The Application of Citizen Science to a Visual Biogas Production Experiment Using Anaerobic Digestion of Food Waste for Educational Use

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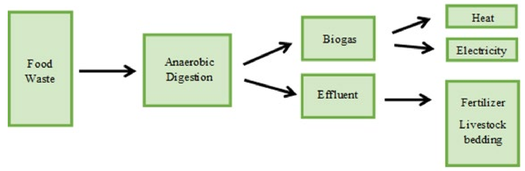
Abstract

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. Therefore, it is important to teach youth about alternative ways to dispose of food waste that have positive impacts on the environment and sustainability rather than harmful ones. Anaerobic digestion is one of the best ways to dispose of food waste while still allowing for the recovery of valuable resources instead of sending food waste to landfills. The multi-step process of anaerobic digestion produces two valuable by-products: digestate and biogas (Figure 1). Biogas is an energy source that can be used to generate heat and electricity and digestate can be used as a fertilizer. Using a simple bottle-reactor experiment, anaerobic digestion can be modeled in a classroom setting for different educational levels. The experiment consists of combining digester seed with food waste to visually show biogas production. With the use of Tedlar bags, students can measure biogas volume and concentrations for different food waste types. Due to COVID-19 this year, three classes (10 sections) high school classes were mentored asynchronous through Zoom to perform the experiment. Each class set up reactors and duplicates at Clarkson were set up as well. All the data collected was combined for analysis, creating a citizen science experience to enhance learning. The purpose of the experiment was to provide an educational resource for teaching K-12 students the importance of recycling food waste and to stress how critical citizen science is to learning and the scientific field. With this experiment, the students were able to see real world environmental impacts while still in the classroom.

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



Background

- In the past two years, an experiment similar to this one has been conducted in Canton Central School District (CSD) high school classrooms with the help of Clarkson University students.
- With COVID-19, being in classrooms at Canton CSD was not feasible, so Clarkson students created a video lecture for the students to view beforehand and then zoomed in to show how to set up the experiment. This also engaged the students who were learning remotely.
- This year since each section could only set up one rector due to limited number of students in person, we incorporated a citizen science aspect to the experiment

Figure 2. The simple bottle reactor experiment that has been used for the past two years

Objectives

- Educate 6-12th grade students about waste disposal and what the best and most sustainable options are for food waste disposal.
- Perfect an experiment that can be used in 6-12th grade classrooms to model anaerobic digestion and the benefits of it, such as visual biogas production and adapted the hands-on experiment so it can take place when students are learning remotely.
- Use the application of citizen science to give students an introduction to an important practice used in the scientific field.
- Make a lasting impact on how students view anaerobic digestion and food waste disposal

Experiment

Variables:
- Type of substrate used (independent variable)
- Volume of gas producced
- Concentration of methane produced

Set-Up:
1. Label the bottles with which substrate will be placed in it
2. Obtain 30 grams 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. Screw the top on the bottle and open the valve on the tedlar bag
6. Place the bottles in the sand in the terrariums and turn the heat lamps on

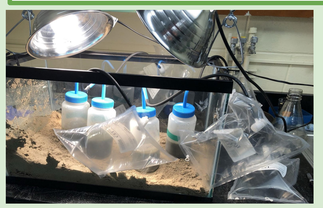


Figure 3. Tedlar bag experiment setup

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: (27) x (200ml) = 5.4 L
- Food waste= 23 bottles x 30g = 690g of food waste
- Heating lamps

Monitoring:
- Check the experiment daily
- Change tedlar bags if needed (to avoid bursting)
- After 3-5 days, measure the volume of gas produced using the water displacement method
- After measuring the volume, measure the biogas concentration with a MRU Biogas Analyzer

Results

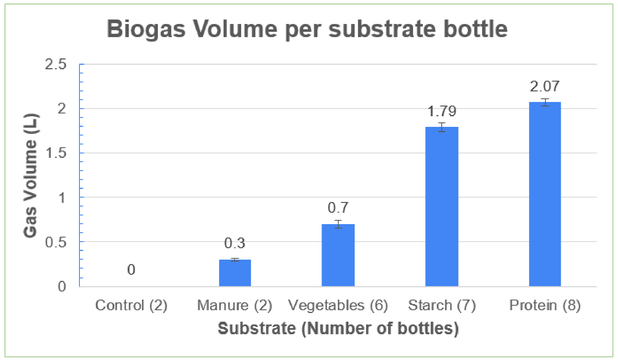
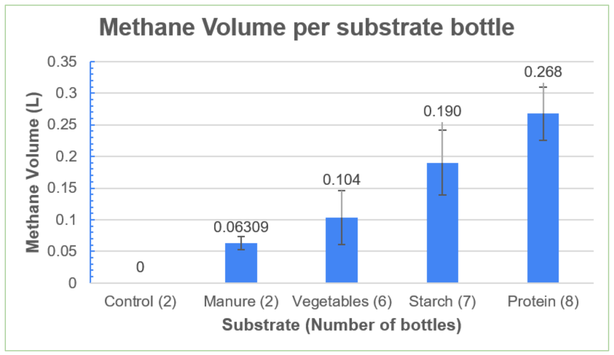


Figure 4. Biogas Volume

Figure 5. Methane Volume



Data Collection

- Clarkson and the Canton Central School High School (10 class sections) data was combined
- Averaged to get the Biogas volume and Methane volume
- Methane content was obtained by multiplying the average methane content by the biogas produced
- Standard deviation for each substrate was also calculated and is shown on the graphs below

Discussion

- Creates a successful virtual learning environment
- Incorporates citizen science to enhance data analysis
- Allows for the comparison of digester health
- The quality of the food input and microbial community

- Primarily Carbon Dioxide (CO_2) and Methane (CH_4) and water vapor
- Trace amounts of Carbon Monoxide, Hydrogen Sulphide and Vocs
- Varying composition due to varying microbial communities and food input
- Gas production rate will vary depending on the age of the digestate as well

Summary

- Easy way to visually demonstrate anaerobic digestion and food breakdown
- Provides a universal educational experiment for teaching about anaerobic digestion and biogas production that integrates citizen science approaches
- 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 in place of natural gas
- Teaching students about citizen science can spark more interest in the scientific field
- The Tedlar bag 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

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[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