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# PRODUCTION OF BIOGAS IN LANDFILL CELLS USING BEEF CATTLE MANURE COLLECTED IN OPEN LOTS

by

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## ABSTRACT

Two laboratory experiments were completed, and a field demonstration project is currently underway, to evaluate biogas production from beef cattle manure collected from open-lot pens at a commercial feedyard. Experiment 1 was conducted at 21°C and Experiment 2 was conducted at 35°C. Collapsible 4 L low density polyethylene (LDPE) containers were filled with 120 g of manure (50 g VS) and water, the containers were flattened, and the air was displaced. For Experiment 1, water was added to obtain wet weight basis moisture contents (MCs) of 12.9% (control), 20, 25, 30, 40, 50, and 75%. For Experiment 2, moisture contents of 35, 50, 57.5, 65, 72.5, and 80% were used. There were five replications at each moisture content. Biogas production was monitored every 7 days using a water displacement method. In Experiment 1, biogas production was minimal after 70 days at moisture contents of 50% or less. At the 75% moisture content, the average biogas production was 1.92 L/container. In Experiment 2, the average biogas production after 45 days was 0.00, 0.61, 0.94, 1.42, 1.84, and 2.40 L/container for moisture contents of 35, 50, 57.5, 65, 72.5, and 80%, respectively. Biogas production began after 7 days for the 80% MC, after 14 days for the 72.5 and 65% MCs, and after 21 days for the 57.5 and 50% MCs. Gas concentrations were analyzed by GC/MS at the completion of the experiments. Unexpected results were obtained for the gas analyses, as the gas contained 62 to 85% $N_2$. We believe that the gas permeability of the LDPE containers may be high enough to allow diffusion of gases into and out of the container. A preliminary literature review indicates that, in comparison to water, the containers have a relatively high permeability to $CO_2$ and moderate to low permeability to $CH_4$ and $O_2$. Our future plans include rerunning the experiments using glass containers. In the field demonstration project, feedyard manure and water (60% moisture content wet basis) was placed into a 91 $m^3$ landfill cell on Feb. 12, 1999. The cell was lined and capped with EPDM geomembrane. No appreciable amount of biogas has been produced in the past three months. Monitoring will continue throughout the summer of 1999.

**Keywords:** biogas, methane, manure, animal waste, anaerobic digestion, cattle

## INTRODUCTION

The concept of alternate energy and fuel sources is not new. The idea for producing methane (biogas) from cattle manure began well before 1970, but the large interest began about that time due to problems in the fossil fuel market. Due to high cost, high maintenance, and design problems, interest in biogas production declined rapidly. Recent interest has surfaced in areas that deal with more than just the conservation of fossil fuels. These areas include groundwater contamination by bacteria from feedlot runoff, odor control due to increased populations around feedlot areas, and the use of biogas effluent for crop fertilizer.

Biogas is composed almost exclusively of methane and carbon dioxide (approx. 65% methane and 35% $CO_2$) although there are traces of $H_2S$, $N_2$, $H_2$ and CO created in anaerobic conditions. Because of the incombustible material in biogas reactors, the energy created is only 400-700 BTU/$ft^3$ as compared to 1,000 BTU/$ft^3$ for natural gas.

The breakdown of cattle manure in biogas is accomplished by three types of bacteria, 1) hydrolytic, 2) transitional, and 3) methanogenic. Hydrolytic bacteria are utilized in the first steps of production by reducing large macromolecules (proteins, fats, carbohydrates) into much smaller molecules such as amino acids, sugars, acids, and alcohols. Transitional bacteria further reduce these molecules into acetic acid, $H_2$ and $CO_2$. The final step of breakdown is accomplished by methanogenic bacteria, which reduce the molecules into methane ($CH_4$) and carbon dioxide ($CO_2$) (Engler et al., 1995). Hansen et al. (1998) states that acetate-utilizing methanogens are responsible for 70% of methane produced in a biogas reactor. Biogas production is also a temperature-dependent process (Misra et al., 1992). The process takes place in either mesophilic (25-40°C) or thermophilic (45-60°C) temperatures. There are advantages and disadvantages in both areas. The use of mesophilic temperatures allow the process of production to be more stable by helping to inhibit excessive ammonia ($NH_3$) production, but these temperatures also do not destroy potentially harmful bacteria. Thermophilic temperatures, while destroying bacteria and allowing increased loading rates due to faster degradation, also cause greater instability because of increased free ammonia load. Though some ammonia is necessary for biogas production, the combination of the two (thermophilic temperature and excessive free ammonia), can inhibit and destroy the bacteria that is necessary for biogas production (Angelidaki & Ahring, 1994). Hansen et al. (1998) show that free ammonia is determined by three parameters: total [$NH_4$], temperature and pH. Angelidaki & Ahring (1994) also found that reducing the temperature to 55°C when the $NH_3$ loading rate was high increased stability within the process and also increased biogas yield. This result was measured by a significant reduction in the volatile fatty acids of the effluent.

Over the years, many types of anaerobic digesters have been tested, with or without success. Schulte (1997) states that gravity types are preferred. The amount of methane potential that escapes with unsettled organic matter in a solids separation device is up to 40%. Storage pits have the disadvantage of settling before the effluent reaches the digester, and resuspension and pumping often produces mechanical problems. One variation that appears to have great potential is a two-staged digester. The two stages use exclusive bacteria, one an acid former, the other a methane former. Each stage operates optimally for its specific bacteria, which is impossible with the two combined. By selectively removing the soluble $CO_2$ from the aqueous phase and passing it through an air stripper, the gas is enriched to 90% $CH_4$. By removing the metals from the effluent, it can also be used as a soil conditioner and fertilizer. Although a very feasible alternate energy source for single family/small farm operations, it is still rather impractical because of the current affordability of other conventional sources. Utility companies will pay almost nothing for electricity produced from methane ($.01/kwh), and the amount most operations could produce would only be sufficient for a single operation.

In the Texas/Oklahoma Panhandles, approximately 16 million metric tons (36 billion pounds) of wet manure are produced annually from feedlots (Parker et al., 1997). The potential energy production from this vast amount of stockpiled manure is incredible, especially if an economically sound way of production is found. The purpose of this experimental project was to investigate producing biogas while minimizing water usage.

## MATERIALS AND METHODS

The experiments consisted of laboratory and field experiments. In the two laboratory experiments, manure samples from a beef cattle feedlot were initially tested for moisture content. Five gram samples were then taken from the dried manure and placed in a muffle furnace at 500°C for one hour to determine the volatile solids content. Exactly 120g of manure were placed into 4-L plastic (LDPE) collapsible containers. The containers were filled with $CO_2$ and flattened and sealed to remove oxygen and create anaerobic conditions. The first experiment consisted of seven varying moisture contents (12.9, 20, 25, 30, 40, 50, 75% by weight) with five replications for each. These were maintained at 21°C throughout the experiment. The second experiment set was six different moisture contents (35, 50, 57.5, 65, 72.5, and 80% by weight), also with five replications for each. These samples were kept in a 1.3m x 1.3m x 0.67m deep plywood box which was equipped with a NuTone wall heater (model 9376N) and a thermostat. This allowed the samples to be maintained at 35°C. The samples were tested periodically for volume of biogas production by displacing the containers in water. After the samples had reached a stabilization point (70 days for Exp. 1 and 45 days for Exp. 2), they were analyzed for $CH_4$, $CO_2$, $H_2S$, $NH_3$ and other trace gases using a Hewlett Packard GCD 1800 GC/MS. Hydrogen sulfide was analyzed using a Jerome 631-X (Arizona Instrument Corp., Phoenix, AZ) hydrogen sulfide meter.

The field phase of the experiment is being conducted at West Texas A&M University's Research Feedlot. Two below ground "landfill" cells were constructed in Fall, 1998. Each cell measures 11m x 11m at ground level and is 2m in depth with a 3m x 3m base. Each cell has a capacity of 985 $m^3$. Each cell was lined with an EPDM geosynthetic liner (Colorado Lining, Parker, CO) on the bottom and top. The first cell was filled with manure, water, and was capped on February 12, 1999. A gas collection apparatus was constructed of PVC pipe to collect gas samples at the top of the cells. The cell was equipped with a data logger and thermometers to monitor manure temperatures at 0.7 and 1.3m above the bottom of each cell. Gas production will be monitored through the summer of 1999. The second cell will be filled and capped at a later date to monitor biogas production during the warmer months.

To collect the biogas from the cell, a large plastic bag is attached to the exit port and is periodically tested for methane content using a GT Land Surveyor (Gastech, Newark, CA) portable methane analyzer.

## RESULTS

The biogas volumes produced in Experiments 1 and 2 are plotted in Figures 1 and 2, respectively. At 21°C, biogas production was negligible at moisture contents of 50% or less. The 75% moisture content produced an average of 1.92 L/container. At 35°C, average biogas production was 0.0, 0.61, 0.94, 1.42, 1.84, and 2.40 L/container for moisture contents of 35, 50, 57.5, 65, 72.5, and 80%, respectively.

The average concentrations of $N_2$, $CO_2$, $H_2O$, and $CH_4$ in the biogas produced in Experiment 1 are summarized in Table 1. For Experiment 2, none of the average methane concentrations were above 5%, and only 6 of the containers were above 2% methane content. The methane analyses run by the GC/MS showed that in Experiment 1 there was a greater percentage of $CH_4$ in the containers than in Experiment 2. All containers showed higher percentages of $N_2$ than was expected. Because these high concentrations of $N_2$ are not typical for biogas generation, further testing is now being conducted to evaluate the permeability of the plastic containers, and future experiments are planned using containers that are not permeable to gases. The following gas permeabilities have been reported for low density polyethylene (Nalgene, 1999):

| **Material** | **Permeability** |
|---|---|
| Water | 1.0-1.5 g.mil/100 $in^2$ day |
| Nitrogen | 180 cc mil/100 $in^2$ day |
| Oxygen | 500 cc mil/100 $in^2$ day |
| Carbon Dioxide | 2700 cc mil/100 $in^2$ day |

No permeability values were found for methane. However, we filled three containers with $CO_2$, $CH_4$, and air and monitored their volumes for two weeks. The container filled with $CO_2$ shrunk to about half the original volume, the container filled with air did not change noticeably, and the container filled with $CH_4$ shrunk about 5-10%. This quick test suggests that $CO_2$ produced in the biogas might leave the container more rapidly than $O_2$ and $N_2$ could enter the container. Because there was a several month time span from the time of completion of the experiment and the time the gas concentrations were measured, it is probable that diffusion through the LDPE has affected the original biogas concentrations. Also, if significant $O_2$ entered the containers during the experiment, the biogas production could have been reduced. For these reasons, we have plans to rerun Experiments 1 and 2 using glassware instead of plastic.

In the field demonstration project, the temperature of manure in the landfill cells started at about 25°C (77°F) and has steadily decreased in about three months to the present temperature of about 17°C (63°F). There has been no appreciable amounts of biogas produced in the three months since manure was loaded in the cells.

## CONCLUSIONS

Though we found some shortcomings with using low density polyethylene containers for biogas production, we are still optimistic about producing biogas from beef cattle manure with limited water. As more research is done and the problems corrected, hopefully in the near future an affordable, reliable biogas methodology will be developed for producing biogas from beef cattle manure where water supplies are limited.

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**Table 1. Average gas concentrations for laboratory experiment no. 1.**

| Water Content | Average Gas Concentration (%) | | | |
|---|---|---|---|---|
| | $N_2$ | $CH_4$ | $CO_2$ | $H_20$ |
| 12.9 | 85% | 0% | 14% | 2% |
| 20 | 86% | 0% | 13% | 2% |
| 25 | 79% | 0% | 18% | 3% |
| 30 | 83% | 1% | 14% | 2% |
| 40 | 76% | 6% | 16% | 2% |
| 50 | 68% | 14% | 16% | 2% |
| 75 | 62% | 20% | 16% | 2% |

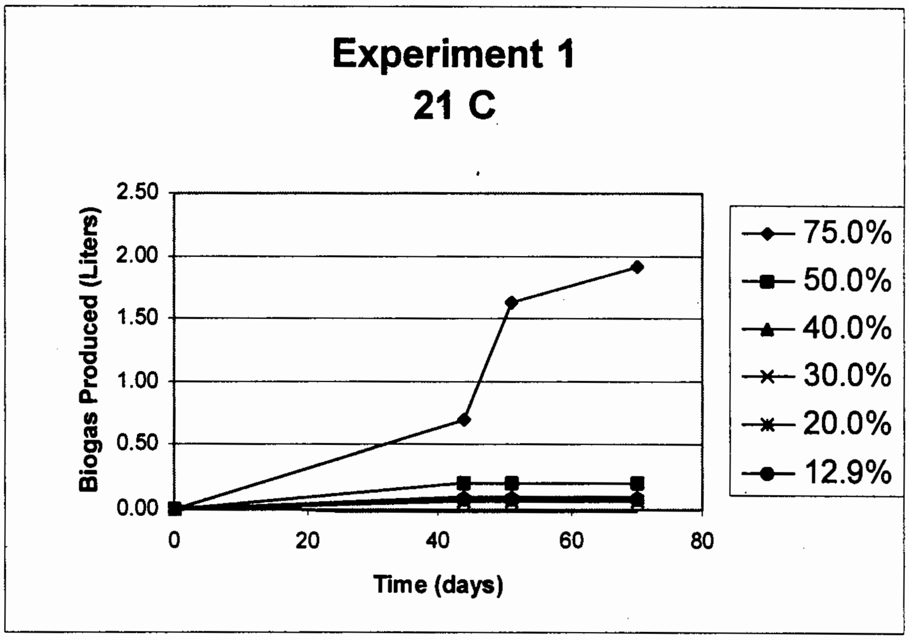


Figure 1. Average biogas produced per container at six different moisture contents with temperature of 21°C.

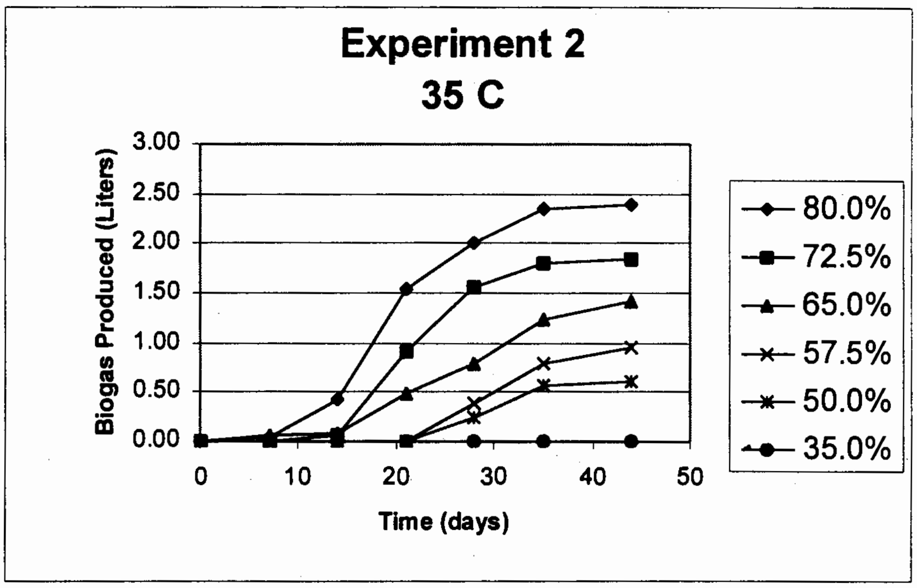


Figure 2. Average biogas produced per container at six different moisture contents with temperature of 35°C.