EQUIPMENT

Methane Generation From Livestock Wastes no. 5.002

by R.W. Hansen[1]

Quick Facts...

Anaerobic fermentation or digestion is the most promising process for converting organic materials to methane and other gases.

A simple apparatus can be constructed to produce bio-gas.

Bio-gas usually contains about 60 to 70 percent methane, 30 to 40 percent carbon dioxide, and other gases.

The heat value of raw bio-gas is approximately half that of natural gas under typical Colorado conditions.

Take precautions when processing and handling the gas. It is highly explosive and difficult to detect.

Colorado State University Cooperative Extension

Energy conservation, coupled with concern for the management of livestock wastes, has revived an interest in generating methane from livestock manures.

Converting organic materials, such as animal wastes, to an easily used form of energy can be accomplished by several methods. The process with the greatest potential is anaerobic fermentation or digestion.

The extraction of energy from wastes using anaerobic digestion to produce bio-gas is not new and the general technology is well known. Bio-gas, which is methane and other gases, has been known as swamp gas, sewer gas and fuel gas. Sewage treatment plants generate bio-gas from the sewage sludge as part of the sewage treatment processes. Many small units were used in Europe and India after World War II.

Characteristics of Bio-Gas

Bio-gas usually contains about 60 to 70 percent methane, 30 to 40 percent carbon dioxide, and other gases, including ammonia, hydrogen sulfide, mercaptans and other noxious gases. It also is saturated with water vapor.

The heat value of the raw gas at typical Colorado atmospheric pressures is about 400 to 600 British thermal units (Btu) per cubic foot. In comparison, natural gas has a heat value of 850 Btu per cubic foot and gasoline contains approximately 120,000 Btu per gallon. Partial removal of the impurities may be required. This is not necessarily difficult, but it does complicate the system.

Basic Digester Process

Methane is produced by bacteria. The bacteria are anaerobes and operate only in anaerobic environments (no free oxygen). Constant temperature, pH and fresh organic matter promote maximum methane production. Temperatures usually are maintained at approximately 95 degrees F. Other temperatures can be used if held constant. For each 20 degrees F decrease, gas production will be cut approximately one half or will take twice as long. A constant temperature is critical. Temperature variations of as little as 5 degrees F can inhibit the methane-formers enough to cause acid accumulation and possible digester failure.

Anaerobic digestion is a two-part process and each part is performed by a specific group of organisms. The first part is the breakdown of complex organic matter (manure) into simple organic compounds by acid-forming bacteria. The second group of microorganisms, the methane-formers, break down the acids into methane and carbon dioxide. In a properly functioning digester, the two groups of bacteria must balance so that the methane-formers use just the acids produced by the acid-formers.

A simple apparatus can produce bio-gas. The amount of the gas and the reliability desired have a great influence on the cost and complexity of the system. A simple batch-loaded digester requires an oxygen-free container, relatively constant temperature, a means of collecting gas, and some mixing. Because methane gas is explosive, appropriate safety precautions are needed.

Tank size is controlled by the number, size and type of animals served, dilution water added, and detention time. The factor that can be most easily changed with regard to tank size is detention time. Ten days is the minimum, but a longer period can be used. The longer the detention time, the larger the tank must be. Longer detention times allow more complete decomposition of the wastes. Fifteen days is a frequently used detention time. Table 1 shows some recommended sizes, dilution ratios and loading rates for different types of animals.

Little volume reduction occurs in an anaerobic digester. Waste fed into the digester will be more than 90 to 95 percent water. The only part that can be reduced is a portion of the solids (about 50 to 60 percent).

The processed material will have less odor. Because it still contains most of the original nitrogen, phosphorus and potassium, and is still highly polluted, the waste cannot enter a stream after it leaves the digester. Lagoons are commonly used to hold the waste until it can be disposed of by either hauling or pumping onto agricultural land.

The volume of effluent actually may be greater than the volume of manure prior to digestion. This increase is due to the dilution water added to liquefy the manure to the desired solid content for the digester.

There is no increase in the amount of nitrogen, phosphorus or potassium in this material, although it may be in a more available form. A small portion of the nitrogen may be lost to the gas portion of the system, thus reducing the amount of nitrogen initially available.

Gas Production

Total bio-gas production varies depending on the organic material digested, the digester loading rate, and the environmental conditions in the digester. Under ideal conditions (95 degrees F temperature and proper pH), it is possible to produce about 45 cubic feet of gas at atmospheric pressure from one day's manure from a 1,000 pound cow. Not all of the bio-gas energy is available for use. Energy is required to heat and mix the digester, pump the effluent, and perhaps compress the gas. Table 2 summarizes the estimated gas production from various animal wastes.

Basic Elements

Figure 1 shows the basic elements of a single-stage anaerobic digester. Submerged inflow and outflow lines are needed to prevent gas from escaping. Either a mechanical mixer can be used, or the liquid or gas can be recirculated for mixing.

Table 1: Loading rate guidelines for heated, mixed anaerobic digesters at 95 degrees F being fed fresh livestock manures.*

Factor	Swine (growing-finishing)	Dairy	Beef under 700 lbs	Poultry layer	Poultry broiler
Dilution ratio manure (manure to water)	1:2.9	Undiluted	1:2.5	1:8.3	1:10.2
Estimated dilution water (gal water/1,000 lbs body wgt)**	15	0	11	47	79
Hydraulic detention time (days)	12.5	17.5	12.5	10	10
Loading rate (lbs volatile solids/cubic foot/day)**	0.14	0.37	0.37	0.13	0.1
Digester volume (cubic feet/1,000 lbs animal wgt)**	30	24	14	72	120

*(From R.J. Smith, The Anaerobic Digestion of Livestock Wastes and the Prospects for Methane Production, Midwest Livestock Waste Management Conference, ISU, Ames, Iowa, Nov. 27-29, 1973)

**To convert to metrics use the following equivalents: 1 gal = 3.8 l; 1 lb = .45 kg; 1 cu ft = .03 cu m.

Table 2: Bio-gas production (60% methane and 40% carbon dioxide) from animal wastes per 1,000 pounds body weight.

Animal	Volatile solids (lb per animal per day)	Probable volatile solids destruction (percent)[1]	Gas (cu ft per day)	Btu (per day)[2]
Beef	5.9	45	30	18,000
Dairy	8.6	48	44	26,000
Poultry, layers	9.4	60	72	43,000
Poultry, broilers	12.0	60	92	55,000
Swine (growing-finishing)	4.8	50	29	17,400

[1]Percent destruction of volatile solids varies depending primarily on detention time and digester temperature.
[2]Calculated at 600 Btu/ft^3* (heat content varies depending on quality of gas). For comparison, some other heating values are: gasoline, 124,000 Btu/gal; diesel fuel, 133,000 Btu/gal; natural gas, 850 to 1,000 Btu/ft^3; propane, 92,000 Btu/gal.
*To convert to metrics, use the following equivalents:
1 lb = .45 kg; 1 cu ft = .03 cu m; 1 gal = 3.8 l.

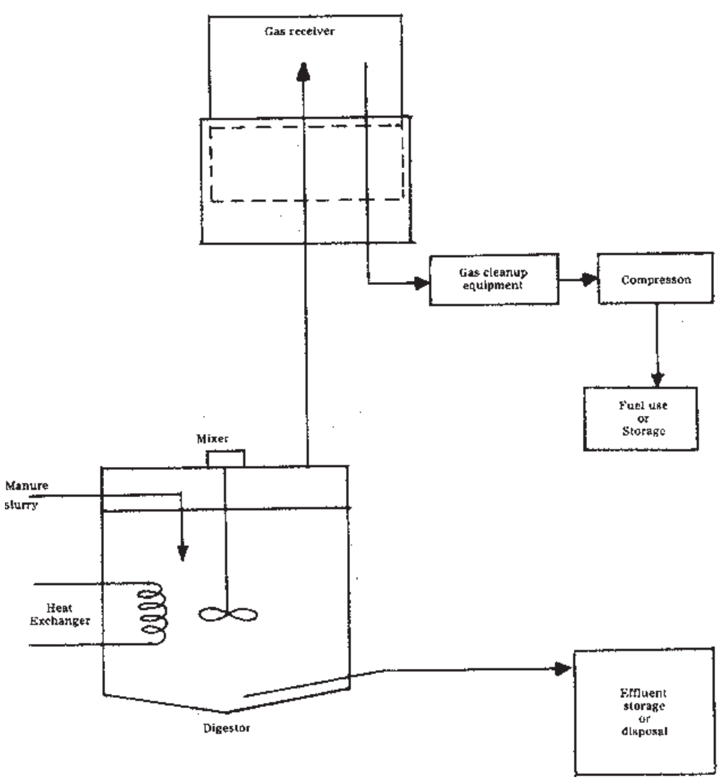

Figure 1: Basic components of anaerobic digester.

A heat exchanger and thermostat maintain the proper temperature. The heat exchanger can be either internal or external.

Methane is drawn off the top of the digester. For gas utilization, a compressor and storage tank are used, along with the hardware to provide flame traps, regulators, pressure gauges, hydrogen sulfide scrubber, carbon dioxide removal and pressure relief valves. A common facility for gas storage is the floating cover that floats upward while maintaining essentially constant pressure.

Methane or bio-gas cannot be converted to a liquid under normal temperatures as can LP gas (LP gas liquefies at 160 psi). Under constant temperature, volume reduction is inversely proportional to the pressure; that is, as the pressure doubles, the volume becomes half as large. The more the gas is compressed, the more energy it takes to compress it.

Liquefaction of methane requires pressures of nearly 5,000 psi and is not practical. If the gas is compressed to just 1,000 psi, it requires about 1,320 Btu of energy to put 6,350 Btu into a storage container.

Because bio-gas cannot be liquefied, it is best suited for stationary uses, such as cooking, heating water and buildings, air conditioning, grain drying, or operating stationary engines. It is not feasible as a tractor fuel. One cubic foot of compressed bio-gas at 3,000 psi would run a 100-horsepower tractor approximately 7 ½ minutes. Most tractor fuel tanks occupy about 8 cubic feet. A special high-pressure tank with 8 cubic feet of gas and 3,000 psi would run the tractor approximately one hour. A 3,000-psi tank bouncing around on a tractor would present a serious safety hazard. The tractor would run 6 minutes on 8 cubic feet of gas compressed to 300 psi, a more realistic pressure.

A well-insulated, three-bedroom home takes about 900,000 Btu per day for heating during cold weather. Because 50 percent of the bio-gas goes back into maintaining the necessary temperature of the digester, it would take the manure from 50 cows to produce enough bio-gas each day for home heating.

Bio-gas is produced on a relatively constant basis. Most applications are somewhat intermittent; therefore, storage is required. The amount of storage depends on the storage time and pressure. High demand applications, such as grain drying, normally are impractical due to the excessive storage capacity required.

Hazards

Methane in a concentration of 6 to 15 percent with air is an explosive mixture. Since it is lighter than air, it will collect in 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.

Summary

Concerns for energy conservation, environmental pollution, and the fact that agricultural organic wastes account for a major portion of our waste materials, has created renewed interest in the processing of these wastes for energy recovery.

Of the several types of energy capturing processes available, anaerobic digestion appears to be the most feasible for the majority of agricultural operations. Anaerobic digestion can stabilize most agricultural wastes while producing bio-gas or methane gas. This concept has been extensively applied in Europe and India during energy shortages. Similar equipment has been used for gas production with domestic wastes.

Primarily, disadvantages are the amount of management required due to the sensitivity of the digesters, the high initial investment required for equipment, and the fact that the wastes still must be disposed of after digestion.

Research is in progress to make the process more practical for energy production. Bacteriologists are investigating new strains of bacteria and culturing techniques for producing methane. Engineers are investigating digester designs and operation to reduce construction and operational requirements and costs.

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