

## Anaerobic Digestion of Manure with Various Co-substrates

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### Introduction

The co-digestion of manure with other substrates such as energy crops, industrial wastes, or food industry wastes enhances biogas production. The addition of co-substrates to manure can improve the carbon to nitrogen balance which results in a stable and maintainable digestion process [1]. Co-digestion also improves the flow qualities of the co-digested substrates [2]. Perhaps the most important drivers for co-digestion of manure with other substrates are the financial benefits associated with the increased biogas yields and income generated from tipping fees when wastes are used as co-substrates. Several studies have been conducted to determine the optimum biogas and methane yields associated with the co-digestion of manure with co-substrates including: corn silage, switchgrass, canola seed cake, whey, waste grease, food waste and corn stillage.

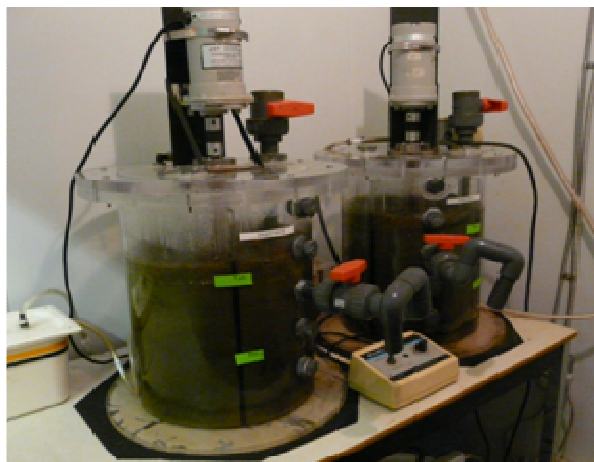
### Bench Scale Digestion Trials to Optimize Biogas and Methane Production

Biochemical Methane Potential (BMP) assays can be used to screen various mixtures of manure and co-substrates for optimum biogas production. The basic approach of a BMP assay is to incubate the substrates, under batch conditions, with an anaerobic inoculum and measure the methane generation [3]. BMP assays are conducted using 500 mL serum bottles and agitated at 120 rpm under mesophilic conditions (35°C). Cumulative biogas production is measured and biogas composition determined using a gas chromatograph.



Credit: ORWC

Figure 1: BMP Assays Using Dairy Manure and Waste Grease



Credit: ORWC

Figure 2: Bench Scale Semi-Continuous Digesters using Dairy Manure and Corn Stillage

To optimize biogas production the digestion process is scaled up to bench scale anaerobic digesters. The semi-continuous digestion studies are conducted in 30 L Plexiglas reactors (Figure 2). The digesters operate as completely stirred tank reactors (CSTRs) using impellers for intermittent mixing. All biogas is collected and volume measured using wet tip meters. The reactors are housed in a heat room maintained at 35°C for mesophilic operation. The digesters are used to determine biogas (m<sup>3</sup>/kg VS) and methane (m<sup>3</sup> CH<sub>4</sub>/kg VS) yields. Yields are optimized by changing operating conditions such as organic loading rates (OLRs), hydraulic retention times (HRTs) and feed compositions.

The co-digestion of manure with various co-substrates is very successful in enhancing biogas and methane production. Table 1 presents mean biogas and methane yields obtained from the co-digestion of dairy manure with energy crops or industry wastes. Typically the addition of only 30% co-substrates enhanced methane yields by anywhere from 1.2 to 1.6 folds when compared to the digestion of dairy manure alone. As the ratio of co-substrates, such as waste grease or corn stillage, are increased methane yields double compared to digesting manure alone.

**Table 1: Biogas and Methane Yields from Digestion of Dairy Manure with Co-substrate [4, 5]**

Substrate (% based on VS of substrates)	Mean Biogas Yield (m <sup>3</sup> /kg VS <sub>initial</sub> )	Mean CH <sub>4</sub> Yield (m <sup>3</sup> CH <sub>4</sub> /kg VS <sub>initial</sub> )
100% Dairy Manure	0.378	0.235
70% Dairy Manure + 30% Corn Silage	0.465	0.305
70% Dairy Manure + 30% Switchgrass	0.479	0.285
70% Dairy Manure + 30% Whey	0.433	0.303
70% Dairy Manure + 30% Waste Grease	0.511	0.358
60% Dairy Manure + 40% Waste Grease	0.569	0.398
70% Dairy Manure + 30% Corn Stillage	0.527	0.301
60% Dairy Manure + 40% Corn Stillage	0.630	0.402

## Monitoring of On-farm Full Scale Digester Systems

### Biogas Production

Several full scale manure digesters in Ontario are being monitored for biogas production and digestate quality. Table 2 presents average biogas and methane yields from two digesters running on dairy manure and waste grease. With the addition of waste grease (45% by vol.) methane yields double when compared to digesting manure alone.

**Table 2: Biogas and Methane Yields from Digestion of Dairy Manure with Waste Grease at Full Scale Digesters**

Digester Feed Composition	Mean Biogas Yield (m <sup>3</sup> /kg VS <sub>initial</sub> /day)	Mean CH <sub>4</sub> Yield (m <sup>3</sup> CH <sub>4</sub> /kg VS <sub>initial</sub> /day)
Dairy Manure	0.479 ± 0.012	0.287 ± 0.009
Dairy Manure + Waste Grease	0.897 ± 0.031	0.583 ± 0.015

### Pathogens

Anaerobic digesters have been shown to reduce pathogens in the digestate. Pathogens are inactivated during exposure to heat and competition with other bacteria groups within the digester. Pathogen destruction depends on temperature and the duration of exposure. Table 3 presents average log reductions in pathogen indicator concentrations at two on-farm digesters operating under mesophilic (40°C) conditions and HRTs > 35 days. Reductions in pathogen indicator concentrations ranged from 1 to 2 logs, which is similar to what has been reported in literature [6, 7].

**Table 3: Geometric Mean Bacteria Concentrations in Full Scale Digesters Using Dairy Manure and Waste Grease**

Pathogen Indicators	Raw Manure (CFU/100 mL)	Digestate (CFU/100 mL)	Log Reduction
<i>E.coli</i>	6.00 x 10 <sup>7</sup>	2.90 x 10 <sup>5</sup>	2.32
<i>Salmonella</i>	6.51 x 10 <sup>4</sup>	8.84 x 10 <sup>3</sup>	0.87
<i>C.perfringens</i>	3.81 x 10 <sup>6</sup>	2.99 x 10 <sup>5</sup>	1.11
Enterococci	9.11 x 10 <sup>6</sup>	7.29 x 10 <sup>5</sup>	1.10



*E.coli* (Raw Manure)



*E.coli* (Digestate)

## Odours

Odours associated with manure are primarily composed of volatile fatty acids (VFAs), ammonia (NH<sub>3</sub>) and phenolic compounds. VFA concentrations monitored in two on-farm digesters are presented in Table 4. The digestion process is highly effective at removing 96% of the VFAs in the digestate and ultimately removing the majority of odours associated with manure and other wastes.

**Table 4: Mean VFA Concentrations in Full Scale Digesters Using Dairy Manure and Waste Grease**

<b>VFAs</b>	<b>Raw Manure (g/L)</b>	<b>Digestate (g/L)</b>	<b>% Reduction</b>
Acetic Acid	4.62 ± 1.18	0.17 ± 0.09	96
Propionic Acid	1.52 ± 0.59	0.08 ± 0.02	95
Butyric Acid	0.88 ± 0.43	0.00	100
<b>Total VFAs</b>	<b>7.03 ± 2.21</b>	<b>0.25 ± 0.18</b>	<b>96</b>

## Conclusion

Anaerobic digestion has been demonstrated to be a highly effective process for producing sustainable alternative energy at the farm with methane production increased by adding co-substrates to the digestion process. The digestion process has also demonstrated the environmental benefits of reducing pathogens and reducing odours from the digestate. The fertilizer value of the digestate is also improved by transforming nutrients into their inorganic form, thereby becoming more available for plant uptake. The adoption of anaerobic digesters on Ontario farms could provide economic benefits as well as environmental benefits to the farm operation.

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