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Supercomputing Challenge Biofuel Proposal

Executive Summary

Identifying the Problem

How can we limit fossil fuel production at a local level while repurposing waste created by our school?

During lunchtime at our school, our team realized the majority of students discarded around half the food items on their trays. We proposed the idea to prevent food waste by converting food loss into biofuels. We needed permission from the school to place bins around the cafeteria and decided to ask our teacher for assistance in getting the approval we needed. We quickly realized there were some problems we had to face, such as some food working better than others. The system we created to make biofuels cannot process all types of food waste safely into biofuel. Therefore, we needed an efficient way to separate the food waste from undesirable elements of lunch. We planned to place trash bins around our Cafeteria and then attach signs onto them labeling what food goes where, similar to how recycling is sorted. We asked students to place their food waste into the respectively labeled bin as well as throw away food that cannot be processed into biofuels.

Importance

We hope to find a solution that would decrease food waste while benefiting the environment. Converting waste into biofuel could potentially limit mass food loss and decrease the number of harmful gasses accumulating in our atmosphere. We will achieve this by turning otherwise waste food into sustainable biofuel energy by researching and developing a system capable of forming methane through fermentation.

Background Research

Our research started with checking New Mexico laws to make sure we were following regulations and legislation. Afterward, we researched the necessities for producing biofuels and found that the combination of food to make the perfect carbon-to-nitrogen ratio (C: N) is an essential factor when processing our food waste. We established that to measure the captured methane from food waste, we needed to use the C: N ratio between 20:1 to 30:1. Our fuels we made by using our school lunch, anything from beans, salad, to potatoes as long as it was vegan. Fermentation is a process used to create biofuel. The food waste is changed into methane, which can be processed into a variety of fuels.

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Constraints

We had many constraints when going into our project. First, our team had problems with food rules and regulations that we had to follow. Our team found out that our process could not convert every food type on the menu into biofuel. This includes meat, plastic, citrus, styrofoam, dairy, and condiments. Another constraint that our team faced was dealing with the people who did not follow our directions, such as throwing waste into the biofuel material cans. This could have limited the efficiency of our biofuel process as the processor cannot convert specific items into biofuel.

Goal

The goal of this project is to reduce food waste by converting that waste into biofuel. People contribute a lot of waste by throwing out undesirable food products. By understanding how to convert that massive amount of food waste into an alternative fuel source, we will have found a viable way to put that waste to use with the benefit of creating methane. This will provide a possible solution for the increasing food pollution in our landfills.

Conceptualization

Proposed Solution

Our team's best solution for food waste was to create a sustainable biofuel generated through waste. Our team approached biofuels already understanding the limits posed by the chemical process of producing the fuel. For example, citrus, meat, heavily processed food, styrofoam, plastic utensils, and plastic wrap all would not work in the chemical transformation. This meant that our biofuel system could not process a significant amount of the waste food and resources produced by the cafeteria. However, we found that by sorting the garbage produced into, processable and not, we still had enough biomass due to the sheer amount of waste the cafeteria created. Using our program, we can simulate the chemical reaction of making biofuels and control the variables of the process seeing how it affects the results.

Potential Methods and Method Selection

To manage the food waste at our school, we considered other potential solutions. We considered tracking food waste and what menu items produced the least waste, burning the food waste to generate power, and using sustainable practices like recyclable food trays. We reasoned that increasing certain menu items would create more waste because students would be less interested in the food over time and would throw away more. We further reasoned that burning the food waste to create power would be less efficient than generating power compared to the process of making biofuels. The final considered solution of using sustainable practices would likely increase production costs and decrease the number of students who can afford school lunch. Our solution for biofuels is a balance between efficiently transferring biomass into energy and reducing the amount of waste our cafeteria produces without affecting school lunch costs and the number of students who can afford it.

Methodology

1. From the 3rd to the 4th week of November, a team of students went out into the cafeteria and set up a series of garbage cans to house different types of food waste. They gathered and sorted meat, preserved foods, and other foods products capable of fermentation and transformation into biofuel.
2. Students collected biomass while measuring and tracking trash weight; they recorded the menu items served.
3. Next, the group of students created a program using the data collected. Our programs detail the C:N ratio of the food types collected, model the data we collected, and simulate the combustion of methane on the molecular level.

CS Models

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1) Python

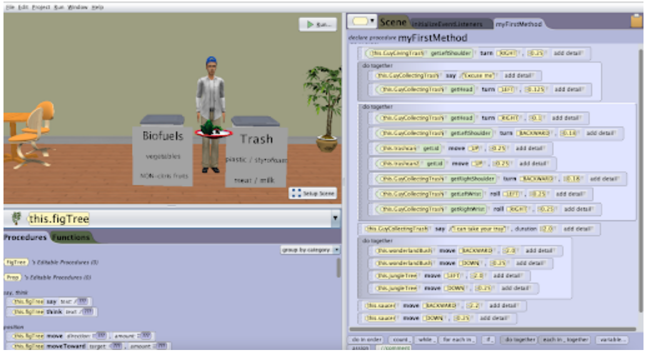
```python
def diffs_between_times(time_array):
    differences = np.empty(time_array.shape)  # Initialize empty array for cumulative time differences
    for timestamp_index in range(time_array.shape[0]):  # Start index for length of time_array
        if timestamp_index + 1 >= time_array.shape[0]:  # If possibly out of bounds, set the difference to 0
            differences[timestamp_index] = 0
        else:
            difference = time_array[timestamp_index + 1] - time_array[timestamp_index]  # Determine difference
            difference = round((difference.seconds / 60) / 60)  # Convert the difference in seconds -> hours

            differences[timestamp_index] = difference  # Append the approx. hour(s) between timestamps to array

    return differences
```

- The Model predicts methane production rate/amount for varying slurry volume, slurry content (acidity, C/N), and time.
    - i.e. For 1000mL of bean/cucumber slurry with a C/N of 30:1, 2000 mL of methane will be made after 24 hours
- Libraries used:
    - Numpy
    - Matplotlib.pyplot
    - Turtle
- Code can be viewed on Github:
    - https://github.com/carlos-miller-466/nm-stem-challenge-2021

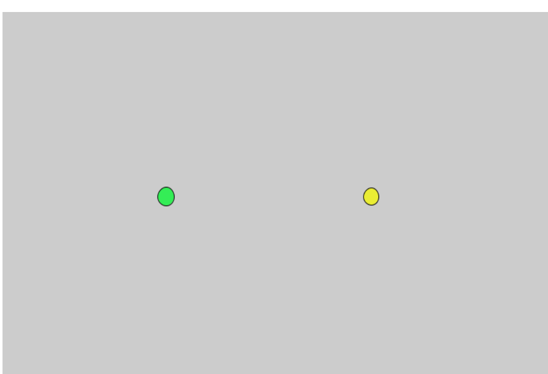
2) Alice 3

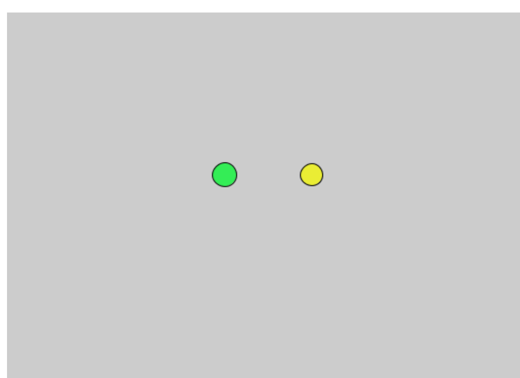


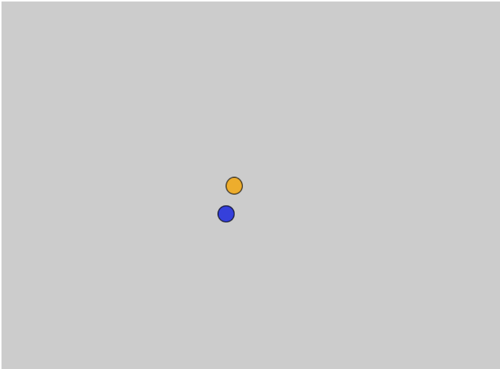
- A simulation of the collection process.
- Separating usable biofuel material from unusable trash.
- Animated code on Alice.

3) Processing:

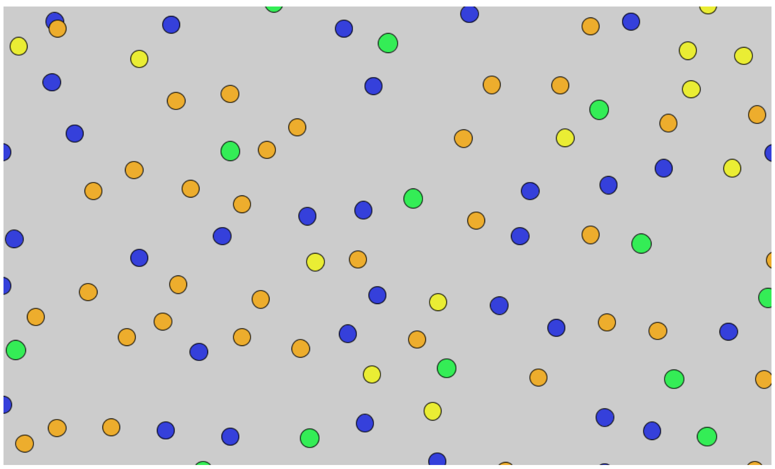
- Programmed in Processing using Python
  - Full Code can be viewed at: https://github.com/Flynn-B/Methane-Combustion-Simulation
- The model simulates the molecular chemistry happening in the combustion of methane gas, the product of the project. The reactants are Methane and Oxygen and the products are CO2 and Water
- Everything is programmed from scratch using Python, including collision detection and collision physics.
- The green circles represent methane, the yellow represents oxygen, the orange represents CO2, and the blue represents water.
- All values such as density, mass, volume are based on real-world numbers with the collision engine using all of these in its calculations



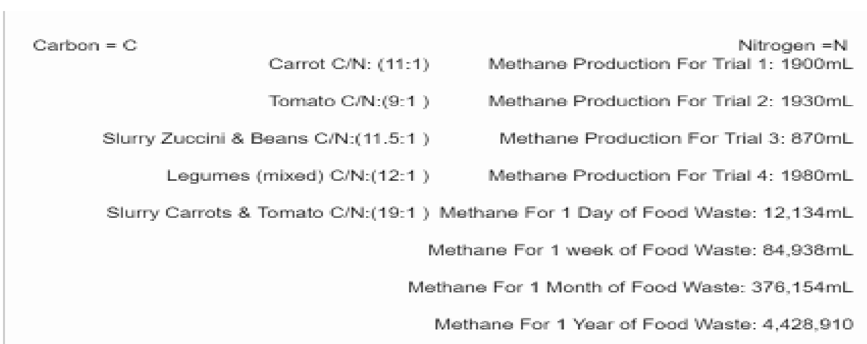




Code can simulate hundreds of molecule collisions at once:



4) NetLogo



- Easily Viewable Information
- Extremely Customizable Code.
- Github-https://github.com/lolchrisisthebest/Cruelix/blob/main/Graph%20for%20SCC%20made%20in%20Netlogo

Testing and Evaluation

Troubleshooting & Testing

Our prototype addresses the urgent need for food waste management. Current landfill practices do not support waste management and are prone to faultiness. Consequently, landfills emit harmful gases such as carbon dioxide and methane directly into the atmosphere. To efficiently and sustainably support our environment, we propose a solution to prevent food waste while simultaneously producing biofuel gas. We have successfully modeled a fuel source collection system operated by an anaerobic digestion system. Which collects and repurposes methane gas. Our prototype reduces greenhouse gasses (GHG), and greenhouse gasses and recycles food waste.

In the future, this prototype could potentially aid research in building a dimensionally dilated system capable of mass digestion and capturing abundant amounts of methane. In addition, our prototype can help derive hydrogen fuel through the sequestration of carbon from methane.

- *C: N Ratio Changing*
  - The pH of the slurry in our system must be tested before the feedstock fermentation to ensure the desired results. The slurry must be measured and weighed to meet the 20:1 to 30:1 C: N ratio tidal for fermentation. However, the composition of foods collected all hold different carbon-to-nitrogen ratios, which forced us to recalculate every feedstock mixture before the trial.
- *Storage*
  - Using a refrigerator, we froze our collection of waste to prevent decomposition. However, our refrigerator could only hold a limited amount of food waste.
- *COVID-19 protocol issues*
  - COVID-19 regulations require the implementation of processes used to ensure a safe environment. We all follow the social distancing guidelines stated by the New Mexico Department of Health.
  - In previous years Taos High school constructed a “share box” in which individuals could give away any uneaten food. However, due to COVID-19 regulations, programs like this no longer exist, and our food waste production has significantly increased.
- *Limitations in food options*
  - We omitted foods with lactic acid and citric acids from our experiment because they reduce the pH level and prevent the system from undergoing fermentation.
  - We choose to exclude meats from our system because it poses a bacterial hazard to our researchers and yields dangerous results when in an uncontrolled environment.
- *Sizing issues*

- Since the product of our system is lighter than air (methane), we could not measure the volume. Rather we determined the volume in the graduated cylinder.
- Weighing the waste was difficult because of material limitations and required several attempts.

- *Redesign (if needed)*
  - *Yet to be done.*
- *Results*
  - *N/A*

Predictions

We believe that by using our reaction, our system will ferment waste into biofuels. Through collections of carbohydrates, fats, and enzymes (proteins), we plan to create a mixture of biomass to create a perfect carbon-to-nitrogen ratio; Ideal for biofuel production. During this process of fermentation, bacterial species introduced will hold the capability of methane production. After some time, our microbial methanogenesis system will generate methane. We predict that our biofuel derived from collected biomass will represent a source of renewable energy.

Prototype Materials

The materials used for the prototype are:

- 1000ml graduated cylinder
- Large erlenmeyer flask
- Plastic tub
- Tubing
- Blender
- Large stopper
- Clamp
- Ring stand
- Heating pad
- Various cafeteria food waste (feedstock), including:
  - Beans
  - Cucumbers

Rendering

Model

The computer model built for our prototype uses Python for demonstrating the chemical reaction and Alice for the collection process. The mathematical model to simulate biogas production can be mirrored in Python using a third-party library called 'NumPy.' The modeled process is an anaerobic decay of organic waste within an airtight digester. Variables that are modified include the amount of biomass, the carbon/nitrogen ratio of feedstock, system pressure, and system acidity. These variables will be visualized with an elementary depiction of the prototype apparatus using the ‘turtle’ library of Python.

Prototype

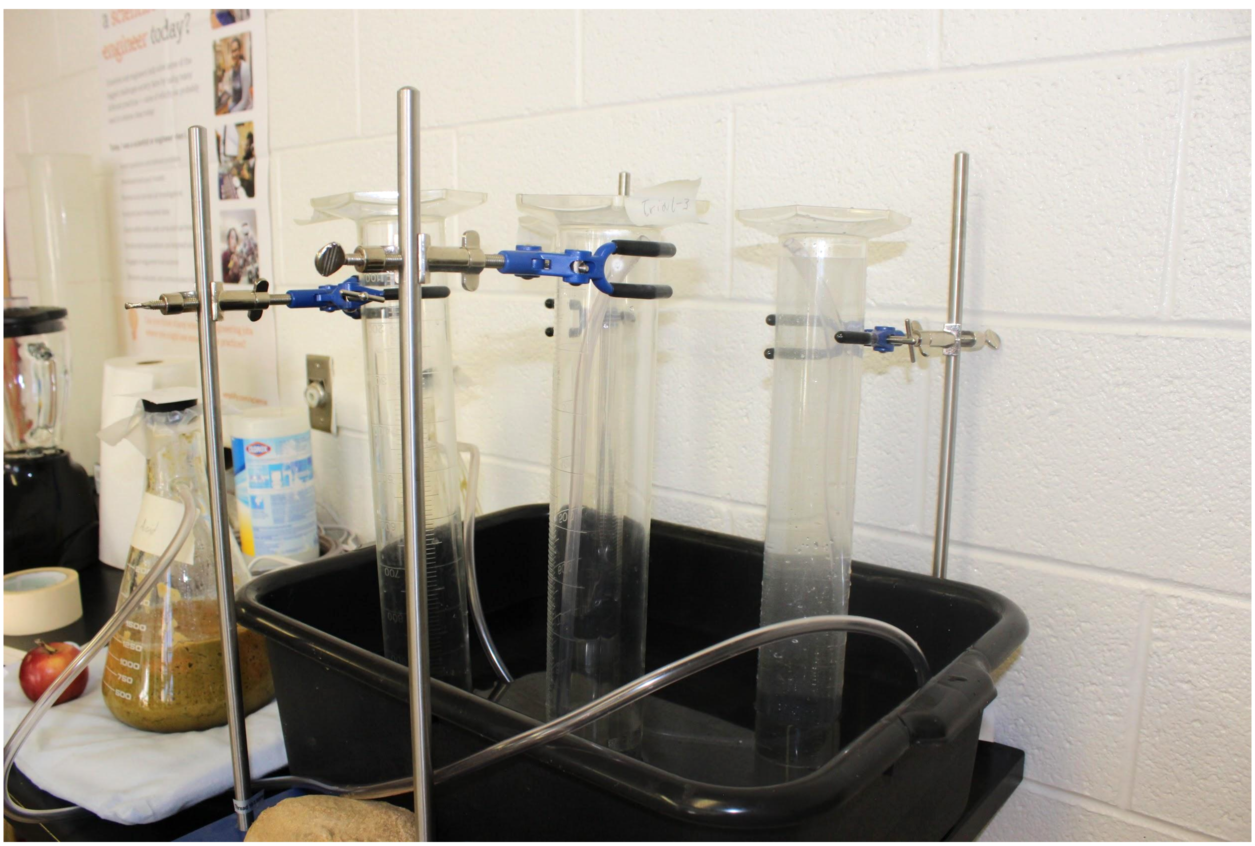
Our prototype is made by using a large Erlenmeyer flask. Attached to the Erlenmeyer flask are a tube and a large stopper covering the top portion of the flask. There is a tub filled halfway with water. In the tub is a 1000ml graduated cylinder filled with water. To ensure minimal water leakage, we installed the graduated cylinder upside down. Inserted in the graduated cylinder is tubing that connects to the flask. A ring stand clasps the cylinder to prevent it from tipping over. The flask is then wrapped in a heating pad.

Prototyping

Our prototyping involves finding the best formula of feedstock to produce the largest amount of biofuel. We first start by collecting food waste from our cafeteria and freezing it to prevent bacterial contamination. When we begin building our prototype, this food waste will be blended to create feedstock. We will test different feedstock mixtures to find the one with a C: N ratio within the recommended 20:1 to 30:1 ratio. A-C: N ratio is a ratio of carbon mass to nitrogen mass in a substance, and substances with 20:1 to 30:1 ratios have the best methane production. Food Scraps usually have C: N ratios near 30:1, so we will see how different food scraps affect the ratio and the production of the biofuel. We will calculate the C: N ratios of each mixture we use and test each one to find the one with the best biofuel production. With each trial, the feedstock will be placed in an Erlenmeyer flask with a large stopper cap. The plastic tubing will be attached to the sidearm of the flask. We will then fill a 1000ml graduated cylinder with water and place it face down in a plastic tub filled halfway with water, maintaining the water level of each. The other end of the tubing will be placed inside the graduated cylinder at its water level. The cylinder will stay securely clamped to a ring stand. We will then take a heating pad and wrap it around the Erlenmeyer flask to allow the feedstock to ferment anaerobically. After 24 hours, The fermentation process should occur on the feedstock. Next, we will check the water level of the graduated cylinder to determine the volume of the methane. If there is a significant amount of methane, we will conclude the experiment. However, we will leave the feedstock mixture for an additional 24 hours if there is a small volume of methane. After completing multiple trials with mixtures of various C: N ratios, we will figure out the formula that produces the most biogas in our biogas reactor.

Safety Protocol

In terms of building the prototype and prototyping, we must take safety measures. We must wear chemical safety goggles, lab aprons, and protective hand covering during prototyping. The food is frozen for safety because this helps prevent bacterial contamination. The risk of potential infection from meat forced us to not use it. The gas produced is low pressure and captured in the inverted graduated cylinder controlled by air pressure. Throughout the process, the system is continuously monitored.



Collaboration

Taos High School's Computer Science and Clean Energy students collaborated on creating the project, creating a proposal, collecting materials, and executing the project. The participating students are Grace Goler, Dominique Vigil, Anabelle Caldwell, Sienna Sategna, Chris Rivera, Carlos Miller, Lola Shropshire, and Flynn Basehart, along with teachers Andrew Leonard from Clean Energy and Tracy Galligan from Computer Science.

The collaboration consisted of organizations, people, students, and teachers.

- MESA
- SLC
- STEM

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