Microalgae for Energy and Nutrient Recovery From Wastewater

Lindsay Burton, Dr. Tzahi Cath, Dotti Ramey

SUMMARY

Microalgae have the capability of providing a solid green backbone to the world's energy needs as crude oil reserves diminish. Cultivation of algae may benefit from the reuse of none potable water through recovery of valuable resources and production of clean water for reuse or discharge with a reduced energy footprint. Microalgae exploit carbon dioxide and nutrients (nitrogen and phosphorous) to produce sugars, lipids, proteins, and potentially more complex biopolymers. The focus of this research is to study how the algae respond to different ammonia concentrations in anaerobic digester centrate as well as analyze how the sparging of additional carbon dioxide to the system effects the growth of microalgal biomass.

BARRIER TO TECHNOLOGY DEVELOPMENT

- There is an absence of practical approaches to produce a concentrated microalgal biomass capable of rapid nutrient uptake
- The potential for using microalgae to recover resources from wastewater is limited by inadequate understanding of their performance using wastewater as a substrate

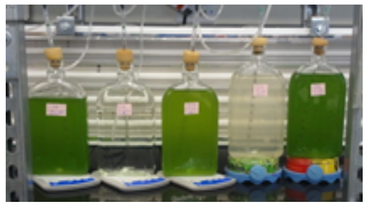
RESEARCH HYPOTHESES

Algae cultivation on wastewater can remove ammonia by shortening the hydraulic retention time of the wastewater in the reactor, and increase total algal growth for the production of biofuels

RELEVANCE

Microalgae cultivation has the potential to produce oil for energy purposes as well as provide a viable, low-energy alternative for nutrient removal from wastewater. Additionally, the burning of fossil fuel industry releases approximately 29 billion tons of carbon dioxide emissions annually. Microalgae are autotrophic photosynthetic fixers of carbon and generators of biomass. An increase in carbon dioxide removal can be achieved by growing and harvesting algae while utilizing nutrients from wastewater. Currently, there is a strong research supported by industry and government to produce biofuels, as well as the desire to utilize the unused nutrients found in the wastewater.

In order to utilize this potential, a highly engineered microalgal treatment system must be designed. To do so, a better understanding of two key factors in needed: 1) how to maintain and sustain a concentrated microalgal biomass for rapid uptake of nutrients; and 2) how to actively manage biological consortia to meet system goals of recovering nutrients, production of valuable bioproducts, efficient and effective biomass harvesting, and reduction of energy consumption.



Roux bottles, stir plates, and sparging experimental set up

EXPERIMENTAL SET UP

		Bottle 1	Bottle 2	Bottle 3	Bottle 4	Bottle 5	Bottle 6
Air Sparged	Run 1	Control: UF Autoclaved AD *	Control: UF Autoclaved AD	Control: F (100 mg/L) AD	F AD (100 mg/L) + MA	Control: UF AD (100 mg/L)	UF AD (100 mg/L) + MA
	Run 2	Control: UF Autoclaved AD	Control: F (130 mg/L) AD	F AD (130 mg/L) + MA	Control: UF AD (130 mg/L)	UF AD (130 mg/L) + MA	
	Run 3	Deionized H2O + MA	Control: F (40 mg/L) AD	F AD (40 mg/L) + MA	Control: UF AD (40 mg/L)	UF AD (40 mg/L) + MA	
Air and CO2 Sparged	Run 4	MA + BBM + NH4	Control: F (130 mg/L) AD	F AD (130 mg/L) + MA	Control: UF AD (130 mg/L)	UF AD (130 mg/L) + MA	
	Run 5	MA + BBM + NH4	Control: F (100 mg/L) AD	F AD (100 mg/L) + MA	Control: UF AD (100 mg/L)	UF AD (100 mg/L) + MA	
	Run 6	Control: UF AD *	Control: F (40 mg/L) AD	F AD (40 mg/L) + MA	Control: UF AD (40 mg/L)	UF AD (40 mg/L) + MA	

* Not sampled to check for contamination

Sampled day 0 and day 4

Legend	
AD	Anaerobic Digester
MA	Microalgae
F	Filtered
UF	Unfiltered
BBM	Bold-Basal Medium

OBSERVATIONS AND RESULTS

Lab-scale testing of the high nutrient concentration anaerobic digester centrate demonstrated that ammonia was removed and algal biomass was produced at all concentrations. Whether or not the centrate was filtered impacted only certain concentrations of ammonia in the AD centrate and effected ammonia removal and biomass growth differently.

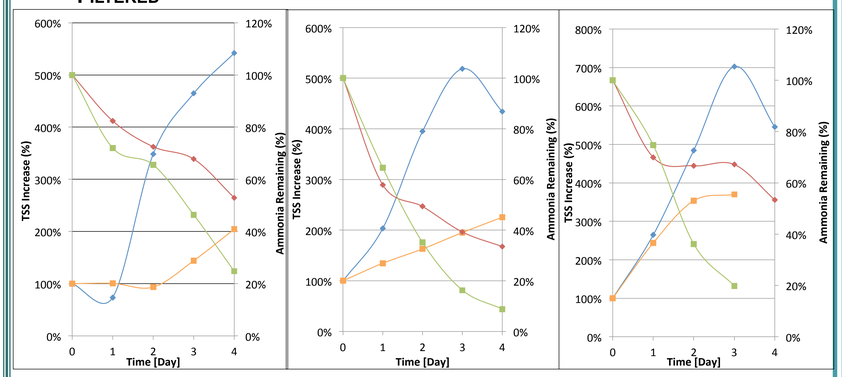
- Algae grew in substrate concentrations up to 130 mg/L NH3
- Anaerobic digester centrate without algae removed a maximum of approximately 60% NH3 from system
- The greatest NH3 removal (91%) was observed on algae grown on filtered AD centrate with a starting NH3 concentration of 100 mg/L NH3
- The greatest microalgae growth when sparging air and CO_2 (a 445% TSS increase over 5 days) with filtered centrate,130 mg/L NH3
- The greatest microalgae growth sparging only air (a 270% TSS increase over 5 days) was seen in filtered centrate, 40 mg/L NH3
- Algae-centrate solutions sparged with air and CO_2 increased algal biomass production up to 320% over air sparged algae solutions
- The growth curve peaked fastest for 40 mg/L NH3 centrate concentrations
- As pH increased greater than 9.25, ammonia appeared to be volatilized

	Concentration	Δ	TSS	NH3
Algae + Centrate	130 mg/L	Filtered	44%	75%
		Unfiltered	108%	70%
	100 mg/L	Filtered	126%	91%
		Unfiltered	93%	76%
	40 mg/L	Filtered	270%	80%
		Unfiltered	206%	60%
Control Centrate	130 mg/L	Filtered	0%	57%
		Unfiltered	29%	48%
	100 mg/L	Filtered	0%	46%
		Unfiltered	-25%	7%
	40 mg/L	Filtered	0%	19%
		Unfiltered	25%	16%

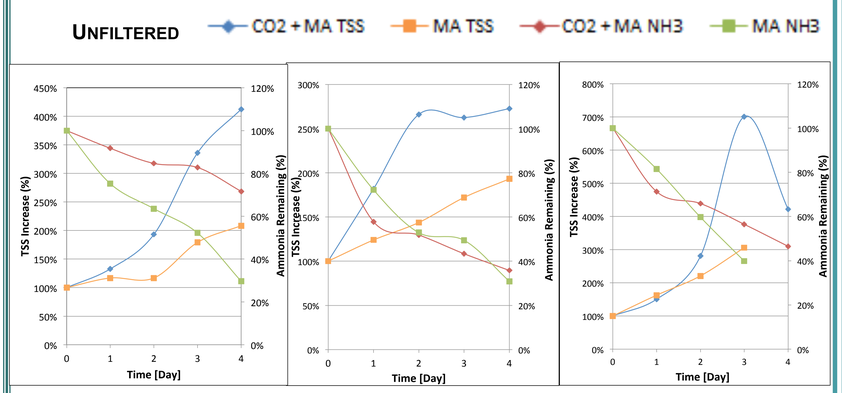
COMPARISON OF AMMONIA REMOVAL AND TSS INCREASE: CO_2 AND AIR

130 mg/L NH3 | 100 mg/L NH3 | 40 mg/L NH3

FILTERED



UNFILTERED



% Increase with Use of Algae		NH3	TSS
Concentration		(Algae- Control)	
130 mg/L	Filtered	18%	44%
	Unfiltered	23%	80%
100 mg/L	Filtered	45%	126%
	Unfiltered	69%	118%
40 mg/L	Filtered	61%	270%
	Unfiltered	44%	181%

Percentage Increase With CO2		NH3	TSS
Concentration		% Increase with CO2	
130 mg/L	Filtered	28%	320%
	Unfiltered	42%	187%
100 mg/L	Filtered	25%	209%
	Unfiltered	12%	219%
40 mg/L	Filtered	33%	175%
	Unfiltered	7%	115%

CONCLUSION AND FUTURE WORK

- Varying ammonia concentrations can be utilized to shorten hydraulic retention time or maximize algae biomass production
- Need to establish a bench-scale setup of continuous feed microalgal systems for wastewater substrate tests
- Determine through a biomass assay the centrate concentration in which the algae grown produces the highest lipid content
- Use mass balance to determine if nitrogen is off-gassing
- Analyze phosphorous for nutrient recycling
- Conduct life cycle analysis to see what concentration would make the most sense on a commercial scale

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