Augmenting anaerobic digestion of microalgal biomass

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What is anaerobic digestion and why to care?

Organic waste
(plant/algae biomass, wastewater, animal manure)

Microbial buffet

Biogas

🌟 Methane potential of USA – 7.9 million tones/year
🌟 5% of natural gas in the electric power
🌟 56% of natural gas in the transportation
Problem: how to efficiently digest algae?

- “Good” algae that polish wastewater and needs to be processed afterwards;
- “Bad” algae that cover surface waters and needs to be processed.
Augmentation is a solution

We have a very efficient anaerobic granular sludge

from Sekiguchi Y. et al., 1999

I LOVE algae!
Solving the problem: finding algae-loving bacteria

Logan City Wastewater Lagoons
Solving the problem: finding algae-loving bacteria

Logan City Wastewater Lagoons

Isolated: *Citrobacter*, *Alcaligenes* and *Pseudomonas* spp.
Experimental set-up
Specific Methanogenic Activity (SMA) test

+ self-digestion controls

9.6 gVSS/L of algae
19 gVSS/L of granules
10% algalytic bacteria
1:2 substrate:inoculum

**Algae came from the surface of a trickling filter polishing municipal wastewater
Results: after 70 days, at 35±2°C, at 100 rpm...
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11% increase due to algalytic mix
Algae already figured things out...

A “clean” experiment on augmentation would be to use an axenic culture of algae

But large scale industries will never do it.
They deal with waste. Waste is contaminated.
How can we help those industries who need augmentation?

We can make a computer model to help predict the success of augmentation!
A computer model for augmenting anaerobic granules

Model is based on:
- Kinetics of substrate consumption (Monod, Haldane, Simple inhibition)
- Bacterial attraction towards substrate

Input parameters:
- Growth characteristics ($K_s$, $K_i$, $\mu_{\text{max}}$, $\mu_g$)
- Diffusivity of substrates/products
- Strength of chemotactic attractance

*Glucose $\rightarrow$ Acetate $\rightarrow$ Methane*

Laboratory image (Sekiguchi, 1999)
Simulated image from our model (40 days)

A computer model for augmenting anaerobic granules

Day 0-17: cellobiose, 1.5 g/L
Day 17-60: cellobiose and oleate

1) Cellobiose and oleate at 1.5 g/L
2) Cellobiose and oleate at 0.5 g/L
3) Oleate at 1.5 g/L

Cellobiose and oleate at 1.5 g/L, 40 days
Cellobiose and oleate at 0.5 g/L, 60 days
Oleate at 0.5 g/L, 60 days
Conclusions and food for thoughts

✓ Algae digestion successfully augmented in batch conditions;

✓ Trial with axenic algal biomass is needed;

✓ When augmenting, remember to feed the existing bacteria, **BUT**, do not overfeed them!
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**Results:** what’s up with the microorganisms?
**Results:** what’s up with the microorganisms?

![Graph showing the number of sequences for different microorganisms in different treatments.](null)
Results: what’s up with the microorganisms?

Augmented VS Non-augmented

- Increased number of polysaccharide and protein digesters (**Bacteroidetes**)
  - More primary fermenters

- Number of Clostridia members shifted to those utilizing amino acids and sugars (**Firmicutes**)
  - More secondary fermenters
<table>
<thead>
<tr>
<th>Algae+Granules</th>
<th>Algae+Granules+Bacteria</th>
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<tbody>
<tr>
<td>Selenomonadales, Proteiniphilum <em>(Firmicutes)</em></td>
<td>Hydrogenispora, Lutispora <em>(Firmicutes)</em></td>
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<tr>
<td>Syntrophomonas, Syntrophorhabdus <em>(Firmicutes)</em></td>
<td>Syntrophobacter <em>(Firmicutes)</em></td>
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<td>Aminobacterium <em>(Firmicutes)</em></td>
<td>Veillonellaceae <em>(Firmicutes)</em></td>
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<td>Christensenellaceae <em>(Firmicutes)</em></td>
<td>Peptococcaceae <em>(Firmicutes)</em></td>
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<td>Sedimentibacter <em>(Firmicutes)</em></td>
<td>Gracilibacteraceae <em>(Firmicutes)</em></td>
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<td>Propionibacteriales <em>(Actinobacteria)</em></td>
<td>Cellulosimicrobium <em>(Actinobacteria)</em></td>
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<td>Phycisphaerae <em>(Planctomycetes)</em></td>
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<td>Geobacter <em>(Proteobacteria)</em></td>
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<td>Desulfovibrio <em>(Proteobacteria)</em></td>
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