Optimization of Lactic Acid Production from Food Waste via Anaerobic Respiration

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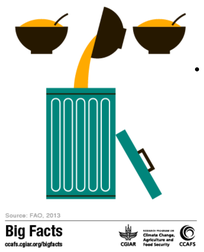
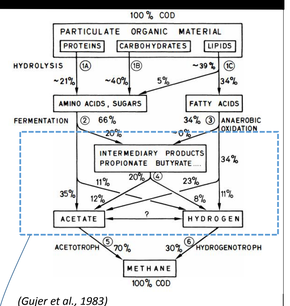
Introduction

The world today is in no shortage of wasted food. Out of the 4.8 x 10^9 metric tons of food that is produced by the world in total each year, a full third of it is wasted or lost (FAO, 2013).



- Wasted food, via microbes, generates organic acids that can be used to synthesize plastics, fibers, adhesives, and solvents (Drumright et al., 2000) (Roscher 2000) (Kolt et al., 2007).
- Most prior research has been on primary sludge as the exclusive substrate (Eastmann et al., 1981), or on food waste with extremely low loading rates (Kim et al., 2004). In addition, the goal of past research has been on methane production, rather than acid production.

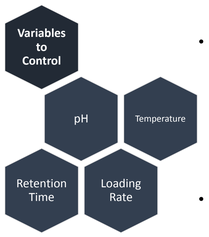


(Gujer et al., 1983)

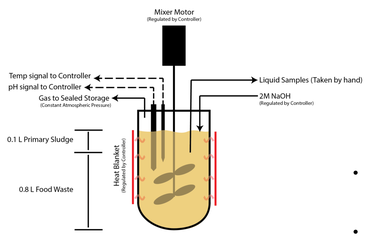
- **The motivation behind this research is to maximize acid production at high loading rates of food waste while disallowing methane production.**

Methods

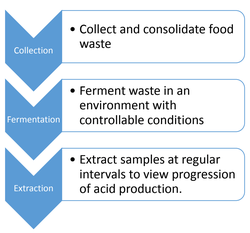
Sample Preparation



- Food waste was taken from local dining halls and homogenized. Preliminary tests were run on the substrate to characterize its density, solids content, nutritional composition, etc. The food waste was then inoculated with primary sludge to ensure a healthy bacteria culture.
- Substrate was then placed into a bioreactor (pictured below), where desired variables were controlled for.



Reactor Set Up

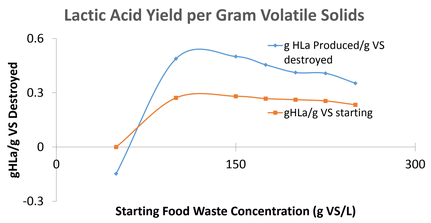


Data Collection

- 5 different batches of food waste were prepared:
  - Batches 1 & 2 were wide screening experiments to establish general parameters.
  - Batch 3 focused on optimizing loading rates.
  - Batches 4 & 5 (the focus of this poster) refined and confirmed previous results.
- Samples were taken from the bioreactors at predetermined intervals to judge progression in acid production.
- The concentrations of acids generated by the bacteria were measured using high performance liquid chromatography (HPLC).
- Data on macromolecule composition and volatile solids concentration were also collected to help characterize the substrate.

Results

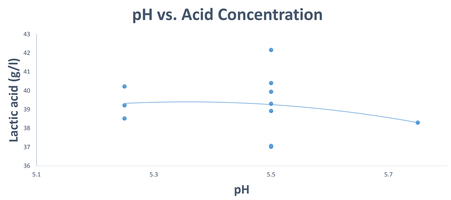
Optimal Loading Rates

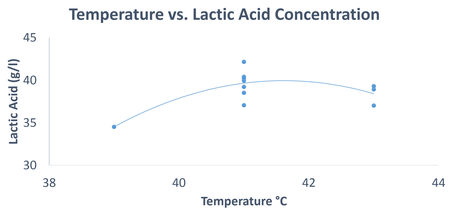


- Batches 1 & 2 showed that lactic acid is the primary product generated in food waste, reaching concentrations as high as 40 g/L after 16 hours. Batch 3 determined optimal loading rates.
  - The loading rate which produced the maximum yield is between 100 and 150 g volatile solids / L (graph at left).
  - Total acid concentrations increased with loading rates of up to 250 g VS / L, which was the undiluted VS concentration in batch 3; therefore, higher VS rates were not tested.
- This information allowed for the elimination of one variable: maximum yield of lactic acid occurs at 150 g VS / L.
  - Focus was diverted towards finding optimal pH and temperature at this loading rate.

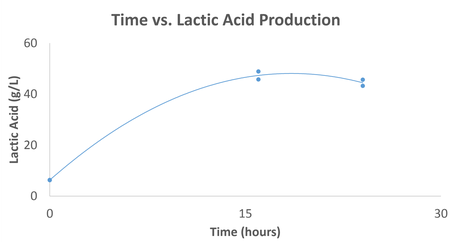
Optimal pH and Temperature Thresholds

- Statistical evaluation of batches 1 & 2 indicated that optimal pH and temperature for lactic acid generation was around 5.3 and 41 °C.
  - Batches 4 & 5 were used to confirm this point with more precise testing parameters.
- Batch 4 & 5 results suggested that the optimal point for lactic acid generation was near pH of 5.5 with a temperature of 41 °C
  - pH of 5.25, 5.5, and 5.75 were tested. The graph to the right shows lactic acid generated at varying pH as temperature was held constant at 41 °C.
  - The other graph shows test results at temperatures of 39 °C, 41 °C, and 43 °C as pH was held constant at 5.5.
- These results suggest that near the optimal "point", acid production seems to plateau. Microbes may be resistant to small variations in environmental conditions, so such small perturbations in pH and temperature may have had a negligible impact on overall acid production. It is more appropriate to refer to these optimal ranges as "thresholds," rather than points.



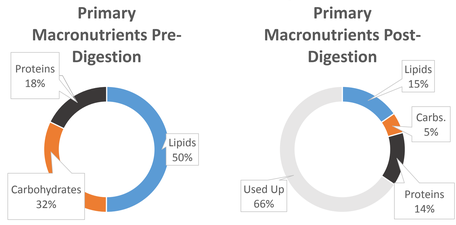


Time



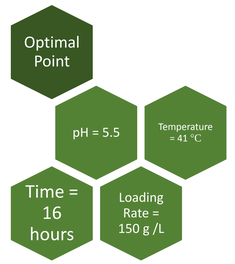
- Two experiments were ran at the optimal points for pH and temperature (5.5, and 41 °C respectively) for a full day. Samples were taken at 0 hours, 16 hours, and 24 hours.
- The data shows that acid production begins to level off at around 16 hours. The data suggests that any additional time may actually result in degradation of the end products.
  - The decline in lactic acid concentrations may be a result of the microbes metabolizing their own waste (the acids), as readily available nutrients have been depleted.

Macronutrient Analysis

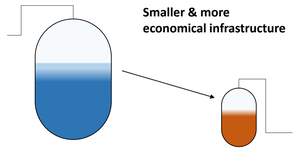


- Microbes in the food waste were able to metabolize a full two-thirds of the macronutrients present in the substrate within 24 hours.
- The microbes consumed the following macronutrients in order of greatest to least preference:
  - Carbohydrates, with an 85% net consumption rate.
  - Lipids, with a 70% net consumption rate.
  - Proteins, with a 22% net consumption rate.
- Waste rich in carbohydrates and lipids is more easily metabolized by bacteria in comparison to waste that is heavy in proteins.

Conclusions



- Food lost to transportation, neglect, or disease can be fermented to generate useful byproduct in the form of lactic acid, which has been shown to reach concentrations of over 40 g / L of food waste in just 16 hours; optimal conditions for fermentation are at a pH of 5.5, a temperature of 41 °C, a retention time of 16 hours, and a loading rate of 150 g Volatile Solids / L.
- *Microbial life in the food waste exhibits a level of resilience to varying temperature and pH.* Small variations in performance across varying parameters suggest tolerance for changing conditions.
- *Technology for harvesting this lost resource should be investigated:* the current market price for lactic acid is 87 ¢ / lb. (Ewing 2013). If all of the wasted food in the world (in one year) were to be fermented for 16 hours, and the lactic acid from said fermentation could be captured completely, there would be approximately 368 billion dollars' worth of product available for human consumption. That's a little more than 1 billion dollars, or 870 million lbs., of lactic acid thrown away each day in the form of food waste.
- *Digesters created especially for food waste can be scaled down tremendously in size and capital:* current large-scale two stage anaerobic digesters have retention times of up to 14 days (Scherer et al., 1999) and thus require huge amounts of space to accommodate all of the substrate it sustains.



Further Considerations

- Research on separating out valuable product from the food waste must be done. The product is useless if it cannot be extracted cost-effectively from the substrate.
- Pretreatments for the food waste should be considered; such measures may aid in increasing total yields, or decreasing retention times.
- Much of this research may be repurposed to the digestion and stabilization of other substrates; human bio-waste is an excellent candidate for this type of research.

References & Acknowledgments

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