Carbon Capture and Utilization – The Algal Way

Joshua Goff[1] and Ann C. Wilkie[2]

[1] Microbiology and Cell Science Major

[2] Faculty Mentor, Soil and Water Sciences Department, University of Florida-IFAS, Gainesville, Florida

Abstract

Coal power plants introduce an abundance of carbon dioxide (CO_2) into the atmosphere. Algae can be grown using this CO_2 to reduce carbon emissions, and the harvested biomass can be anaerobically digested to produce methane gas (CH_4). To evaluate the feasibility of growing algae on flue gas, locally sourced algae were cultivated in eight open raceway ponds operated under similar conditions of pH control, fertilization rate and harvest frequency. Pond cultures were harvested and characterized for total solids (TS), volatile solids (VS) and chemical oxygen demand (COD). Light microscopy was used to identify the different algal genera in each pond in order to understand how the different morphotypes might affect methane production. Five ponds consisted predominantly of microalgae, while the other three were predominantly filamentous cultures. Methane index potential (MIP) batch assays were conducted in triplicate at 35˚C for 28 days on the harvested algae. On average, the filamentous algae had significantly higher methane yields (464 LCH_4/kgVS) than the microalgae (163 LCH_4/kgVS) due to their less rigid cell-wall structure allowing the biomass to be more readily converted into CH_4. The research demonstrated that algae can be utilized to lower carbon emissions while providing an alternative and renewable energy source.

Introduction

Carbon Emission Remediation & Methane Production:

Burning coal produces numerous greenhouse gases that are emitted via flue gas. Among these emissions, CO_2 is the most significant and is produced in the greatest quantity. Algae can be grown on the CO_2 by piping flue gas from the stack directly into an open raceway pond. This is demonstrated at the Stanton Energy Center located in Orlando, Florida. Once the algal biomass is grown and harvested, it can be anaerobically digested to produce CH_4, which can be used as a substitute for fossil fuels in power plants[1].

Microalgae and Filamentous algae:

Polyculture ponds at the Bioenergy & Sustainable Technology Laboratory, UF and at the Stanton Energy Center, Orlando Utilities Commission (OUC) were used in the experiment, with a wide variety of different species present. Structural differences between different species may play a role in the capacity and rate of CH_4 production. Filamentous species tend to possess far less rigid cell walls than microalgae, which should allow the organic matter to be more easily accessed by the microorganisms responsible for anaerobic digestion.

Figure 1. Algal Open Raceway Pond at Stanton Energy Center

Objectives

Determine if algae grown on flue gas can be effectively converted to a renewable fuel, by evaluating the methane index potential of different algal species and simultaneously determine if differences in a species' cellular characteristics and chemical compositions play a role in methane yields.

Figure 2. Flue gas emissions at Stanton Energy Center

Methods

Sample Preparation:

- Algae were harvested from 4 ponds at UF and 4 ponds at OUC, and then centrifuged to form pellets
- Samples were characterized according to Standard Methods[2]
  - Total Solids (TS)
  - Volatile Solids (VS)
  - Chemical Oxygen Demand (COD)

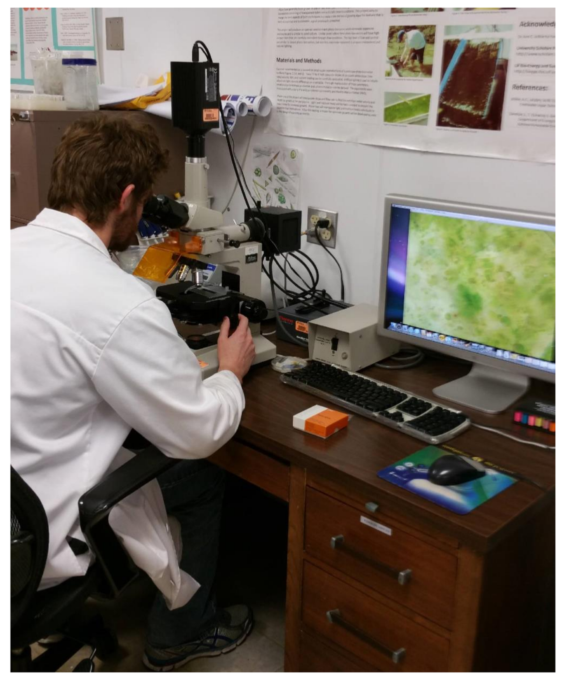
Methane Index Potential (MIP) Assays:

- Batch assays conducted at 35°C over 28 days in triplicate
- Methane gas measurements collected routinely and corrected for standard temperature and pressure
- Controls included inoculum only as a baseline and inoculum with glucose, cellulose, and starch.

Microscopy:

- Light microscopy was performed at 25x, 40x and 100x magnifications to determine species and structural significance.

Conducting MIP assays



Microscopy on Algal Samples

Results

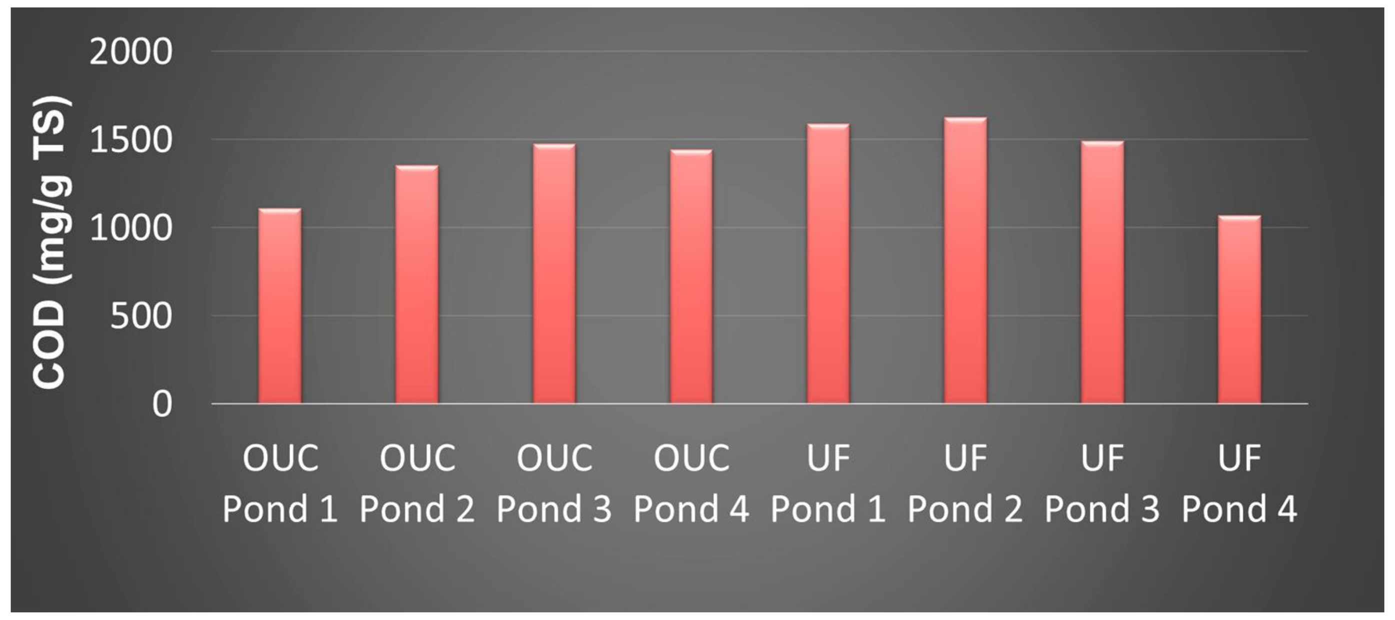


Figure 3. Organic Matter in Algae Samples

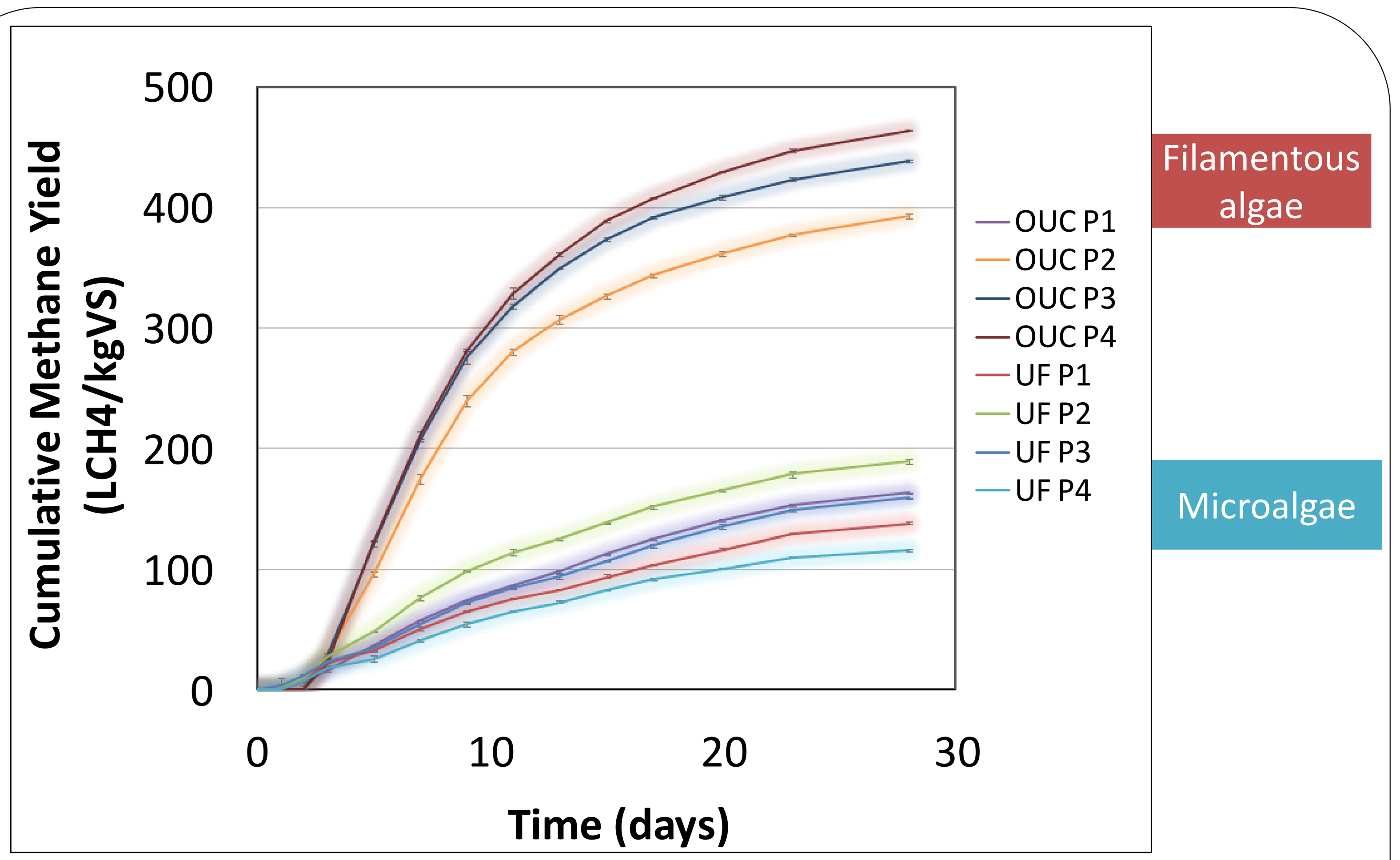


Figure 4. Cumulative Methane Yields for All Algae Samples

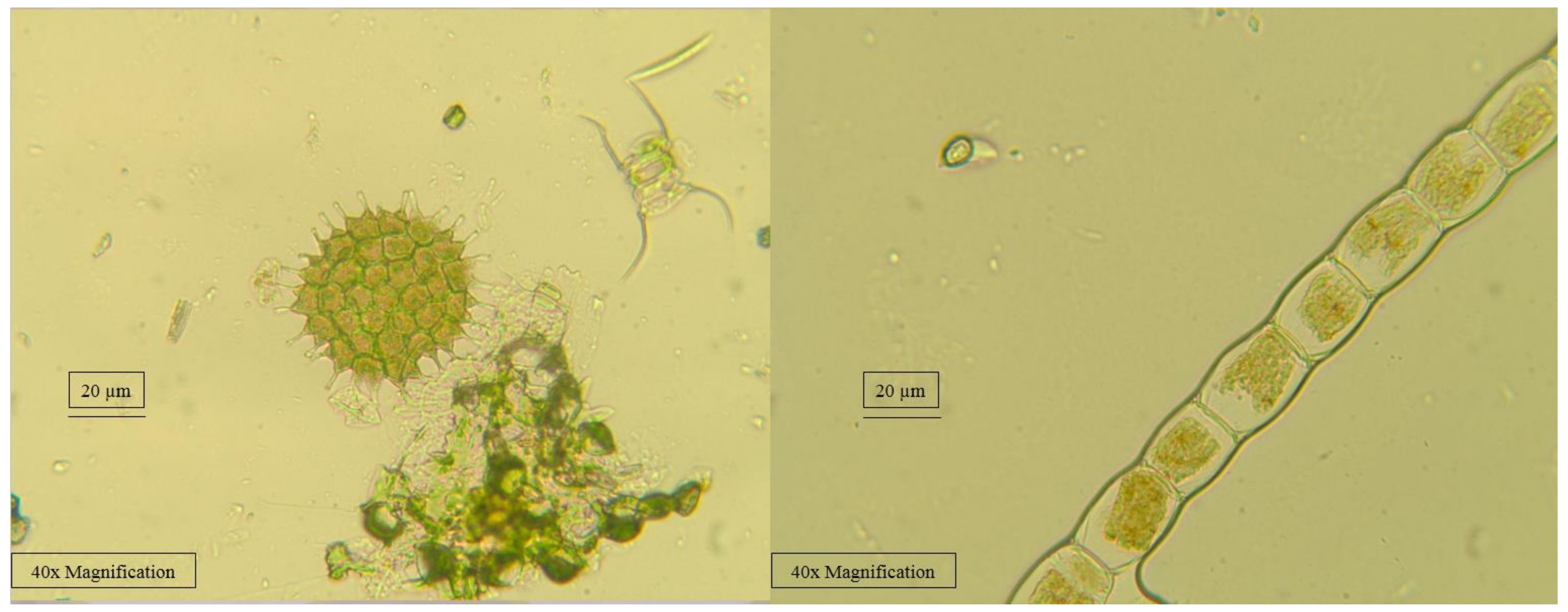


Figure 5. Pediastrum boryanum microalgae (left) and Microspora stagnorum filamentous algae (right)

Conclusions

- CO_2 produced from coal-powered plants can serve as a viable source for growing algae.
- There was no significant difference between the chemical oxygen demand concentrations of filamentous and microalgal species.
- The filamentous algal species resulted in higher average methane yields (464 LCH_4/kgVS) than the microalgae species (163 LCH_4/kgVS) after 28 days.
- The morphology of the algae strains played the most significant role in determining the methane yields among different algal species.

References

1. Ward, A., Lewis D.M., Green F.B. (2014). Anaerobic digestion of algae biomass: A review. Algal Research-Biomass Biofuels and Bioproducts, 5, 204-214.
2. APHA. (2012). *Standard Methods for the Examination of Water and Wastewater*. 22nd ed. Washington DC: American Public Health Association/American Water Works Association/ Water Environment Federation.

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