Methanogenesis for a Sustainable Future:

Understanding the dynamics of biochemical methane potential assays as a function of Focused Pulse treatment

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Background

In many wastewater treatment plants, a community of bacteria degrade the organic compounds in waste activated sludge (WAS) into methane, CH_4 (Figure 1). Currently, however, the methane-generating efficiency is low. Since there is not a high enough quantity of methane to be harvested, it is often simply burnt and wasted.

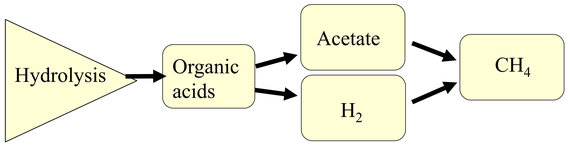

Figure 1. Summary of key anaerobic food web reactions occurring under normal environmental conditions. Arrows represent bacterial communities. Source: Jean Juang

Focused Pulsed® (FP) pre-treatment of OpenCEL is a promising new technology that increases the rate of methane production by applying a applied high voltage pulse (31 kV) for a very short period of time (8 µsec). This breaks down the complex sugars in wastewater to be consumed more easily. Specifically, FP pre-treatment opens the pores in the cell wall, and osmotic pressure then causes these cells to lyse. This makes the biomass more readily available for the bacteria to convert into methane.

An ideal way to observe the effects of FP pre-treatment is with biomechanical methane potential (BMP) assays, which provides a measure of anaerobic digestibility (Fig 2).

Question

How are BMP assays affected by Focused Pulse Treatment in terms of overall methane production and the intermediate steps of methanogenesis?

Hypothesis

If the BMP assays are monitored for both control WAS samples and FP-treated samples, then the treated samples will produce more methane in a shorter time frame due to the release of nutrients becoming available for consumption.

Variables

Independent Variable- Untreated versus Treated WAS

Dependent Variable- Amount of Methane, Concentrations of Solids, Organic Acids, Protein

Materials and Methods

Each BMP bottle contains 70mL of sample, 30 mL of anaerobic digested sludge inoculum. Inoculum is untreated samples of sludge containing the natural methanogenetic community of bacteria (obtained from anaerobic digester in Mesa Northwest Water Reclamation Plant) that is used to provide an initial community of live bacteria to generate methane right away.

Results

The data confirms that FP-pretreatment results in greater cumulative methane production.

The addition of inoculum facilitates greater initial methane production. However, methane production in the inoculum-free samples begins after 10 days and the cumulative production catches up by the 28th day.

Figure 2. BMP bottles setup. Bottles are sealed to maintain a completely anaerobic environment. Source: google.com

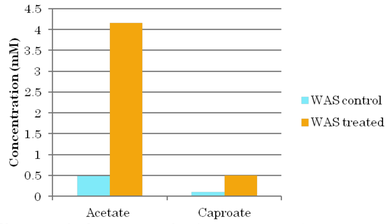

Figure 4. Increase in Acetate and Caproate can be immediately noted after FP pretreatment, supporting hypothesis. Source: Jean Juang

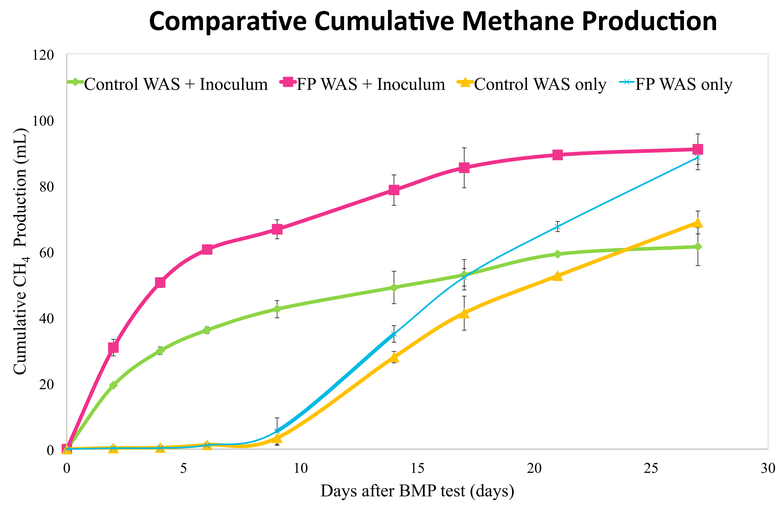

Figure 3. Cumulative biogas production (after inoculum compensation) for WAS control and treated samples. Results are averages of batch serum bottles. Source: Jean Juang

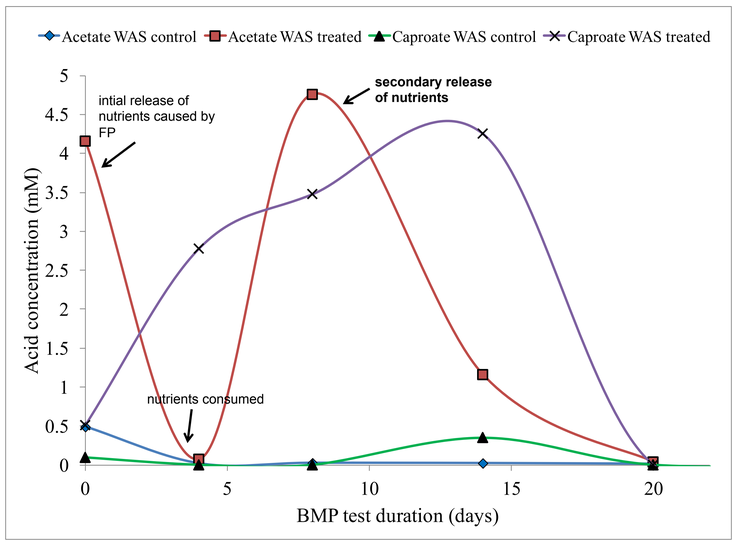

Figure 5. Trend of organic acids as a function of FP treatment and time during batch BMP assays.. Source: Jean Juang

- Release of acids as function of pre-treatment is evident as a result of FP treatment. Rapid consumption was evident from the depletion of acetate.
- Secondary release of acetate (10 and 15 days) and subsequent consumption was accompanied by the high slope of methane increase.
- Caproate is a higher acid that is fermented further to acetate. Release of caproate was more gradual and occurred more significantly for FP treated WAS with no sharp peak pattern as observed with acetate. Could indicate that the rate of caproate fermentation to acetate took time to set in.

References

1) Rittmann. B. E.; McCarty, P. L. (2001) Environmental Biotechnology: Principles and Applications. McGraw-Hill: New York.

2) Zhang, H., DiBaise, J.K., Zuccolo, A., Kudrna, D., Braidotti, M., Yu, Y., Parameswaran, P., Crowell, M., Wing, R.A., Rittmann, B. E., Krajmalnik-Brown, R., 2009. Human gut microbiota in obesity and after gastric-bypass. Proc. Natl. Acad. Sci. U.S.A. 106, 2365–2370

Materials and Methods

- •Frictionless syringe
- •Test tubes
- •Glass papers
- •Tweezers
- •Weighing boat
- •Scale
- •Safety glasses
- •Suction pump
- •Hach Protein Kit
- •HPLC machine
- •Glass Bottles
- •Filters

Total and Volatile Suspended Solids (TSS and VSS)

- determine if the nutrients that the bacteria were consuming were indeed from the lysed cells
- used filter paper with 1.2 µm pores and a pump
- TSS sample was heated in an oven at 100 degrees Fahrenheit overnight, and then weighed.
- VSS sample was heated in a 300 degree oven for thirty minutes and then weighted.

Semi-Soluble Chemical Oxygen Demand (ssCOD)

- determines the quantity of nutrients in the liquid
- followed the procedures outline in the Hach Company Chemical Oxygen Demand kit.

Gas Chromatography

- Acquires gas composition data used to calculate concentration of methane

Protein

- Data used to chart the pathway from WAS solids to methane and utilized the Hach Protein Kit.

Organic Acids

- see the intermediate steps in the methane reaction
- provided a comparison to the protein data, as both organic acids and proteins are intermediates.
- utilized the HPLC, a liquid chromatography machine

Conclusions

Pre-treated samples results in an average of a 50 percent increase in cumulative methane production. Methanogenesis correlates with the increase in ssCOD (acetate and caproate), presumably from the lysed cells.

Notably, methanogenesis occurs after a lag time even without inoculum. This suggests that a bacterial community remains in the WAS despite FP treatment.

The effectiveness of Focused-Pulse pretreatment depends on the concentration of solids present in the sample prior to treatment. The secondary release of nutrients shown in Figure 5 was less pronounced in samples with fewer initial solids. This translates to less effective methanogenesis. Preliminary data with samples containing comparatively almost no initial solids show only a 10 percent increase in methanogenesis after FP treatment.

FP treatment could allow wastewater plants to harvest methane while reducing landfill matter. With further research this could be a sustainable possibility.

Further Research

Future research includes looking at applying FP treated compounds to bacterial communities that generate

- Hydrogen Gas (Microbial Electrolysis Cell)
- Electricity (Microbial Fuel Cell)

Preliminary work on cyanobacteria and other biomass sources will continue to be expanded on.