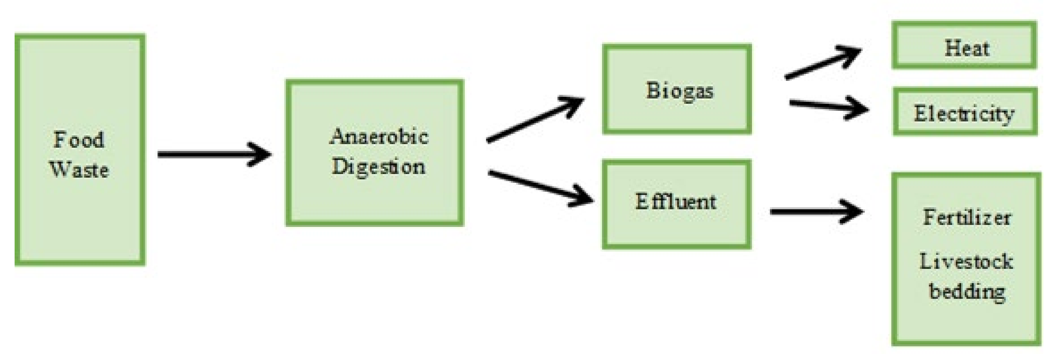
Visual Biogas Production Experiment Using Anaerobic Digestion of Food Waste for Educational Use

Jeffrey Brashich[1] and Miranda Wolf[2]
[1]Dept. of Civil and Environmental Engineering, Clarkson University
[2]Institute for a Sustainable Environment, Clarkson University
Dr. Jan DeWaters and Dr. Stefan Grimberg, Clarkson University

Abstract

Food waste represents approximately 20% of solid waste entering municipal landfills. Organic wastes in landfills are responsible for a significant release of greenhouse gas emissions contributing to climate change that is currently occuring on Earth. Therefore, it is important to teach youth about alternative ways to dispose of food waste that has a positive impact on the environment and sustainability rather than a harmful one. Anaerobic digestion is one of the limited number of ways to dispose of food waste while still being able to recover valuable resources instead of sending food waste to municipal landfills. The multi-step process of anaerobic digestion produces two valuable by-products: effluent and biogas. Biogas is an energy source that can be used to generate heat and/or electricity while the digester effluent can be used as a fertilizer. Using a balloon and Tedlar bag experiment, anaerobic digestion can be modeled in a classroom setting with the ability to be applied to different education levels. The purpose of the experiment is to provide an easy-to-use educational resource for teaching K-12 students the importance of recycling food waste. The experiment consists of combining digester seed (organisms), with samples of food waste from the school cafeteria to visually show biogas production. With the use of Tedlar bags and balloons, students can measure biogas volume and concentrations for different food waste types.

Figure 1.
A flowchart showing the process of anaerobic digestion and its products



Background

- At Canton Central Schools, grades 6-12 collect excess food waste during lunch hours.
- The food waste is transported over to Cornell Cooperative Extension for use in an anaerobic digester.
- This experiment helps to link the efforts in the classroom to its applicable environmental impact, by serving as a visual aid for students
- Providing a hands-on experiment provides students with the background knowledge, potentially increasing participation.

Figures 2. Food collection done by students in the Canton Middle School

Objectives

- Educate 6-12th students about waste disposal and what the best and most sustainable options are
- Create an experiment that can be used in 6-12th classrooms to model anaerobic digestion and the benefits of it, such as visual biogas production
- Analyze the data obtained from the experiment to identify which substrates are the most efficient at producing biogas and which produced the highest methane concentrations
- Make a lasting impact on how students view anaerobic digestion and food waste disposal

Experiment

Variables:

- Exact amount of substance added to bottles
- Volume of the balloons and bags
- Permeation through the balloons
- Variation in bottle temperature, changing the reaction rate
- The airtightness of the systems

Set-Up:

1. Label the bottles with which substrate will be placed in it
2. Obtain 60 grams or 60 ml of substrate for each bottle
3. Obtain 200 ml of effluent for each bottle
4. Place the substrate and the effluent into the bottles and stir
5. **Balloon Experiment:** stretch the balloon around the mouth and use electrical tape to seal the balloon to the bottle
6. **Tedlar Bag Experiment:** screw the top on the bottle and open the valve on the tedlar bag
7. Place the bottles in the sand in the terrariums and turn the heat lamps on

Monitoring:

- check experiment daily
- record observations on the size of the apparatuses
- change tedlar bags if needed
- Measure concentration

Materials:

- Reactor setups (squeeze bottle, tubing, tedlar bag)
- Labels
- gloves
- 2-3 Terrariums with sand about 3-4 inches tall with two heat lamps attached on the outside
- Large graduated pitchers
- Aluminum Weigh Pans
- Digester effluent: (30) x (200ml) = 6 L
- Food waste - 9 x 60g = 600 g of each substrate
- Heating lamps

Figure 3. Tedlar bag experiment setup

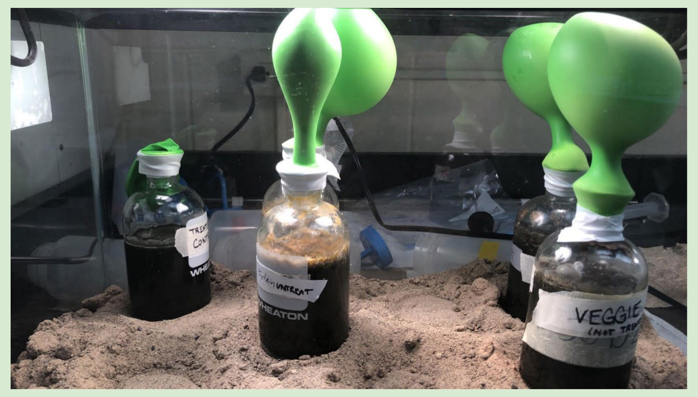
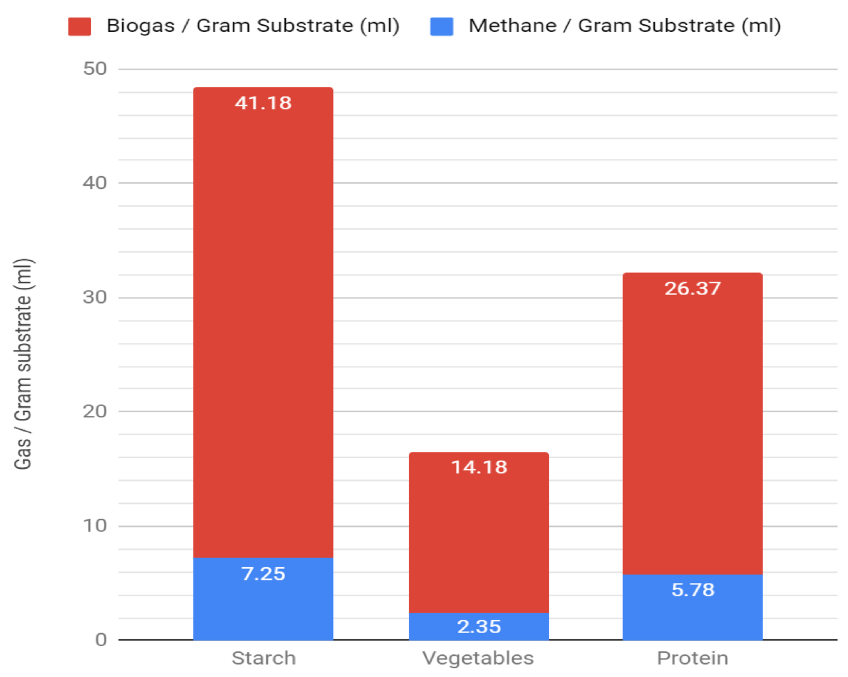


Figure 4. Balloon experiment setup

Data Collection and Results

Data was collected by each group of students at the end of the week. The volume of bags was measured using displacement techniques. The gas concentrations were measured by the instructor. 27 total groups produced a total of 41 bags needed to be measured. Particularly in regards to this experiment, it was determined that starches are the most efficient at producing methane, due to the sheer volume of gas being produced, while vegetables produced the highest methane concentration biogas.



Substrates	Total volume Biogas (L)	Average volume Biogas (L)	Total volume methane (L)	Average methane %	Average methane Volume (L)	Biogas / Gram Substrate (ml)	Methane / Gram Substrate (ml)	Required for 1 L (g)
Starch	22.24	2.47	3.91	16.84	0.42	41.18	7.25	24.28
Vegetables	7.66	0.85	1.27	17.36	0.1	14.18	2.35	70.51
Protein	14.24	1.58	3.12	16.7	0.33	26.37	5.78	37.93

Discussion

Biogas is the resulting mixture of multiple organic based gases, primarily Carbon Dioxide (CO_2) and Methane (CH_4) and water vapor account for approximately 90% of the gas. Trace amounts of things like Carbon Monoxide (CO), Hydrogen Sulphide (H_2S), Volatile organic compounds, and particulate matter totaling < 10% [1]. The variation in the resulting biogas makeup is due to differences in feed composition and operating conditions of anaerobic digesters. The process in which biogas is produced is managed by multiple different types of anaerobic microbes. Each are in a symbiotic relationship, producing molecules for each other resulting in gas production at multiple stages. Multiple groups of organisms involved in producing biogas and the concentration of methane in the gas depends on how well the organisms work together.

As multiple stages occur during the anaerobic digestion process, the rate of gas production will vary with time. The maximum rate of gas being produced usually occurs around the 24-hour mark from the start of the experiment, usually falling off towards day 3. Although the concentration of methane in the biogas only increases as the reaction matures. Overall this experiment favored Carbon Dioxide production over Methane production. This reaction can also be easily modified to increase or decrease gas production, as well as experimenting with different seed to substrate ratios.

Summary

- Easy way to visually demonstrate anaerobic digestion and food breakdown
- Provides a universal educational experiment for teaching about anaerobic digestion and biogas production
- Through the use of the Tedlar bag experiment, methane gas concentrations and production rates can calculated. This allows for analysis of the efficiencies of different variable inputs (cellulose, protein, carbohydrates, polysaccharides, lipids, etc.)

Sustainability

- Anaerobic digestion minimizes the amount of food waste that ends up in municipal landfills which helps limit the amount of harmful greenhouse gases produced by landfills
- Biogas, one of the byproducts of anaerobic digestion, can be used as a cleaner from of energy
- The Tedlar bag and balloon experiment is a key way to educate children of all ages on sustainable practices. Today's children are tomorrow's future and teaching them how to be sustainable and getting them interested in sustainability is key for a better future of the Earth

References

[1] Jeff Kuo & Jason Dow (2017) Biogas production from anaerobic digestion of food waste and relevant air quality implications, Journal of the Air & Waste Management Association, 67:9, 1000-1011, DOI: 10.1080/10962247.2017.1316326

[2] Cunsheng Zhang, Haijia Sua, Jan Baeyens, Tianwei Tan (2014) Reviewing the anaerobic digestion of food waste for biogas production, Renewable and Sustainable Energy Reviews, V38, 383-392, DOI: 10.1016/2014.05.038