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KSU

Reclaiming Energy from Swine Manure

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Summary

Of several types of processes to capture energy from organic wastes, anaerobic digestion appears to be most attractive for swine wastes. It can stabilize the waste while producing biogas or methane gas. Theconcept has been extensively applied in Europe and India during energy shortages. Similar equipment has been used for gas production with domestic wastes. Anaerobic digestion has the additional attraction of preserving most of the plant nutrients for application to agricultural land.

Primary disadvantages are the management required by sensitive digesters, the high initial investment required for equipment, and the fact that waste still must be disposed of after it is digested.

Research is in progress to make the process more practical. Bacteriologists are investigating new strains of bacteria and culturing techniques. Engineers are investigating digester designs and operation to reduce construction and operational requirements and costs. Investments in such research appear more worthwhile with each rise in the cost of energy.

Discussion

The energy shortage and concern with livestock wastes has revived interest in producing energy from livestock manures. The conversion of such organic materials to heat energy can be accomplished several ways. Heat energy could be reclaimed by burning manure -- as pioneers burned buffalo chips. Processes such as pyrolysis can produce combustible gases or liquids. Those methods of using the heat energy in animal manures have two common disadvantages -- the necessity of removing moisture before combustion or during the conversion process and the loss of important plant nutrients.

The heat energy available from direct burning of swine manure has been estimated at 6285 Btu/lb of total dry solids, which a 130-lb feeder pig produces at the rate of about 285 lbs per year. Burning the dried manure produced annually by a pig would produce 1,791,225 Btus. That is equivalent to the following quantities of common fuels:

Natural gas at 1050 Btu per cu ft	- 1705 cu ft
Fuel oil at 140,000 Btu per gal.	- 12.79 gal.
LP Gas at 100,000 Btu per gal.	- 17.91 gal.
Gasoline at 120,000 Btu per gal.	- 14.92 gal.

Depending on whether or not urine could be effectively separated from fresh feces, and on other factors, moisture content on a wet basis, could be 75 to 90 percent. Assuming 970 Btu per lb. to evaporate water, the water associated with

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each pound of solids (heat content 6285 Btu) would require 5490 Btu's to evaporate. If sun-drying of wastes (as with buffalo chips) could be made compatible with modern swine production systems, direct burning of manure would be more promising. However, air pollution by odors and particulates, would remain and could require expensive equipment for after-burners and scrubbers.

Pyrolysis takes place at temperatures from 390 to 1650 degrees F. Heat value from gases produced is seldom more than 20 to 30 percent of the fuel value of dry manure because so much energy must be returned to the process or is lost from high temperature products that come from the process. For those reasons and others, many authorities feel that methane generation by anaerobic digestion is the most promising. Publicity in the popular press often has made that sound easy.

Anaerobic digestion of wastes to produce bio-gas is not new; the general technology is well known. Bio-gas, which typically consists of a mixture of about 60 percent methane (CH_4), 35 percent carbon dioxide (CO_2), and 5 percent of numerous other gases, some of which may be odorous, is saturated with water vapor as it comes from a digester. Its heat content is about 600 Btu per cu ft. Many municipal sewage treatment plants generate bio-gas from sewage sludge as part of the treatment proces and use the bio-gas to heat the digester to about 95 F. Unless the treatment plants are very large, the excess gas is flared. Sewage plants serving more than one million people sometimes scrub impurities and water vapor from the excess gas, transport it by pipeline, and market it.

Many small bio-gas producing units were used in Europe during and after War II but most have been abandoned. The World Health Organization assisted in developing bio-gas digesters in India. It has been estimate that 5,000 to 10,000 dung gas generators are operating there and in other developing countries. Those systems are relatively simple, labor intensive, and generally do not produce enough gas to be of significant economic value in U. S. agricultural production.

Although it is possible to produce bio-gas using rather simple equipment, the amount of gas produced from a given quantity of raw wastes and the reliability desired greatly influence costs and complexity. A simple batch-loaded digester requires an oxygen-free container, relatively constant temperature, a means of collecting gas, and some mixing. Since methane gas is explosive, appropriate safety precautions are needed.

You can simply place a mixture of organic matter and water in a buried tank and allow it to decompose completely. That is inefficient for producing methane since production goes from no methane to a peak and back to none. Feeding at least once a day is necessary to insure good conversion to methane. With a batch system, it may take two weeks to a month before gas production begins; therefore, maintaining the most desirable microbial environment makes the system more efficient and reduces the required detention time. For good efficiency, continuous feeding and removal of digested manure is desirable.

Tank size is controlled by the number, size, and type of animals served, dilution water added, tank temperature, and detention time. The best

tank temperature is 95 F. That requires using much of the gas produced to heat the tank even when it is well insulated because incoming wastes and dilution water must be heated and heat lost from the tank must be replaced. The factor that can be most easily changed with regard to tank size is detention time. With a heated digester, 10 days is a minimum; a longer period is better because longer detention times allow more complete decomposition of the wastes. Fifteen days is frequently used. The longer the detention time, the larger the tank must be. For swine, a realistic recommendation would be to add three parts of dilution water for each one part of manure and urine. That makes the total material requiring ultimate disposal about 4 times the volume of manure produced because volume is reduced very little during the digestion process. Processed material has less odor than partly decomposed manure -- not much less than fresh manure. Since 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 needed to hold the digester effluent until it can be pumped or hauled onto agricultural land. Plant nutrients are well preserved in the digestion process. That is another characteristic that makes anaerobic digestion attractive. But much of the nitrogen could be lost by holding the effluent in a lagoon too long before spreading it on land.

For growing-finishing swine, it can be estimated that, with a dilution ratio of three parts water to one part of swine wastes (about 15 gallons per 1,000 pounds of pigs) and a detention time of 12.5 days, the digester should have a volume of 30 cu ft per 1000 pounds of pigs served. A realistic estimate would place the gas yield from a heated digester at about 29 cu ft per day for each 1000 pounds of pig weight. That gas would produce about 17,400 Btu's. For some purposes, it could be burned without scrubbing. Some cleaning of the gas might be desirable for use in internal combustion engines.

At KSU, we have worked with a system that we hoped would eliminate adding dilution water. The advantages are obvious -- smaller digester size, less heating to support the digestion, and less fluid to dispose of.

When we did not dilute the wastes, high ammonia concentrations were toxic to the gas producing bacteria. Certain other bacteria thrived but gas producing bacteria are a relatively few species, all sensitive to their environment. We used a rather complicated method to scrub ammonia from the digester fluid and trapped it in phosphoric acid. That made ammonium phosphate, a concentrated and stable form of fertilizer. The chemistry of the system works. But we need simpler hardware and a method that requires less energy to operate the system. We are studying those possiblities now.

At least a dozen experiment stations and innovative stockmen are experimenting with different ideas to make methane production practical for medium to large-scale livestock producers. There is no system yet developed that we can recommend.

Simply placing a plastic cover over a manure lagoon to trap the gases that can be seen bubbling to the water surface deserves further investigation. Those gases usually contain at least 50

percent or more methane; however, we have strong evidence to indicate that, to be succesful, lagoons would require considerable enlargement to hold the dilution water required. Covering a lagoon will alter the bacterial environment. Much of the ammonia in urine and formed during decomposition of solids in open lagoons escapes to the atmosphere. We hypothesize that when ammonia is trapped under cover, dissolved ammonia in the lagoon water will remain high enough to be toxic to methane-forming bacteria. A commercial company has recently introduced a plastic bag to receive pig wastes drained from under slotted floors. The claim by that company that gases are not formed inside the bag tends to support our hypothesis. Observations now being made on the plastic-bag storage system at the University of Illinois may give us the answer.

Meantime, we should not forget the energy value of plant nutrients in swine manure and urine. Annual production of N, P, and K in wastes from a 130-lb feeder pig are about 21.4, 7.1 and 14.0 pounds respectively. Energy required to produce those respective nutrients is estimated at 24.0, 21.8 and 4.8 thousand Btu's per pound. To replace the nutrients in pig wastes with commercial fertilizer requires 737,000 Btu's. We lose much of the nutrients by the way we now handle and store manure. As we continue to look for better ways to produce energy from manure, we must also seek better ways to conserve the energy represented by the plant nutrients.

If sufficient improvement is made on today's experimental digesters and if the price of energy warrants their use, additional problems remain to be solved. Bio-gas is produced on a relatively constant basis. Most applications are somewhat intermittent. Therefore, storage will be required. The amount of storage will depend on storage time and pressure.

Liquification 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's of energy to put 6,350 Btu's into a storage container.

Since bio-gas cannot be liquified, it is best suited for such stationary uses as cooking, heating water in buildings, air-conditiong, grain drying, or operating stationary engines. It is impractical for use as a tractor fuel. One cubic foot of compressed bio-gas at 3,000 psi would run a 100 horsepower tractor approximately 7 1/2 minutes. Most tractor fuel tanks occupy about 8 cubic feet, which would require replenishing approximately once an hour. A 3,000 psi tank on a tractor would be a safety hazard, but 8 cubic feet of gas compressed to 300 psi, a more realistic pressure, would run a tractor 6 minutes.

High demand application such as grain drying probably would be impractical because of the excessive storate capacity required.

Assume that a well insulated 3 bedroom home takes about 900,00 Btu's per day for heat during cold weather and assume further that 50 percent of the bio-gas goes back into maintaining temperature necessary for the digester during winter, the manure from 800 130-lb feeder pigs would produce enough bio-gas each day to heat the home.