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Biogas Production Facilities on Farms
A 1985 Look at Recent Experiences

by

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ABSTRACT

Biogas is a useful fuel. It is being produced and used on some Canadian farms. Electricity cogeneration is the most common usage. Heat is recovered from the coolant and exhaust systems for digester and space heating. Results are poor on the refeeding of residue of anaerobic digestion as a protein supplement. There is also concern over the public perception of this practice as well as the high cost of recovery. It may, however, be a replacement for some minerals.

On the other hand, significant odour reduction was noted by all operators. This may have limited monetary value, but in several cases, it has permitted livestock operations to function in close proximity to neighbours.

Introduction

On-farm production of biogas by anaerobic digestion was first promoted by Lapp et al at the University of Manitoba in 1974, as a method of energy self sufficiency.

Work has expanded since that time and another 12 known biogas digesters using livestock manures have been constructed in Canada since 1978.

In the fall of 1985, R.G. Winfield and Associates, R.R. #2, Glanworth, Ontario, NOL ILO was hired to prepare a report on the perceived benefits, problems and experiences to date of these units. This paper is based on that report.

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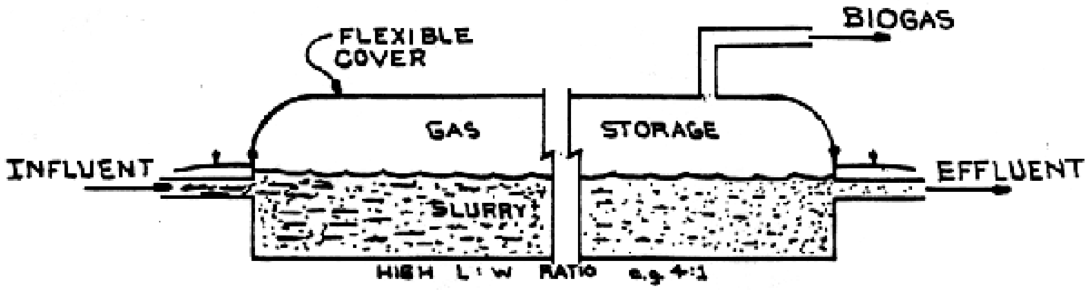
Types of Digesters

The three main types of digesters are shown schematically in Figure 1. Brief descriptions are:

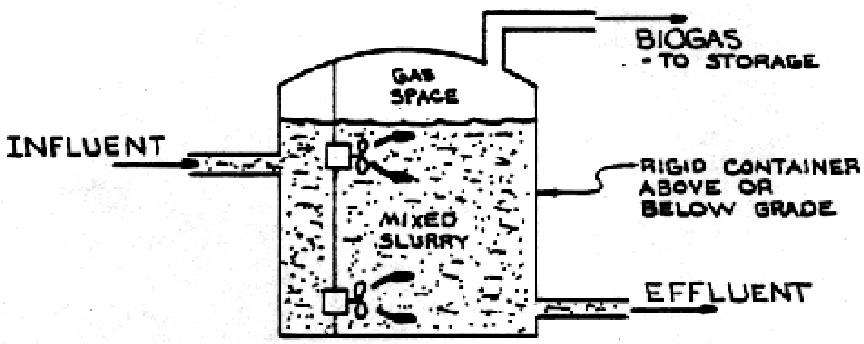
I. Tunnel flow or plug-flow. This is normally a relatively long horizontal, concrete channel with a flexible cover to contain and store the gas. Influent enters at one end and theoretically moves hydraulically as a "plug" to the discharge end.
   This system is working satisfactorily with dairy cattle manures of high solid contents (10% solids). Biogas storage is normally under the flexible cover over the concrete channel. It is the lowest cost of the 3 types.

2. Totally Mixed Digester. This is commonly a circular silo type configuration with a rigid top. It can be constructed above, partially above, or below grade.
   Provision is made to completely mix the digester contents, usually intermittently, to minimize foaming and energy use. Mixing methods include external drive paddles, submersible sewage sludge pumps and hydraulic circulation. There is no storage capability under the rigid top. These digesters appear to offer maximum flexibility of input materials.

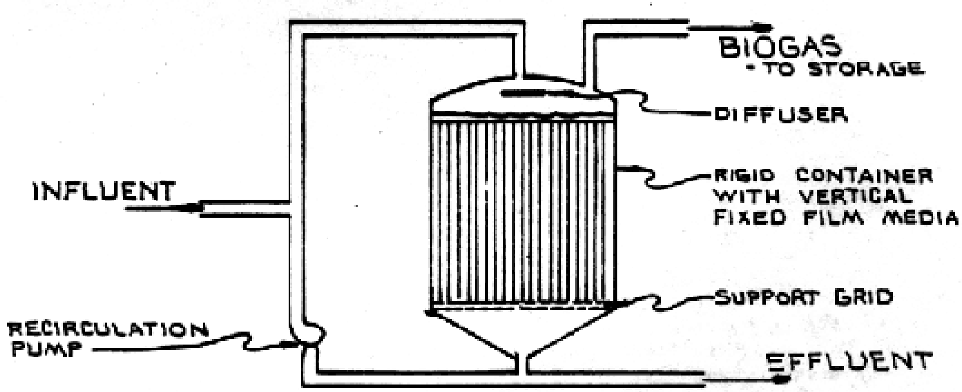
3. Fixed Film Digester. This concept was developed by the National Research Council of Canada. The technology is similar to that of the totally mixed digester except that the digester tank is filled with vertical 100 mm diameter, mechanically grooved PVC tubes cross webbing. These tubes, have a total surface area of $100m^2/m^3$ of digester, for bacterial attachment. Dilute manure with a low solids content appears to be a requirement for these units.
   The cost of the media can be quite high ($\$130/m^3$). Also prescreening is required to remove the larger solids and animal hair, which can cause plugging of the vertical tubes. This prescreening does remove some of the volatile solids. The concept needs further development before it can be generally recommended.



a) TUNNEL (PLUG FLOW) TYPE.



b) TOTALLY MIXED TYPE.



c) DOWNFLOW FIXED FILM TYPE.

FIGURE 1 : SCHEMATICS OF THE THREE COMMON TYPES OF ON - FARM ANAEROBIC DIGESTERS.

The Product

Biogas is a by-product of the anaerobic decomposition of organic materials. It is composed of 60-70% methane (CH_4), 30-40% carbon dioxide (CO_2) and small amounts of hydrogen sulphide (H_2S), water vapour and other gasses.

The CO_2 reduces the energy content of the gas in storage and causes a sluggish rate of burn. But compensating adjustments in burners and engines appear to permit satisfactory performance.

The H_2S levels vary from less than 0.1% to about 1%. The lower levels are tolerable and obtainable from some digesters. Factors affecting H_2S production levels are not well documented.

Water vapour should be condensed out and removed daily. Gas lines must be installed so that all condensation drains to a water trap(s).

Evaluation

Biogas is a useful fuel. It can be burned directly or used to fuel an engine to generate electricity. High grade heat can be recovered from the engine coolant and the exhaust system.

Engine Usage

This is the most common use of the biogas in Canada. It is used to cogenerate electricity on the Gasser Farms Ltd.*, Selves Farms Ltd., Pitten Farms Ltd., Linden Lee Farms, Folkema Farms, and CRIQ. Engine heat is also recovered on most of these units for digester heating and for space heating such as the farm home and office, farm shop, milking parlour, calf barn, weaner barn, etc.

At Cattleland Farms, the biogas is burned in an engine to provide hydraulic power to operate a centrifuge. Originally, 3 older gasoline engines were used. These have been replaced with one diesel unit. Surplus gas is flared.

The three farms visited in the U.S.A. also produce electricity. Two farms, Foster Bros. and Shugah Vale Farm sell all their production to the local utility and buy back at a lower rate. By producing during periods of peak demand, Foster Bros. realize $0.09 U.S. per kWh. Shugah Vale Farms are paid $0.78 U.S. per kWh. The third farm, Mason-Dixon utilizes all of the electricity as generated.

Most of the engines were SI (spark ignition) units designed to operate on natural gas. To burn biogas successfully, the timing had to be advanced significantly to compensate for the sluggish burning characteristics of the fuel. This was caused by the 30-40% carbon dioxide in the mixture. Also, the engine horsepower had to be de-rated by 30-40% because of the $C0_2$.

*See Tables 1-4 for digester type, location, characteristics.

Table 1 - Tunnel Digesters

Owner	Livestock	Digester Volume (m)	Retention Time (Days)	Usage	Benefits	Problems	Costs $ '000
Mason-Dixon Farm PA	1000 Dairy Cows	600 (increased later)	12	Electricity Co-generation	Provides electricity to run milking/dairy operation. Odour reduction	Scum formation	
Foster Bros. VT	330 Dairy Cows	600	20	Electricity Co-generation	Electricity sales @ $0.09/kWh. Heat water solids composted. Odour reduction.	Large gas storage required to permit day time operation only.	$250 U.S -1982
Shugah Vale Farm NH	350 Dairy Cows	750	22	Electricity Co-generation	Electricity sales @ $0.078/kWh solids composted for sale. Odour reduction.	Foaming on startup. Gas production lower than anticipated.	200 U.S -1984
Gasser Farms Ltd., P.Q.	350 Dairy Cows	880	25	Electricity Co-generation Barn heat	Produced 83% of their electrical usage.	Demand charges resulted in only 50% reduction in cost. Scum formation	200 +

Table 2 - Totally Mixed Digesters

Owner	Livestock	Digester Volume (m)	Retention Time (Days)	Usage	Benefits	Problems	Costs $'000
Cattleland Farm, Ontario	4000 beef animals	715	10	Odour Control Extensive ROAD feeding tried.	ROAD as protein supplement. Composting prescreened solids.	Palatability Reduced rate of grain.	$ 477
Selves Farms Ltd., Ontario	375 sow farrow to finish	212	15.5	Electricity Co-generation Home & shop heating ROAD usage	Electrical self-sufficiency on home farm only. Odour control.	Palatability of ROAD	270
Pittens Farms Ltd., Ontario	250 Dairy Cows	305	15	Electricity Co-generation Space Heating	Reduced electricity purchases		225
Linden Lee Farms, P.E.I.	Swine & Poultry	305	18	Electricity Co-generation Space Heating Grain Drying	Reduction of purchased energy. Odour Control	Cereal based ration possible causing low gas production.	166
Olds Agric. College, Alberta	110 sow farrow to finish & 50 Dairy cows	386	26	Odour Control	Demonstrate use of biogas & to test ROAD	Cereal based ration possibly causing low gas production. Floating straw.	

Table 3 - Fixed Film Digesters

Owner	Livestock	Digester Volume (m^3)	Retention Time (Days)	Usage	Benefits	Problems	Costs $'000
Folkema Farms Ontario	100 sows + followers	54		Electricity Co-generation Solids separated before digestion and refed.	Odour Control Reduced purchases of electricity.	Heat exchanger on engine exhaust failed.	
Centre de Researche P.Q.	1400 hogs	66	5	Electricity Co-generation Heat for greenhouse. Composting solids.	Odour control Demonstration	High content in H_2S gas possibly due to feeding of cereal grain.	
Kemptville of Ag. Tech. Ontario	160 steers	48	12	Research facility to test different manures, feeding rates, temperatures, etc.	Odour control Demonstration	Fixed film tubes plugged w/hair, and solids. High maintenance	$ 195

Table 4 - Other Digesters

Owner	Livestock	Digester Volume (m^3)	Retention Time (Days)	Usage	Benefits	Problems	Costs $'000
Fallis Farms, Ontario	95 sows + followers	108			Odour Control. Hoped to produce electricity.	Digester heat exchanger pipes corroded. Sludge accumulated in bottom. No longer operating.	
LEL Farms, Ontario	Swine	400	31	Heating farrowing room & nursery	Odour Control		Low cost simple concrete tank
University of Guelph, Ontario	Swine	several digesters		Varied	Research. Much information gained for design of other systems.		

Selves Farms Ltd. has found the biogas to be an extremely clean burning fuel. After extensive testing over a 2 year period, for presence of low pH or other contaminants, oil change intervals in its 90 kW generator have been extended to 2000 hours.

Cattleland Farms and the University of Guelph have both operated diesel engines by aspirating biogas into the air intake and injecting a small amount of diesel fuel to initiate combustion. Again the engine output must be de-rated and some (about 10%) diesel fuel is required. Biogas has a high octane rating and can be burned in high compression engines.

Biogas is produced continuously and electricity is used every day of the year on farms. Thus co-generation appears to make the best practical use of the fuel.

However, the biogas digester capacity must approximate the required daily electricity usage on the farm. This is further complicated by peak and valley demands of electrical usage.

In most cases, temporary gas storage is required to partially or fully meet peak demands. Selves Farms Ltd. feeds its digester twice daily to stimulate maximum gas production at periods of peak demand (morning and evening feedings). The gas is pumped into low compression storage tanks which provide for some 45 minutes of heavy demand usage.

The Mason-Dixon Farm in Pennsylvania partially overcomes this problem by maintaining a steady demand. Milking is on a 20 hour per day basis because of the very large herd size. This, however, is quite a unique situation. In most cases, the utility supplies some electricity to meet peak demands.

No farm has been able to achieve complete self sufficiency in electricity. Purchases are made to cover peak loads and down time. Judicious use of the biogas energy can provide the normal electrical load and the major part of every peak load. Good management is required, however, to ensure that peak loads are always partially met by the farm generator. Otherwise, demand charges will occur. Even a single heavy usage from the utility for 20 minutes during a billing period would generate a demand charge that would apply to the entire period. This, of course, reduces the dollar value of the farm produced electricity.

In general, generation of electricity is only 20-25% efficient. Cogeneration, where heat is recovered from the engine coolant and exhaust, can bring the combined efficiencies up to 60% or better. However, most farms require heat, except for digester temperature maintenance, during the cold months only.

<u>Heating</u>

Biogas is more efficiently utilized as a heating fuel than as a producer of electrical energy. Unfortunately, the gas cannot be practically liquified for long term storage.

The CRIQ in Quebec, has located its digester adjacent to 2 greenhouses which produces off season tomatoes. This site provides an excellent opportunity for the use of biogas as heating energy. LEL Farms Ltd., also plans to supply hot water heating to a farrowing nursery unit, if and when, biogas production is adequate.

Odour Control

This is a side benefit that cannot be overlooked, even thought it is difficult to put a monetary value upon it. Every digester operator appreciated this aspect of his system, even though he may not feel that it was essential in his operation.

On the other hand, the Cattleland Farms digester has been and will continue to be operated primarily to reduce environmental impact and permit the large feedlot to co-exist with urban encroachment. Cogeneration of electricity on this farm would be considered only if the utility buy back rate was high enough to justify the capital expenditure.

Likewise, LEL Farms Ltd. has installed a simple, rudimentary digester, at its own expense, primarily to control odours from an extensive swine and poultry complex.

Residue of Anaerobic Digesters (ROAD)

This product has also been called single cell protein and methane digestion residue. It does contain single cell protein as well as many other components. Some of these products, as determined by Mowat, at the University of Guelph are shown in Table 5.

Cattleland Ontario and Selves Farms Ltd., have fed or are feeding ROAD produced on the farm to their livestock. The purpose was to reduce the purchases of high priced proteins at Cattleland Ontario. More recently, Selves Farms Ltd. began using lower feeding levels of ROAD to replace phosphorus supplements. Savings of $7/tonne were evident in the premix.

Folkema Farms has screened some solids from the manure before digestion and refed this material to gestating sows.

ROAD has been promoted as a partial protein supplement, resulting in savings of purchased feeds.

In research at the University of Guelph, Mowat 1985, concluded that the ROAD produced from cattle wastes has little, if any, feeding value for beef cattle. When ROAD was the only supplemental protein source, growing cattle had markedly depressed weight gain and feed efficiency. The reduced performance was shown to be due, at least in part, to low nitrogen and energy availabilities.

ROAD produced from swine wastes has a much greater potential as a feed source, but mainly for beef cattle. The potential was shown to be much greater than cattle ROAD because of the higher crude protein and energy contents as well as improved crude protein and dry matter digestibilities. See table 5.

Table 5 Partial Nutrient Composition of ROAD produced from Beef Cattle and Swine Wastes

Nutrient	Mean		Range	
	Cattle	Swine	Cattle	Swine
Dry Matter (%)	20.7	22.6	17.1 - 28.6	19.6 - 25.6
Composition of dry matter				
Crude protein (%)	24.7	37.5	21.9 - 27.0	33.2 - 42.8
True protein (%)	14.7	18.7	9.4 - 18.4	14.6 - 22.2
Gross energy (kcal/g)	3.0	3.2	2.3 - 3.5	2.7 - 3.6
Ash (I)	36.4	36.4	30.0 - 43.1	30.4 - 42.3
Phosphorus (I)	1.6	5.1	1.3 - 2.2	2.4 - 6.5

Palatability was also a problem. Feed intake of groups of animals, steers and dairy cattle at the University of Guelph, and pigs at Selves Farms Ltd. was indeed reduced. Selves Farms Ltd. has added artificial flavouring trying to overcome this problem. Results have shown that this can be done successfully, from a feed intake point of view, but the cost of such materials about equals the savings in the cost of the phosphorus in the premix. Selves Farms Ltd. is now investigating the possibility of reducing other materials in the premix.

Other methods of overcoming palatability problems have included introducing the ROAD gradually, and feeding minimum amounts.

There has been some concern over the build up of heavy metals and of antibodies. This latter may have some beneficial effect.

Controversy has existing in the past concerning the feeding of dry poultry manure as a source of protein to beef cattle. Although, this may make sense from an economic point of view, public perception may be unfavourable. A zealous or inaccurate press report, for example, could force politicians, or food companies to declare that ROAD is not socially acceptable as a feed stuff for animals, and that food products in Canada, or in a particular province are not produced from animals being fed any form of recycled manure.

These things, plus the capital cost of equipment to recover ROAD indicate very strongly that this product is not a particularly attractive feed additive. Table 6 shows that the capital cost of the protein recovery system at Selves Farms Ltd., was nearly 1/3 of the total capital expenditure. A great deal more work is required before ROAD feeding can be generally recommended.

Table 6 - Summary of Capital Costs for Selves Farms Ltd. Anaerobic Digester & Protein Recovery System (July 1983)

Description	Cost $000	% of Total Capital
Site Work, Manure pumping & modifications	33	12
Digestion System	31	11
Biogas Utilization System including heating	62	23
Protein Recovery System	79	30
Digester control building, electrical and mechanical contracts, freight, engineering	64	24
	269	100

Summary

Without exception, owners of all anaerobic digester system visited are enthusiastic about the concept. In most cases, recovery of capital has fallen short of projections, but the added benefit of odour control is a real advantage.

Biogas production and cogeneration of electricity in Canadian installations has fallen short of expectations of electrical self sufficiency. It was also difficult to meet peak farm demands because of the lack of low cost biogas storage. Except for P.E.I., the buy-back rate offered by the utilities does not provide sufficient revenue to justify the relatively high capital expenditure that is required for two way energy flow.

The refeeding of the residue of anaerobic digestion (ROAD) had been projected as a significant source of protein supplement for livestock. However, the separation equipment is costly and both research results and field experience have proven that the product is not as valuable as originally considered. There is also concern about the public perception of the refeeding of this product. It is not recommended.

On the other hand, odour control does justify continuing research and development. Technology advancements, to improve biogas production rates and quality, will be in the best interest of farmers when renewable energy becomes price competitive.

Reference
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