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BIOGASIFICATION OF MARINE ALGAE: NANNOCHLOROPSIS OCULATA AND BOTRYOCOCCUS BRAUNII (BRIEFING SLIDES)

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14. ABSTRACT Algae has the potential to be a useful source of biomass derived energy due to the high lipid content and rapid growth rate of the organism. Currently, there are many methods available to harvest the energy from algae, such as transesterification of lipids to biodiesel or thermal gasification of the cells to produce synthesis gases. A new approach was identified to use algae in a biological gasification process in which the algal cells were digested into methane. By using biogasification, traditional thermal processes requiring large amounts of thermal energy input can be replaced by methods that require minimal additional input of energy, thus raising the overall energy efficiency of the system. Initial experiments obtained 248 L methane/kg Volatile Solids algae and still increasing. Using algae has the potential to more than double the available methane production over traditional terrestrially derived biomass under optimized growth conditions given these results.					
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BIOGASIFICATION OF MARINE ALGAE

(NANNOCHLOROPSIS OCULATA AND BOTRYOCOCCUS BRAUNII)

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Outline

- Introduction
- Materials and methods
- Results
- Conclusion
- Future work

Introduction

- What are algae?
- Algae–Potential feedstock for biofuel
- Why anaerobic digestion of algae?
- Algal species: *Nannochloropsis oculata* and *Botryococcus braunii*

What is Algae?

- CHARACTERISTICS

- Autotrophic
- Unicellular- multicellular
- Freshwater- saltwater
- Eukaryotic

- Morphology

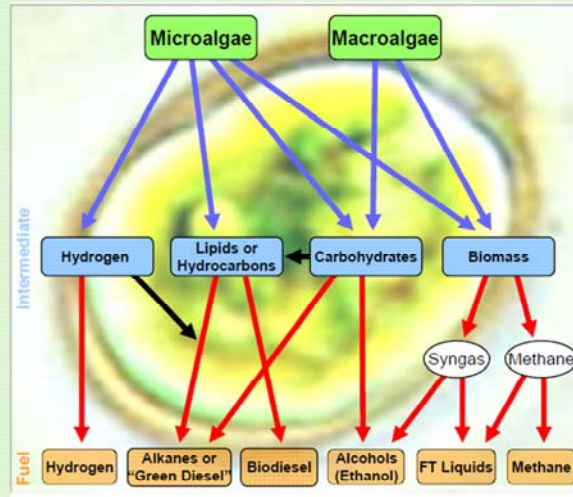
- Colonial, capsoid, coccoid, palmelloid, filamentous, parenchymatous

Algae

Potential feedstock for biofuel

- Much higher productivity than their terrestrial cousins
- Non-food resource
- Can be grown anywhere
- Can utilize saline water
- Can utilize CO₂ from waste streams
- Can be used in conjunction with wastewater treatment
- An algal biorefinery could produce oils, protein, and carbohydrates

Algae based biofuels



6

A schematic for taking the two main types of algae, micro- and macro-, and converting into useful energy sources.

Some microalgal species are capable of producing hydrogen in an anaerobic environment, while nearly all species of microalgae are capable of producing useful amounts of lipids, carbohydrates, and biomass.

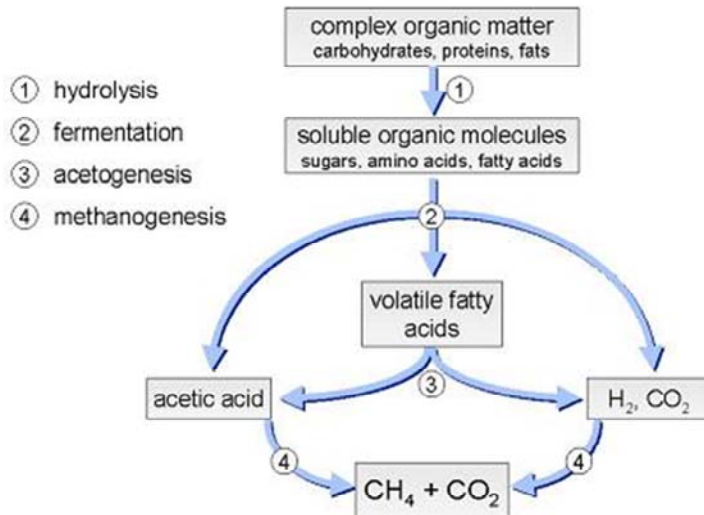
Macroalgae can produce large quantities of carbohydrates and biomass, yet are not capable of generating lipids or hydrogen.

From each of these components, a different source of energy can generated.

Why anaerobic digestion of algae?

- Challenges to biodiesel conversion
 - Dewatering, separation, extraction and purification of lipids
- Challenges to gasification or combustion
 - Dewatering of algae

Anaerobic digestion



Anaerobic digestion is the process of microbially decomposing organic matter in an oxygen-free environment in order to produce methane and carbon dioxide. The methane that has been generated can then be combusted for energy recovery.

In this process, the first step is to hydrolyze or break down complex organic material into simpler compounds.

The second step is to ferment these simpler sugars into small chain fatty acids which are then treated by acetogenic bacteria to produce hydrogen, acetic acid, and carbon dioxide.

Finally the hydrogen, acetic acid and carbon dioxide are fed to methanogenic bacteria to generate methane and more carbon dioxide.

Benefits of Anaerobic Digestion

- Simple in operation
- Less capital investment
- No extensive dewatering in suspension
- Low cost pretreatment processes (if required)
- Predators can be digested too
- Clubbed with other waste source
- Nutrients (phosphorus, nitrogen) are conserved and can be recovered for growth

Net Energy

Stoichiometry



Process	Energy production Higher Heating Value (HHV) KJ/g algae	Energy production Net Heating Value (NHV) approx. KJ/g algae
Combustion	17-21	9-12
Gasification	40	20
Biodiesel	20	18
Anaerobic digestion	22	20

- > from stoichiometric calculations, 1 g algae produces 0.6 L methane at STP
- > from stoichiometric calculations, 1 g algae produces 0.5 g oil (maximum)
- > Biodiesel uses methanol
- > Gasification utilize steam/hydrogen/nitrogen which reduces the net energy of the process.

Stoichiometric equation for taking algae and water, via anaerobical digestion to methane and other products.

The table shows heating value outputs of algae from anaerobic digestion as well as other common methods to convert algae into a source of energy.

Objectives

- Experimentally quantify methane potential through anaerobic digestion
- Estimate rate of production of methane
- Determine effect of nature of species and conditions of growth on methane potential and rate of biogasification
- Estimate amount of N and P released during digestion
- Evaluate and optimize reactor designs for anaerobic digestion

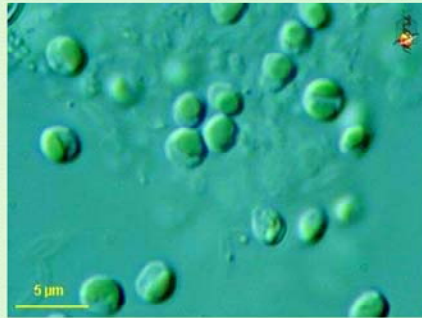
Materials and Methods

Algal species

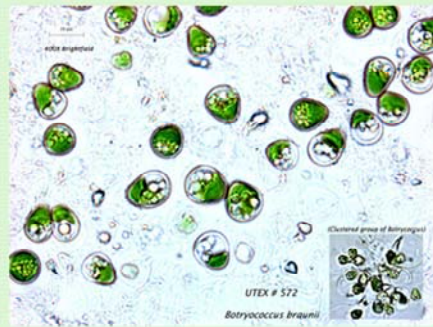
- *Nannochloropsis oculata*
 - unicellular
 - spherical
 - saltwater algae
- *Botryococcus braunii*
 - unicellular
 - pyramid shaped
 - planktonic microalgae
 - freshwater algae

Two algal species obtained from researchers at Air Force Research Laboratory, Tyndall AFB. These two species were model species chosen for energy harvesting because of favorable traits in oil production capacity as well as overall growth rate.

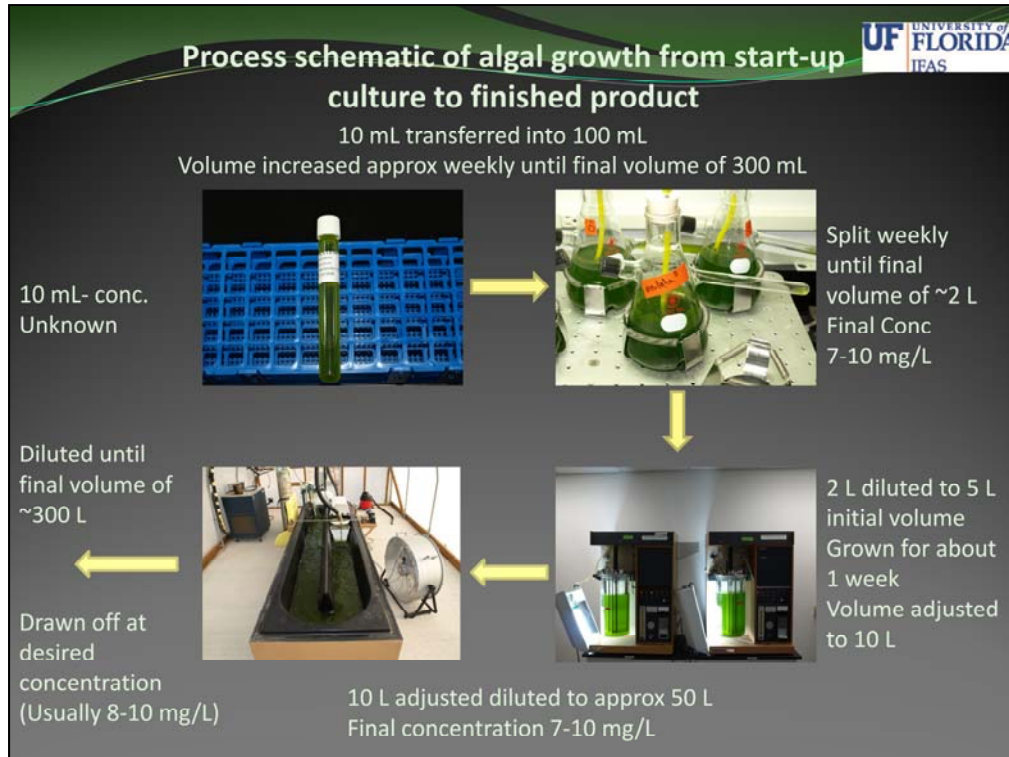
- *N. oculata*



Source: *N. oculata* – Wikipedia
B. braunii - Wikipedia



- *B. braunii*



Process flow taking purchased quantity of algae (10 mL vial) and growing into a useful source of algae to be processed into energy.

Growth

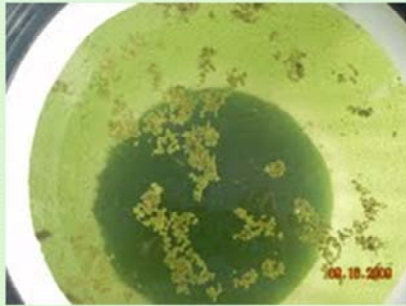
- Doubling time = 20 h. (Not optimized)
- Total time before raceway = approx 6-8 weeks

Harvesting

- Algae harvested in 30-gal batches
- Drawn off into settling hopper
- PH adjusted to 10.5 and allowed to settle overnight
- Supernatant decanted from top and solids-rich bottom drawn off
- This process results in algae with 10% solids by weight

Process for taking algae from a raceway reactor and concentrating the cells into a more-manageable volume.

Settling and Filtration



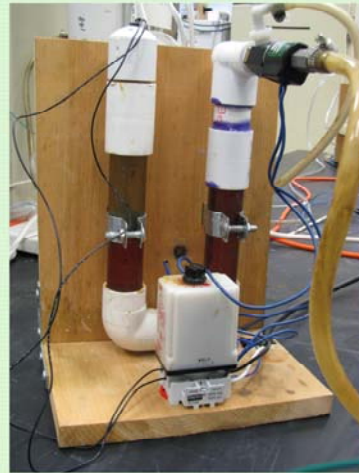
Images of algae after they have been settled, decanted and harvested.

Lab scale settling (*N. oculata*)



- 12 L algae settled to 950 mL of sludge
- Total solids = 2% (w/w)
- Total volatile solid = 50% TS
- Expected yield = 664 L

Anaerobic digestion apparatus



20

Pictures of anaerobic digestion, bench-scale version, and methane collection apparatus.

Bioreactors digesting algae

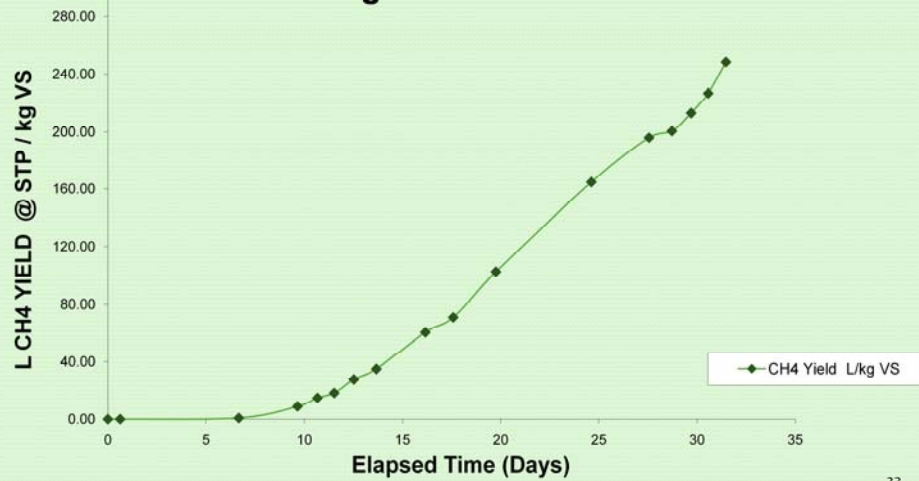


Analytical measurements

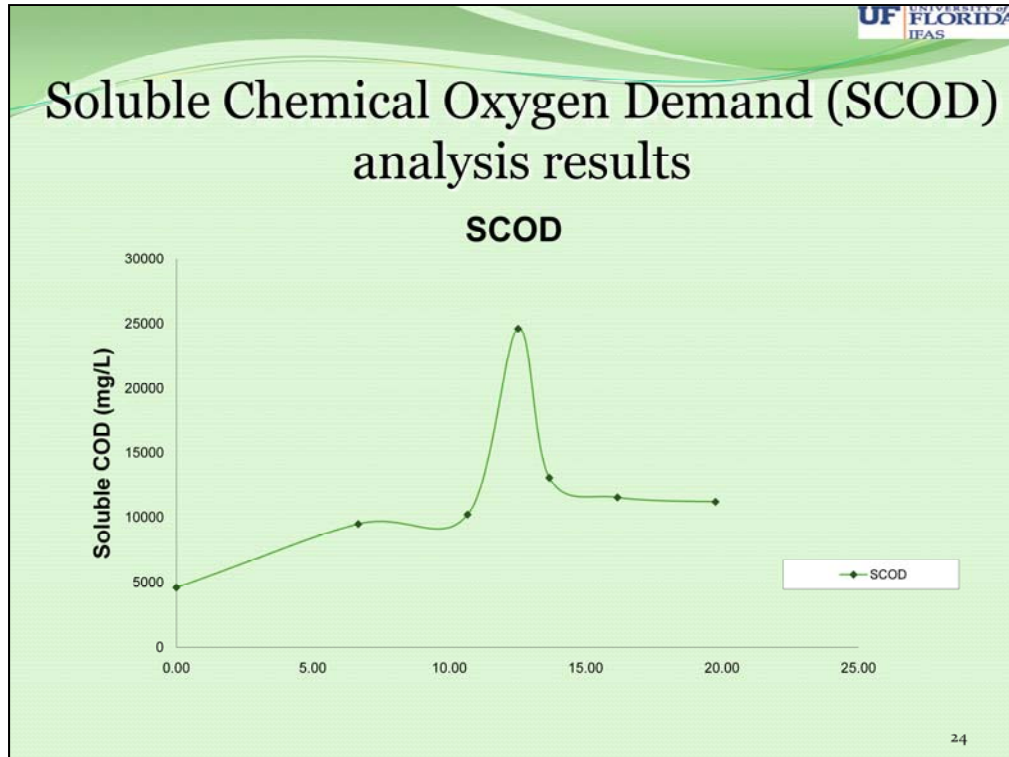
- Biogas volumetric flow rate
- Methane and carbon dioxide composition
- pH
- Soluble Chemical Oxygen Demand (SCOD)
- Ammonia and orthophosphate
- TKN and TP

Results

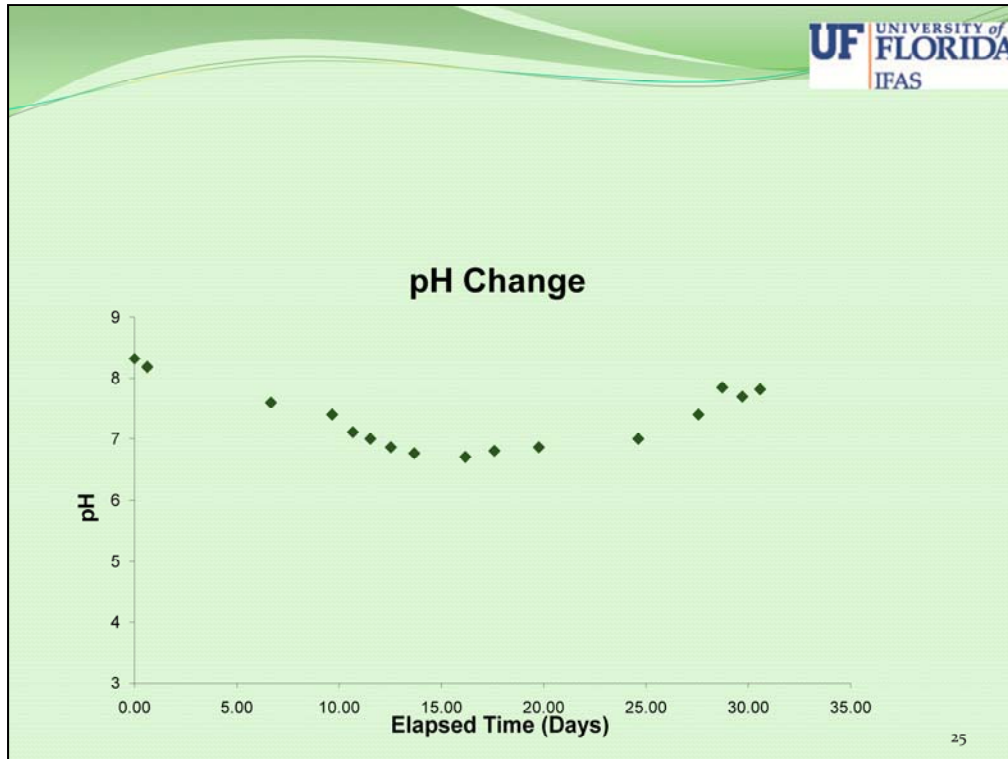
Cumulative methane production during anaerobic digestion of *N. oculata*



This chart shows the cumulative volume of methane produced during digestion of algae. After initial buildup of bacteria concentration a fairly constant linear volume of methane was produced every day.



Chemical oxygen demand showing the amount of nutrients available for degradation into methane. At midpoint of the experiment there was a peak of COD suggesting that most of the algae had been broken down into useable sugars and ready for further conversion into methane. After that point sugars began to break down showing a decrease in overall COD, while still having quantities of fatty acids available for methanogenesis.



PH change is due to the conversion of sugars into acid and to methane.

Conclusions

- Adapted anaerobic digestion to saline conditions
- Methane yield obtained so far was
`248 LCH₄@STP/kg VS and increasing
- Digestion could be initiated without pretreatment
- Methane yield from algae was more than terrestrial biomass (typically 160- 250 L CH₄ / kg VS) if it approaches theoretical yield of 540 LCH₄/kg VS)

Future work

- Optimize reactor design, loading rates for improved methane yield from algae
- Investigate pretreatment methods
- Develop other settling procedure

QUESTIONS

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