Small Scale Anaerobic Digestion in an Urban Environment

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Abstract

Climate change is quickly impacting the environment . Humans are an active contributor to the increasing rates of climate change; food waste contributes to 8% of greenhouse gasses. At Loyola University of Chicago there is a need to work towards reducing this carbon footprint, this can be done using Loyola's food waste. The food waste can be captured and utilized in the processes of anaerobic digestion to create biogas. Anerobic digestion follows four steps, hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Introducing this program to Loyola will help eliminate food waste and benefit the environment. In order to accomplish Loyola's net carbon goals, we have experimented with small-scale anaerobic digesters to test this beneficial program.

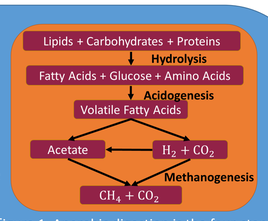

Figure 1. Anerobic digestion is the four-step process of breaking down food waste

Introduction

The small batch anaerobic digesters resemble the reactors that could one day be used on Loyola's campus. Some investigations have already been completed to find the different pretreatments that the inoculum could undergo. The pretreatments help determine what would be most effective in producing methane gas. Experiments have also been conducted to understand how the system stays healthy. A list of previously conducted experiments can be seen below.

- Different levels of Dilution
- Different levels of Aeration
- Caps kept off for extended periods of time
- Different amounts of feed
- Number of feedings

An explanation of the basic set up, and an example experiment can be seen in the Methods Section

Definitions

Anaerobic Digestion- A four step process in which waste is broken down by anaerobes to produce methane
Hydrolysis- When a molecule of water breaks one or more chemical bonds. The lipids, carbohydrates, and proteins in food waste break down to become fatty acids, glucose, and amino acids [1]
Acidogenesis- When the fatty acids, glucose, and amino acids ferment to become volatile fatty acids [1]
Methanogenesis- The process in which anaerobes consume volatile fatty acids to produce CO_2 and CH_4 [1]
Acetogenesis- The process of volatile fatty acids, or CO_2 becoming broken down into acetate. This process can happen directly after acidogenesis or after methanogenesis [1]
Substrate- The food that anaerobes consume
Influent or Inoculum-The digestor drawl used as the base for the experiments
Effluent- The different gasses collected, as well as the remain drawl
Automatic Methane Potential Test System (AMPTS)- The system used to conduct experiments from BPC instruments

Materials

In order to conduct an anerobic digestion experiment to gather data on methane production at a small-scale level the AMPTS must be utilized. AMPTS experiments all follow a similar procedure. Preliminary to an experiment being conducted the following materials must be gathered.

- Automatic Methane Potential test system
  - The AMPTS Scrubbers are filled with 2M NaOH
  - Figure # shows the different pieces to the AMPTS that are needed
- Crucibles
- Tongs
- Furnace
- Incubator
- Dessicator
- Inoculum- Digester drawl from Metropolitan Wastewater Reclamation District
- Substrate
- A scale
- A funnel
- Ethanol
- Gloves, goggles, lab coats
- Water

Once the materials have been gathered the methods below can be followed to collected data

Methods- TS/VS

•Total solids versus volatile solids tests are carried out to determine how much inoculum and substrate is needed
- •First the crucibles are burned at 550 °F in the furnace for 30 minutes, this is to ensure that anything that was in the crucibles is now gone
- •Place crucibles in the dessicator. Be sure to use tongs and oven mitts to ensure safety. Let the crucibles cool for 30 minutes
- •Once the crucibles are cooled weigh them. Be sure to keep track of the order that the crucibles are in to properly conduct TS/VS. This is the dry crucible mass.
- • Then fill each crucible with either inoculum or substrate. It is best to have three of each. Record the weights.
- • Once all the crucible's weights have been recorded place each one into an incubator set to 105 °F for 20-24 hours
- • After the time in the incubator weigh the samples again. This is the samples dry weight. All of the water in the crucibles has evaporated. While weighing one crucible keep all others in a dessicator.
- • Next, place the crucibles back into the furnace for 2 hours at 550 °F. After the two hours weigh the crucibles again to get the burned weight of the samples.
- • Once all the weights are taken use the AMPTS software to determine the amount of inoculum to substrate needed to start the experiment.

References And Acknowledgements

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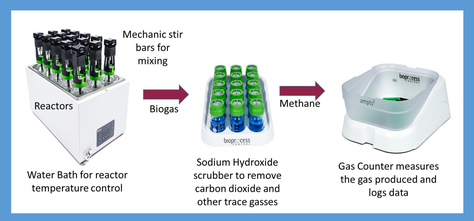
1. Park, Jong-Hun, et al. "Effect of Feeding Mode and Dilution on the Performance and Microbial Community Population in Anaerobic Digestion of Food Waste." *Bioresource Technology*, Elsevier, 8 July 2017, https://www.sciencedirect.com/science/article/pii/S0960852417311124.
2. Bonk, Fabian, et al. "Intermittent Fasting for Microbes: How Discontinuous Feeding Increases Functional Stability in Anaerobic Digestion." Biotechnology for Biofuels., vol. 11, no. 1, BioMed Central,, 2018, https://doi.org/10.1186/s13068-018-1279-5.

Methods

- After TS/VS numbers are collected it is time to set up the AMPTS experiment. The set up of the AMPTS experiment can be seen in figure 2
  - Each different treatment could require a different substrate to inoculum ratio. Follow what the software says is the correct weight of each when filling the fifteen 500mL bottles. Use the scale and funnel to fill each bottle with inoculum. It should be around 400 grams of inoculum. Make sure to label each bottle to keep track of the different triplicates
  - Turn on the water bath so that it can warm up.
  - While the water is heating up make sure that the software is set up to start a new experiment.
  - Begin to arrange the bottle in series. It should look be organized similar to figure 3.
  - Attach the caps to the bottles, and attach the wires in series to ensure that each bottle is properly mixed.
  - Check that the tubes that run from the bottles to the scrubbers are attached correctly and in order. Then check the tubes between the scrubbers tubing to the gas counter.
  - Once everything is in order the software can start collecting data, and the bottles will start mixing.
  - Feed different bottles as often as decided per experiment

Figure 2. AMPTS schematic diagram. Using AMPTS allows for the quantification of methane and total gas from a series of AD reactions performed in parallel. Figure adapted from BPC Instruments.



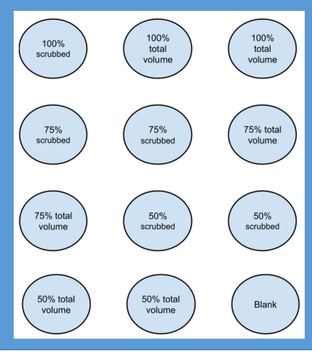


Figure 3. Reactors schematic. Demonstrates how the reactors are organized and filled.

How to Read AMPTS Data

The following experiment was conducted in 2022. The experiment was used to see how the different sizes of microbe populations effected methane production. The inoculum was diluted at various amounts. Both the volume of total gas, carbon dioxide, methane and other gasses, and just methane were collected. Each dilution was fed an initial amount of substrate, then two more times. Although AMPTS software does produce a graph, it is easier to understand the trends if the data is put into MATLAB. The following figures show the trends in each triplicate.

From figure 4 it can be seen the undiluted inoculum preforms the best with the most methane production. However, the 75% inoculum trial was not far behind. This means that if a quarter of the microbe population dies out for some reason methane can still be efficiently produced.

In figures 5,6,7 each dilution of inoculum has graphs showing how the different feedings effected gas production. For all three setups it can be seen that with each feeding there was an increase in gas production. Again, the graphs between the 100% and 75% inoculum look similar, with the feeding likes following similar patterns. In all the experiments the third feeding produced the most gas. This could be because the microbial population has been established and ran out of substrate from feedings one and two.

Visualizing data is helpful in determining how to optimize conditions for the most effective food waste removal and biogas production. This data is also helpful in determining next steps.

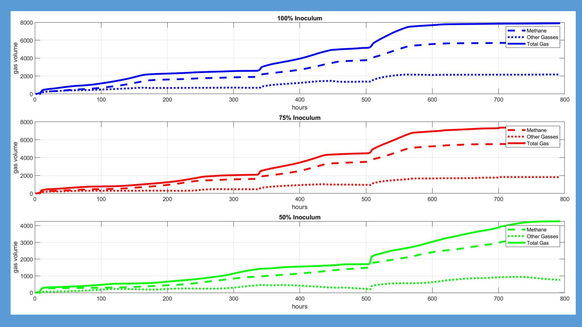


Figure 4. All three pretreatments. Volume of gas produced versus time. Gas compositions displayed

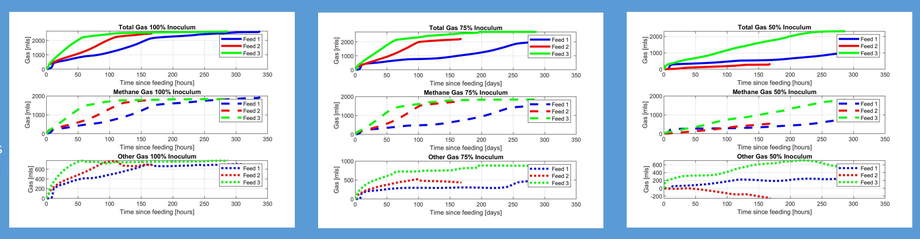


Figure 5. (Left) 100% Inoculum. Figure 6, (Middle) 75% Inoculum. Figure 7. (Right) 50% Inoculum. Gas produced versus time. Displaying how much gas each feed produced. 1st feed was the initial feeding from the set-up

Future Outlook

There is still plenty to investigate when it comes to advancing anaerobic digestor knowledge, and how it can be applied to an urban campus setting. The following items are suggested for further research

- Three out of the fifteen reactors were used to collect gas into gas bags. No data was taken from these, but the collected gas can be experimented on. Gas chromatography can be used to determine the contents of the "other gas"
- More feeding experiments can be carried out to determine how often the reactors should be fed to create maximum gas production
- Feeding experiments should be conducted to determine an effective ratio of lipids, carbohydrates, and proteins
- Gene sequencing can be utilized to determine the microbes that are more fit from the systems
  - This will help build a catalog of microbes that are useful for anaerobic digestion