
Possibilities for Anaerobic Digestion On Ontario Swine Farms

**Final Report
Project # 07/125
For
Ontario Pork**

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Introduction

This project involved the use of two pilot scale anaerobic digesters at the University of Guelph Ridgetown Campus to measure biogas production from liquid swine manure, liquid swine manure mixed with corn silage and liquid swine manure mixed with shredded sugar beets. To establish benchmark levels of methane production, the project started with swine manure (only). The other organic materials were added to the swine manure for the next phase of the study. The study was done using two pilot scale, mesophilic, complete-mixed digesters

The project was started in July, 2007 using the larger of the two digesters. Liquid swine manure was tested first. During October and November, corn silage was also added (i.e. along with the liquid swine manure).

The smaller digester was used to test treat sugar beets. This was started in January, 2008 and completed in February. This digester had also been operated using liquid swine manure for a period of time before the sugar beets and liquid swine manure were tested.

Background

Anaerobic digestion is the breakdown of organic matter in the absence of oxygen. A typical system involves adding heat to maintain a specific temperature. The input material is usually in liquid form and at least 60% of the solids are volatile solids (i.e. organic matter). This process typically takes around 20 to 30 days. It yields biogas and a liquid digestate. The biogas consists mainly of methane and carbon dioxide. Of the two gases, it is the methane (CH_4) that has the higher value, as it represents a source of energy. Most installations on farms in Ontario and other parts of the world use the methane to power a generator, producing electricity (and heat). Other installations may burn the biogas directly to produce heat. Still others, though not many at this point, use special systems to purify the methane so that it may be exported from the facility through the local natural gas lines.

Most of the on-farm interest in anaerobic digesters in North America has involved livestock manure. However, materials such as animal fats, which are high in volatile solids, can produce large amounts of methane very quickly. In addition, presently in Europe, many digesters are receiving corn silage and ground grains, as these materials also yield high amounts of biogas. A recent literature review by Van Haren and Fleming (2005) documented several types of systems (e.g. covered lagoon, complete mixed, etc.). It also listed several general truths concerning the technology: a) the potential methane yield for livestock manure is in the order of $500 \text{ L CH}_4 / \text{kg VS}$ (where VS = Volatile Solids), b) fresh manure yields more methane than aged manure, c) biogas typically contains 60 to 65% methane, 35 to 40% carbon dioxide and trace amounts of H_2S , NH_3 and H_2 .

In Ontario, farmers now have the ability to add to anaerobic digesters a certain amount of materials originating off the farm, without the huge amounts of red tape that applied to this practice until a few months ago. The process of using these materials has been streamlined, in an attempt to make better use of the energy contained in the

materials. Examples of these materials include: grease trap wastes (restaurants), septage, source separated organics (municipalities), slaughterhouse wastes, fish plant wastes, etc. Making it easier to access these products for anaerobic digesters will give industries more options for disposal and will give farmers access to products that can improve the performance of their digesters.

In 2007, the Ontario Power Authority announced details of a Standard Offer Contract that guarantees a set price for supplying renewable electricity to the power grid in Ontario. This price is higher than what has been available in the past and has increased interest among farmers in anaerobic digestion.

Anaerobic digestion has the potential to represent a source of income for Ontario farmers, mainly through the sale of renewable energy as electricity. Of course, there is also the potential to use “surplus” heat, or to burn the gas directly to produce heat, or to clean up the gas to allow export from the farm as natural gas.

Much is known on the subject, based on the large numbers of digesters in Europe. However, at this point, there is no experience on Ontario swine farms with these alternate organic materials, whether generated on-farm or off-farm. We need information on gas production for typical inputs that may be used in Ontario, as well as Ontario cost information.

Objectives

This project addresses Ontario Pork's number one research priority: the Environment. Environmental benefits of anaerobic digesters include: odour reduction from farm, pathogen reduction in digestate, reduced emission of greenhouse gases from farm, production of renewable energy. Specific objectives are:

1. To test liquid swine manure, by itself and with typical organic additions – including corn silage, off-farm sourced organic “wastes” and one other crop input – measuring biogas production and digestate quality.
2. To document logistical considerations for each recipe tested.
3. To calculate gas yields based on the 4 recipes used, and to calculate costs of producing electrical power for the various recipes.

Project Setup

General

This project was carried out at the Ridgetown campus of the University of Guelph. The original plan was to test four recipes: a) swine manure alone; b) swine manure mixed with corn silage; c) swine manure mixed with an organic “waste” from off-farm sources (e.g. grease trap wastes, waste oils, etc.); and d) swine manure mixed with sugar beets or ground grain (the choice to be dictated by logistics). Logistics dictated that only three of these options could be evaluated – a), b) and d). Each recipe needed to run for several weeks, allowing time for the microorganisms to reach equilibrium and for the system to stabilize.

The volume of gas production was recorded daily and gas samples were collected to determine the concentrations of methane for the various recipes. The gas was then flared off. Samples of inputs and outputs were collected for nutrient analysis.

The swine manure originated on a farm near Ridgetown – manure from the same farm was used throughout the study. This manure was tested to ensure that it was representative of Ontario swine farms.

Anaerobic Digester #1

The first digester is shown in Figure 1, with a schematic shown in Figure 2. It is a “complete-mixed” system, operating in the mesophilic temperature range (target 38°C). It consists of a mixing/preheat tank (liquid capacity = 3200 L), and the main digestion tank (liquid capacity = 7900 L, stainless steel), and all related piping, pumps, mixers, heating system and controls. Input materials are first pumped into the mixing/preheat tank in order to raise the temperature somewhat. In this way, there is less of a shock to the microorganisms when inputs are added to the digester (especially in winter). In addition, it allows for more convenient operation of the system, as materials don’t need to be prepared every day – they are already waiting in this first tank. Mixing is done in each of the digester’s tanks using a vertical shaft with paddles, driven by an electric motor. Timers operate the mixers on a schedule of one hour, four times per day for the mix tank, and ½ hour, five times per day for the digester tank. Any gas created during this period is captured and stored with the gas from the main digester. When it is time to add material to the digester, 450 L of liquid is first removed from the digester. Next, 450 L of liquid from the mix tank is added to the digester. This operation occurs typically once per day and four to five times per week. This gives an average hydraulic retention time for the system of approximately 20 to 25 days.



Figure 1 Pilot scale Anaerobic Digester #1 at the Ridgetown Campus – the mix tank is hidden and the main digester is the large tank on the right

Material was introduced to this digester on July 12, 2007. The system was considered to be at a steady state by August 21. Initially, 500 L of liquid dairy manure was added to the pre-mix tank. An additional 1200 L of dairy manure was added to the digester tank. This was done to inoculate the digester with the proper anaerobic organisms to facilitate digestion and the production of biogas. A few technical “bugs” were worked out of the system during this startup phase.

The digester was operated using only liquid swine manure from August 22 until October 9. Corn silage was then added to the mix, starting on October 18 and ending on November 26. The corn silage was added to liquid swine manure in a small tank and mixed, using a shredder pump, for about ½ hour. This mix was then typically pumped into the mix tank, and then transferred from the mix tank to the digester on a daily basis – for 5 days per week.

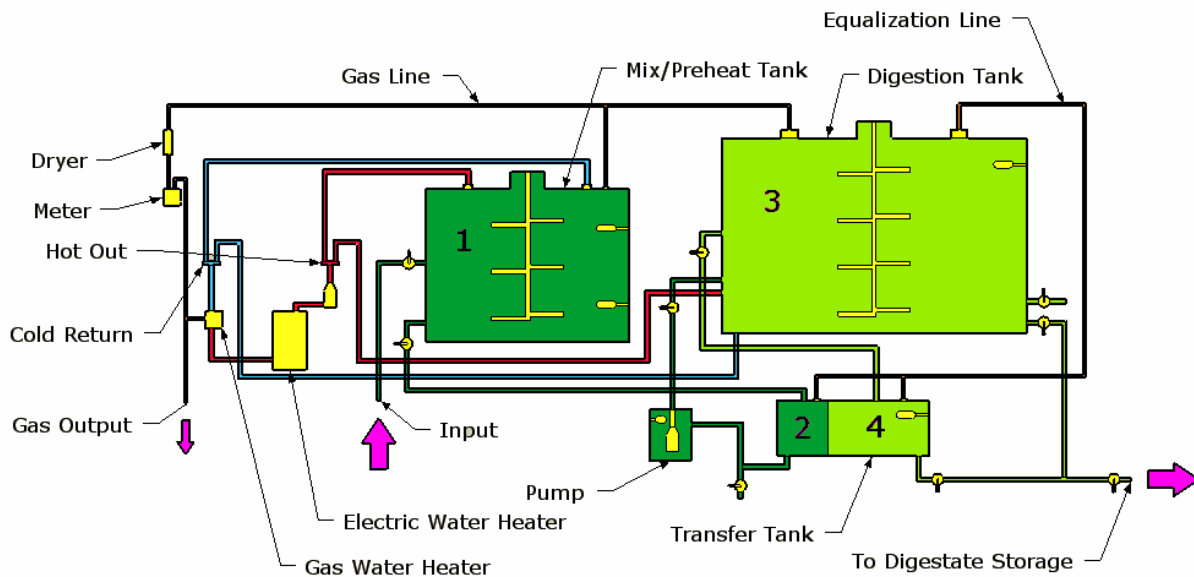


Figure 2: A schematic of Digester #1, showing the general layout and main components of the system

Anaerobic Digester #2

The second digester (see Figure 3) has a digester tank with a total volume of 2.2 m³. If a liquid depth of approximately 75 cm is maintained, the liquid volume is 1.45 m³. This is a trailer-mounted poly tank (un-insulated) that is portable and can also be used for on-site demonstrations. There are large windows for viewing - for demonstration and monitoring the digestion process. The average hydraulic retention time for this digester is intended to be approximately 21 days. This digester does not have a premix tank - all materials are added directly to the digester. It is heated using an electric water heater with a pump circulating the hot water through a heating loop inside the digester. The

digester has a hopper with an auger to feed solid materials into the digester. This can be run on a timer to introduce inputs gradually. There is an agitator (Delta Equipment Model PG mixer) with a timer that mixes the digestate 30 seconds every half hour or when required. This digester also has a gas flow meter to measure gas volume produced (Master-Touch MPNH, EPI – Eldridge Products Inc. model 800-321-FLOW). A gas analyzer (Pronova Analysentechnik, Model SSM 6000 Continuous) measures the levels of methane, oxygen and hydrogen sulfide in the biogas.



Figure 3: Digester #2 - Portable 2.2 m³ anaerobic digester

Digester #2 had been operating on liquid swine manure for a period of time before the start of the project. Sugar beets were chopped using a large wood chipper (see Figure 4) that could quickly shred the beets into small pieces. The sugar beets were then added to the digester using the attached hopper and auger. Liquid swine manure was added as well, but on a weekly basis. It was pumped into the bottom of the digester tank. This process ran into some problems, so the liquid swine manure and the sugar beets were premixed in a tank using a chopper pump. This mixture was then pumped into the digester. This also gave some problems, so the mixed sugar beets and liquid swine manure were added through the hopper and auger – which worked satisfactorily.



Figure 4: Wood chipper used to shred sugar beets into small enough pieces so they could be transferred into the digester.

Sample Collection

Samples were collected of each of the following: the raw materials added to the digester, the digestate upon removal from the digester, and the biogas. The following procedures were used for sample collection.

A – Sampling of Inputs and Digestate

Samples of the following were collected for nutrient analysis:

- fresh corn silage
- liquid swine manure
- digested corn silage and liquid swine manure
- shredded sugar beets
- digested sugar beets and liquid swine manure

The samples of fresh corn silage and sugar beets were collected when they were used. These were composite samples. Digestate samples were collected as the digestate was transferred out of the digester to the final storage. Samples were collected directly from the transfer stream.

B - Biogas Sampling

Between September 20, 2007 and December 13, 2007, 57 biogas samples were collected from Digester #1. This included biogas generated from liquid swine manure (18 samples from September 20 to October 8, 2007) and biogas generated from digested corn silage and liquid swine manure (39 samples).

The sampling procedure involved using a 20 mL syringe and a 3-way valve. Gas was drawn from the gas stream coming from a jet attached to the anaerobic digester and storage bag. The collected gas was then injected into a pre-evacuated sealed vial (10 mL). The vials were refrigerated until shipping to the lab.

First, the syringe was flushed with fresh air (at least three times) to ensure that the syringe contained no residual biogas. The 3-way valve has a tube that can be inserted into the gas jet to be sure no air contaminates the sample. Gas was drawn into the syringe and the needle was inserted into the pre-evacuated vial. The 3-way valve was rotated to allow the gas to enter the vial. Assuming the vacuum was intact in the vial, the syringe plunger would start to draw down and then the remainder of the gas was drawn into the vial. The syringe was left in the vial with the plunger held down for three to five seconds and then removed from the vial. The sample numbers were recorded, as well as the time and date of sampling and the presence (or absence) of a vacuum in the vial.

During sample collection there often wasn't enough gas pressure to produce a pure stream of biogas. As a result, a large number of the collected samples were contaminated with ambient air and gave results that did not represent the actual values expected from biogas. The sampling technique was changed on November 19 to address this issue. Unfortunately, this problem was not known until the results of the testing were received – several weeks after sample collection.

Sample Analysis

The nutrient samples were delivered to the Laboratory Services Division of the University of Guelph, Guelph, Ontario. All nutrient samples were tested for Total N, P, and K, NH₄-N, Total Carbon, Organic Carbon, Inorganic Carbon, Ash, Dry Matter, Electrical Conductivity and pH.

The initial gas analysis was done using Gas Chromatography by the lab of Dr Mario Tenuta, Department of Soil Science, University of Manitoba. These tests included methane, carbon dioxide and nitrous oxide. Results were reported in parts per million (based on volume).

From November 27 to December 4, 2007, seven biogas samples from Digester #1 were also tested using a portable gas analyzer (SEWERIN model SR2-DO). They were tested for methane, carbon dioxide, oxygen and hydrogen sulfide. Results were compared to the results from the gas chromatograph analysis.

Biogas samples from Digester #2 were tested using the gas analyzer (Pronova Analysentechnik, Model SSM 6000 Continuous) provided with the unit. These samples were tested for concentrations of methane, oxygen and hydrogen sulfide.

Results and Discussion

Liquid Swine Manure

The start-up phase of this study consisted of gradually adding liquid swine manure to the digester from July 12 to August 21. By August 22, the system appeared to be operating at a steady state and the liquid swine manure study was started. This study ran until October 9. Throughout the study 11,700 L of swine manure were digested with an average of 244 L throughput per day. This produced 264 m³ of biogas that averaged 68.0% methane (i.e. 180 m³ of methane was produced). The average daily biogas production was 5.7 m³ per day.

The digester performed quite well during this portion of the study. The average temperature in the digester was 37.3°C throughout this period. Ambient air temperatures were relatively warm during this period and the digester had no problems maintaining the desired temperature.

Liquid Swine Manure Mixed with Corn Silage

This part of the study was also run in Digester #1, continuing on from the “liquid swine manure” study. On October 18, a mixture of corn silage and liquid swine manure was added to the mix tank. The corn silage was of good quality, originating on a beef farm in the area. This study ran until November 26.

The requirement to mix the corn silage with liquid manure for this study was prone to problems. Unfortunately, this digester is designed to handle only liquid inputs – i.e. having a total solids content of up to about 10%. The corn silage had to be mixed so that it could be transferred as a liquid using a pump.

The manure was initially added to a 700 L tank. The chopper pump was started in a mixing mode and the corn silage was added gradually to the tank. Any silage that floated was pushed beneath the liquid surface using a shovel. The pump was allowed to run for an hour or more to maximize the amount of mixing and shredding that occurred.

Once the material appeared to be well chopped and mixed, the pump was connected to the mix tank fill line and the mixture was pumped into the tank. During this transfer, a shovel was used to manually move the settled solids. This transfer operation was prone to having the hoses plugged. In the event this happened, additional liquid swine manure was added to the original 700 L tank. This was then pumped into the digester mix tank. A small amount of swine manure remained in the digester mix tank from the previous study. It simply became part of the inputs to the digester.

The corn silage created significant “materials transfer” problems with the digester. As mentioned, transferring it into the mix tank often resulted in plugged transfer hoses. Pumping extra liquid manure through the hoses helped to unplug them. This, then, resulted in more liquid manure entering the mix than intended. Once the silage was in the digester mix tank, it frequently plugged the transfer hose and pump that moved the digestate from the mix tank into the main digester tank. The affected hose had to be back-flushed using a pump and liquid swine manure. Eventually, to avoid this plugging problem, the mixture of corn silage and liquid manure was transferred directly into the digester tank through a drain port (i.e. bypassing the digester mix tank). However, this too eventually plugged and could not be flushed. At this point, the study was halted.

Unfortunately, the transfer systems for the digester were simply not designed to handle coarse dry solids such as the corn silage. Because of the problems in mixing the corn silage into the liquid manure, the study was not able to achieve the target level of silage addition. Those systems in other parts of the world that successfully digest corn silage (e.g. in Germany) have made adaptations to handle this material. The important lesson is that the digester design must take into account the types of expected inputs.

This study ran for 39 days, ending on November 26. Throughout the study, 227 kg of corn silage was added to the digester along with 4681 L of swine manure. This was an average of 5.82 kg of corn silage per day and 120 L of liquid swine manure. This produced 214 m³ of biogas that averaged 55.8% methane - resulting in the production of 119 m³ of methane. The average biogas production was 5.5 m³ per day.

With colder temperatures towards the end of the project, the digester had difficulty maintaining the proper temperature. By early November the digester temperature had dropped to 31°C, lower than the target of 37°C. Unfortunately, this almost certainly would have had a negative impact on gas production.

Liquid Swine Manure and Sugar Beets

This phase of the study was carried out using Digester #2. It had been designed with the capability to handle solid inputs. These solids could be placed into a hopper, with an auger to feed the solids into the digester.

On January 9, 2008, the process of adding sugar beets was started. The sugar beets were of good quality, having only recently been harvested. As mentioned earlier, the sugar beets were shredded using a wood chipper. On each of January 10, 11, 14,

15 and 16, 2008, 33 kg of shredded sugar beets were added to the digester. This period was used as a time to deal with any operational issues and to develop appropriate protocols for dealing with this solid material. Digester #2 was equipped with a hopper and a 5.0 cm diameter inclined auger to feed solid material into the digester tank. Unfortunately, the auger did not handle the shredded sugar beets very effectively, so an operator had to gradually feed the sugar beets into the hopper - which was very time-consuming.

As noted, Digester #2 had a biogas meter that could measure the concentration of methane on a continuous basis. When the digester was loaded at the intended rate of 33 kg sugar beets per day, the quality of the biogas declined. Methane levels dropped from around 70% for liquid swine manure to as low as 37% when sugar beets were added to the digester at 33 kg/day. When loading was interrupted over the weekend (i.e. two days with no loading), the methane levels rose to around 70% by Monday.

On January 21, measurements for the manure and sugar beets began. Manure and/or sugar beets were added on several occasions until February 8. On January 24, liquid swine manure and shredded sugar beets were mixed in a tub using the chopper pump and the resulting liquid was pumped into the digester (i.e. the hopper was not used). However, there were problems getting all the solids into the digester using this method, so the remaining material was added through the hopper and auger. This appeared to work well, so this method was used to add sugar beets for the remainder of the study. On the days when material was added, loading rates were adjusted to 16.5 kg sugar beets per day along with 90 L of liquid swine manure.

By February 11, pumps to move the initial liquid manure had frozen in the nearby manure storage. As a result, no more material was added to the digester. Gas production was monitored until February 27, when it was apparent the pumping equipment was not going to thaw out. At this point, the study was ended.

During the study, a few leaks were discovered in the digester and in one case a valve was accidentally partly opened, allowing oxygen to enter the digester. This halted digestion. Methane concentrations continued to be quite variable during the entire study, with values in the range of 25.5% to 72.1% (STD = 9.6). The average methane content in the biogas during this study was 56.7%.

Even with the added blanket insulation on the exterior of the digester tank, the system still was not well insulated. It was very difficult to maintain the target temperature of 37°C when the ambient winter temperatures were much colder. The digester temperature dropped to as low as 28°C on one occasion. The average daily temperature during the test was 34.2°C (STD = 3.1).

This study ran for a total of 48 days, from January 9 to February 27, 2008. However, the period of greatest interest ran from January 21 to February 8 – a total of 18 days. During this time, 99 kg of sugar beets were added to the digester, along with 560 litres of swine manure. This was an average of 5.5 kg of sugar beets per day and 31.1 L of liquid swine manure. This produced 13.6 m³ of biogas that averaged 54.7% methane, yielding 7.44 m³ of methane. The average daily biogas production was 0.756 m³ per day.

Chemical Analysis

Results of the sample analysis of inputs and outputs are summarized in Tables 1 and 2. It is clear that the three inputs represent a range of chemical properties. Even though the N content was similar, a much higher percentage of this N was in the NH₄-N form in the swine manure than in the corn silage or sugar beets. The corn silage had the highest Volatile Solids content (i.e. 96.6%, on a DM basis) and the highest C:N ration (i.e. 44).

Table 1 - Average chemical characteristics of digester inputs

Parameter	Units	Swine Manure	Corn Silage	Sugar Beets
NH ₄ -N	mg/kg (as is)	3470	126	54.0
NH ₄ -N	mg/kg (DM basis)	91200	360	163
Total N	% (as is)	0.45	0.36	0.50
Total N	% (DM basis)	11	1.09	2.05
Total P	% (as is)	0.11	0.07	0.07
Total P	% (DM basis)	2.5	0.20	0.30
Total K	% (as is)	0.23	0.32	0.39
Total K	% (DM basis)	6.0	0.93	2.1
pH	pH units	7.4	8.3	4.5
Dry Matter	% (as is)	4.43	32.4	20.1
O.M. (VS)	% (DM basis)	65*	96.6	84.9
E.C.	mS/cm	9.2	1.4	NA
Total C	% (DM basis)	43	45	39
C:N	ratio	4.2	44	20

* Values for Ash Content (determined by Loss on Ignition) were missing for the swine manure. This data is needed to calculate the Organic Matter (i.e. Volatile Solids) content. The value was assumed to be equal to that obtained for a previous study, using swine manure from the same source.

One of the characteristics of the digestate that is demonstrated in Table 2 is that the NH₄-N now represents a much higher percentage of total N. This has implications for farmers who will rely on this liquid as a source of crop nutrients. As expected, values of total N, P and K in the digestate are similar to levels in the inputs – the digestion process should have no impact on these totals (even though the relative concentrations of different forms of N changes). The Dry Matter content of the digestate is lower than that of any of the inputs. The concentration of C in the digestate was lower than for any of the inputs, confirming that C is lost from the system in the form of methane and carbon dioxide. This is also confirmed by the fact that the C:N ratio for each digestate was rather low (i.e. in the range 1.6:1 to 3.2:1) – lower than for each of the inputs.

Table 2 - Chemical characteristics of digester outputs

Parameter	Units	Digestate from:		
		Swine Manure	Manure & Corn Silage	Manure & Sugar Beets
NH ₄ -N	mg/kg (as is)	4110	3710	2830
NH ₄ -N	mg/kg (DM basis)	109000	219000	92300
Total N	% (as is)	0.47	0.40	0.39
Total N	% (DM basis)	12.3	23.3	12.8
Total P	% (as is)	0.15	0.04	0.10
Total P	% (DM basis)	3.8	2.36	3.31
Total K	% (as is)	0.24	0.25	0.25
Total K	% (DM basis)	6.4	14.5	8.15
pH	pH units	8.17	8.20	8.10
Dry Matter	% (as is)	4.0	1.70	3.12
O.M. (VS)	% (DM basis)	NA	NA	NA
E.C.	mS/cm	11.0	11.2	NA
Total C	% (DM basis)	37.7	37.4	34.3
C:N	ratio	3.22	1.6	2.73

NA = Not Available

Digester Performance

A number of standard performance indicators are used in the evaluation of anaerobic digesters. These have been summarized in Table 3. They help to make comparisons between the three trials in a meaningful way.

Even though it appears that the sugar beet trial was rather short, the 18 days refers to the “steady state” period of inputs and active monitoring – following a startup period where sugar beets and manure were added to the system.

The normal target for the hydraulic retention time is in the range of 20 to 35 days. In each case, the mass of daily inputs could have been increased. This is further backed up by the low values for the Average Loading Rate (expressed as kg VS/m³ digester capacity). The rule of thumb is to not exceed a value of 4.5. In the study, values ranged from 0.67 to 1.26.

The concentration of methane in the biogas was highest (68%) for the swine manure. However, when looking at gas production expressed as L/kg VS, the mixture of corn silage and manure yielded the highest value. Somewhat surprisingly, the lowest value was for the sugar beets and manure mixture, although this test likely does not represent a fair assessment of the potential.

The conditions that were closest to “ideal” were experienced during the swine manure trial in Digester #1. The other two trials (especially the sugar beet test) ran into weather-related issues don’t show up in the Table 3 indicators.

Table 3 – Performance indicators for the 3 AD trials

Quantity	Units	Swine Manure	Swine Manure + Corn Silage	Swine Manure + Sugar Beets
Length of trial	days	48	39	18
Average Loading Rate	kg/day	244	5.82 kg corn silage + 120 kg manure	5.5 kg sugar beets + 31.1 kg manure
Average Hydraulic Retention Time	days	32.4	62.8	39.6
Volatile Solids added	kg/day	7.03	5.28	1.84
Average Loading Rate	kg VS/m ³ digester capacity	0.89	0.67	1.26
Biogas produced	m ³ /day	5.7	5.5	0.76
Methane Content	%	68	55.8	56.7
Methane Produced	m ³ /day	3.88	3.07	0.413
Methane Produced	L/kg VS	552	581	224

Energy Inputs

For both digesters, electricity is used to heat the digester and operate all of the equipment. In the first study (swine manure only), Digester #1 used 37.9 KWh per day. The largest single user was the heating system, which used 27.1 KWh per day. In the second study (i.e. swine manure and corn silage), Digester #1 used 58.8 KWh per day. The heating system was responsible for 47.1 KWh per day. The daily “non-heating” energy needs did not vary by much between the first two trials. The difference in energy inputs appears to be related to the fact that the second trial took place in colder weather and the heat input was therefore higher. Digester #2 was not equipped with an electricity meter, so corresponding data for the third trial (i.e. using sugar beets) were not available.

It would be possible to calculate the energy inputs to the system and compare these to the potential energy produced in the form of methane gas. This was never the focus of this study, however. Farm scale systems typically have a much lower heat loss (when expressed on a “per of unit volume basis”). Anyone designing a system must be aware that a certain percentage of the heat and electricity generated must go back into the system to maintain the digester temperature and run the equipment. The design challenge is to keep this percentage as low as possible.

Odour Analysis

Odours from the digestion of liquid swine manure were confined to the storage of the liquid swine manure prior to digestion. As expected, no odours were released from the digesters. The level of odours from the digestate, based on observations during transfer into an underground storage, was reduced compared to the un-treated manure.

Odours from the subsequent trials, using corn silage and using sugar beets, followed the same pattern.

Economic Analysis

An economic analysis was not carried out, as originally planned. However, a number of factors were identified that should be considered in performing such an analysis. These include:

- For materials that are available only on a seasonal basis, some form of storage will likely be needed on site.
- While labour inputs are minimal, regular supervision and monitoring of the digester is essential.
- There is no loss of plant nutrients from livestock manure during digestion.
- Currently in southwestern Ontario, corn silage has a value in the order of \$40 to \$45 per wet tonne, based on 35% DM (Wand, 2008).
- It may be possible to get quantities of organic material at little or no cost.
- Ontario's Standard Offer Contract guarantees a minimum price for electricity sold on to the grid and this arrangement covers a number of years into the future – taking some of the guesswork out of the budgeting process.
- In certain situations, a value may be placed on odour reduction or on possible pathogen reduction (not measured in this study but documented by others).

Summary

Between July, 2007 and February, 2008, a series of tests was performed using two small anaerobic digesters at the Ridgetown campus of the University of Guelph. Methane production was measured using the following three inputs: a) Liquid swine manure, b) swine manure mixed with corn silage, and c) swine manure mixed with shredded sugar beets. The main findings of the study are as follows:

- The mix of swine manure and corn silage yielded 581 L methane per kg of Volatile Solids. This value likely could have been exceeded if the temperature in the digester could have been kept on target during the latter portion of the test. Methane represented 55.8% of the total biogas production.
- Liquid swine manure (at 4.4% DM) yielded 552 L methane per kg VS. Methane represented 68% of the total biogas production.
- The mix of swine manure and sugar beets produced only 224 L methane per kg VS. Almost certainly, this value underestimates the true potential, as there were problems in maintaining digester temperature during the winter-time trials. Methane represented 56.7% of the total biogas production.
- The study ran into a certain level of hardship in blending the corn silage and the sugar beets with manure and introducing this liquid into the digesters. Even though this proved to be a challenge for the equipment used in this study, systems exist on the market that handle these solid inputs much better.

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