrated mechanism for homogenizing the waste. Instead, settling of solids is encouraged so that a sludge blanket is formed, maintaining biomass within the system, thus reducing the required holding time. These reactors are highly efficient and have been successfully up-scaled to the commercial scale. In general, waste generated at Colorado animal feeding operations is too high in solids for application of an upflow sludge blanket reactor unless it is combined with wastewater.

Fixed Film Digesters

In a fixed film digester, bacteria colonize a provided support structure within the reactor. This support structure is a high surface area material suitable for colonization, such as PVC pipe or shredded plastic. Fixed film reactors have successfully been implemented with low solids content (< 3%) dairy manure wastewaters in Florida, but are not likely to be a good fit with wastes produced in Colorado.

Anaerobic Digestion Considerations

Biogas Handling

Methane in a concentration of 6 to 15 percent with air is an explosive mixture. Since it is lighter than air, it will collect under rooftops and other enclosed areas. It is relatively odorless, and detection may be difficult. Extreme caution and special safety features are necessary in the digester design and storage tank, especially if the gas is compressed.

Corrosive Biogas

The biogas generated from anaerobic digesters contains hydrogen sulfide, and thus is highly corrosive. Sulfides must be removed prior to supplying the biogas to a generator due to their effect on generator components. A simple, low cost method for removal of sulfides from biogas is passage through iron particles. Here, sulfides attach to the solid surface and are removed from the gas. The iron particles require replacement every six to twelve months.

Dry Wastes in Colorado

Due to the arid climate in Colorado, animal wastes, as collected, can have a very high solids content. Dairies are typically thought to be a very good fit for installation of anaerobic digestion technology. However, waste management methods applied at Colorado dairies differ from other parts of the United States. Because water is so scarce in Colorado, water is not often utilized to flush dairy barns as is typically done elsewhere. Instead, manure is often scraped from concrete floors or dry lots. While dairy waste has a solids content of 10-14% as excreted, solids content has been measured as high as 90% on dry lots in Colorado. For wastes containing more than 13% solids, substantial quantities of water may be required for anaerobic digestion. This can add to the cost of operating the digester. In addition, when clean groundwater is added to an anaerobic digester, it will adsorb nutrients and pathogens which may then become a nuisance. Dilution of waste with water is most practical when there is an available source of wastewater to utilize.

High Inorganic Content

When manure is collected from dry lots, the collected waste is often dry with high inorganic content consisting of rocks and soil particles. The rocks and soil particles cause major operational problems for anaerobic digesters and must be removed before the waste is processed. Sand in bedding can also be a problem for AD if it ends up in the waste material supplied to the system. Removal of rocks, soil, and sand typically involves addition of water to the waste and subsequent settling of the particles, thus adding complexity, capital cost, and additional maintenance for an AD system.

Feasibility

Anaerobic digestion is not a good fit for all animal feeding operations. Care should be taken to ensure that AD is feasible at an operation before installation. While Colorado conditions and typical management practices do create challenges for installation of anaerobic digestion technology, there are technologies that can be a good fit. Guidance is required to select appropriate technologies.

Also of note is that combining animal feeding operation wastes with wastewater generated onsite or by nearby facilities such as food processing plants or domestic wastewater treatment plants can be beneficial by both decreasing waste solids content and increasing methane production capacity. This is typically referred to as co-digestion and is gaining much popularity. The ability to combine manure with other wastes must be carefully evaluated prior to AD installation/operation. In particular, it is recommended that wastestreams are not varied seasonally or daily, but rather that a consistent waste is supplied to the AD reactor at all times.