Cultivation of alkaliphilic microalgae for direct air capture and conversion of CO_2 to fuels and products

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Direct Air Capture Kickoff Meeting

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Program Overview

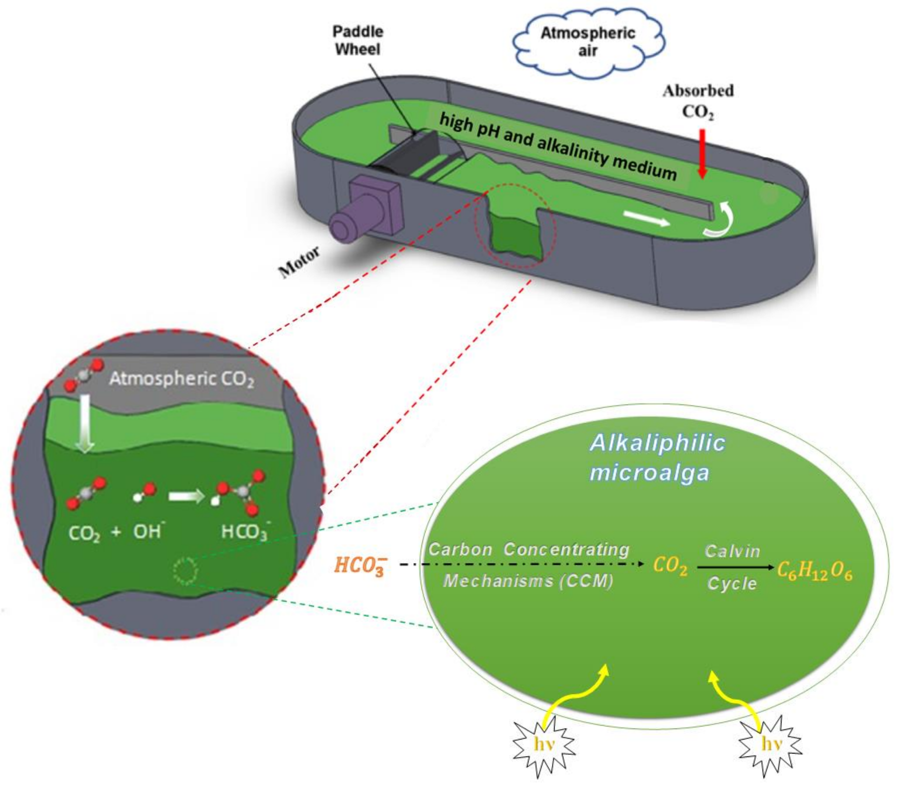
a. Funding: $ 2,397,698 (Federal) + $ 498,978 (cost share)

b. Overall Project Performance Dates: Oct 2017 to June 2021

c. Project Participants – University of Toledo, Montana State University, and University of North Carolina at Chapel Hill

d. Overall Project Objectives

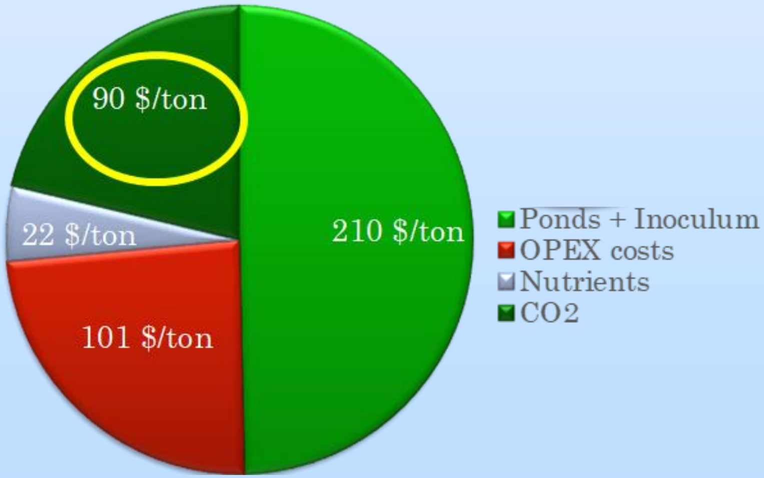
1. Improve scale and productivity of novel alkaliphilic algal cultures cultivated in high-pH and high-alkalinity media.
   - Establish seasonal productivities and the influence of scale-up
2. Improve biomass composition
   - Media and cultivation conditions optimization
3. Develop molecular biology toolkits
   - Gene editing and microbial ecology



Technology Background

Advantages of our technology

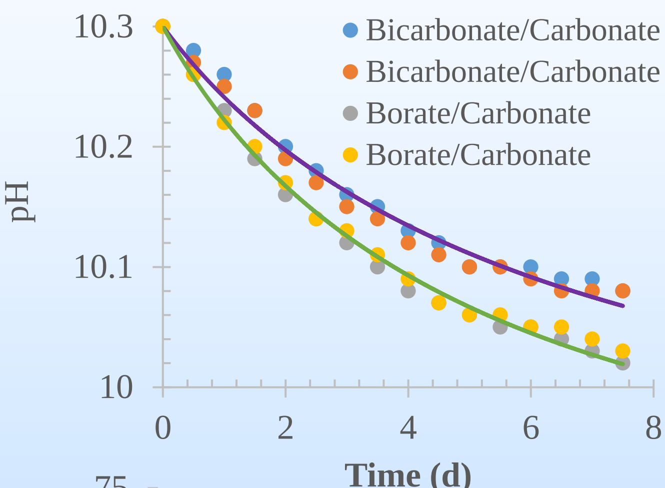
1. Harsh pH conditions (pH>10) can mitigate detrimental microbial contamination and predator populations
2. Alkaline solutions scavenge CO_2 from the atmosphere at rapid rates. Thus, costs and geographical constraints associated with CO_2 supply can be mitigated (or eliminated)

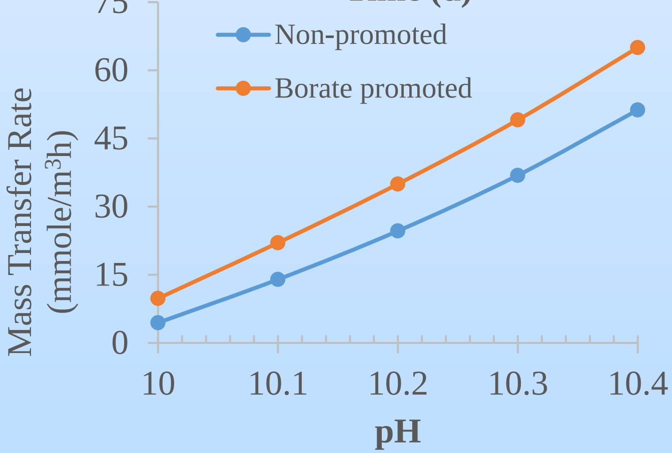


Technology Background

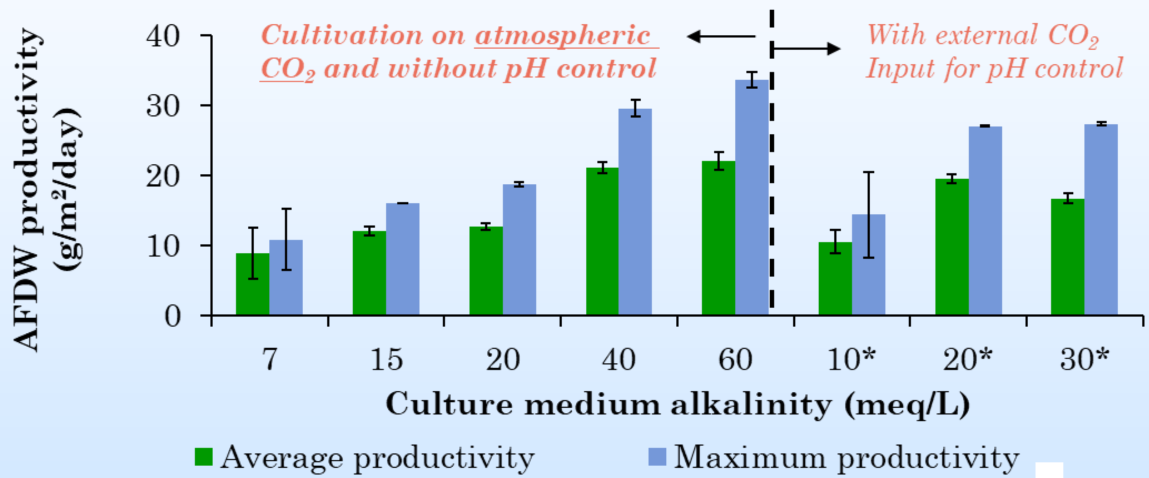
Data that supports the premise of the project

High pH drastically enhances the rate of atmospheric CO_2 mass transfer





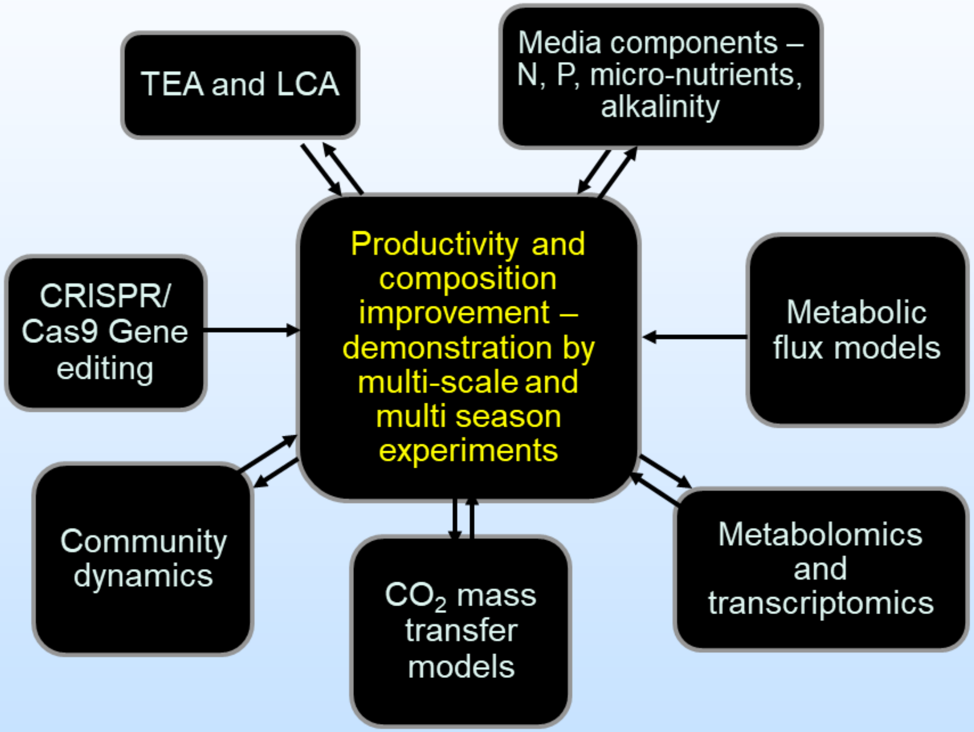
High media alkalinity improves CO_2 fixation and biomass growth rates due to higher availability of bicarbonate



Energy flow	Description	Notation	High HCO_3^- (65 mM)	Low HCO_3^- (7 mM)
Towards carbon fixation	Effective PS II quantum yield *(photons utilized per incident photons)*	Y(II)	0.37	0.23
	Photosynthetic efficiency *(electrons per photon)*	α	0.16	0.10
	Maximum electron transfer rate *(μmole/m^2/s)*	ETR_{max}	20	15
Dissipation	Total regulated + unregulated dissipation *(photons dissipated per incident photon)*	Y(NPQ) + Y(NO)	0.65	0.78
	Maximum quantum yield	F_v/F_m	0.7	0.7

Technical Approach/Project Scope

Experimental design and work plan



Key milestones

- **<u>Go/no-go</u>**: Demonstrate the potential for production of >1200 GGE/acre/year. (***Q7***)
- Isolate one or more isogenic gene-edited mutants and test for novel phenotypes. (***Q11***)
- Demonstrate a biofuel intermediate productivity >1500 GGE/acre/year. (***Q12***)
- Correlate microbial community structure to SLA-04 culture productivity. (***Q12***)

When successful, the project will

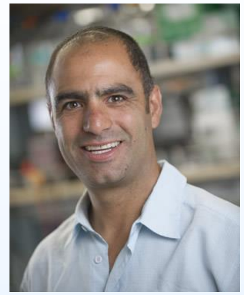
- De-couple microalgae biofuels production from CO_2 sources and significantly expand possible geographical locations for cultivation
- Decrease the cost of microalgae cultivation
- Develop toolkits for broad use by the microalgae community

Team and Facilities


Sridhar Viamajala
Cultivation and scale-up


Robin Gerlach
C and nutrient management


Matthew Fields
Microbial ecology

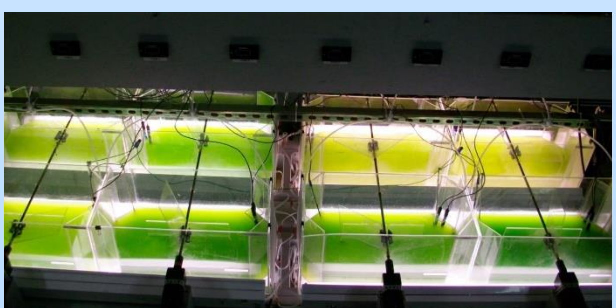

Blake Wiedenheft
Gene editing


Ross Carlson
Metabolic flux modeling


Brent Peyton
Cultivation and scale-up


Greg Characklis
Economics and LCA

- Raceway ponds (20 L to 1200 L)
- Photobioreactors – 0.5 L climate simulation e-PBRs (12) and 500 L tubular reactor
- Continuous flow centrifuge
- Conversion reactors – fluidized bed, fixed bed, batch
- State-of-the-art equipment/facilities for molecular biology and chemical analyses

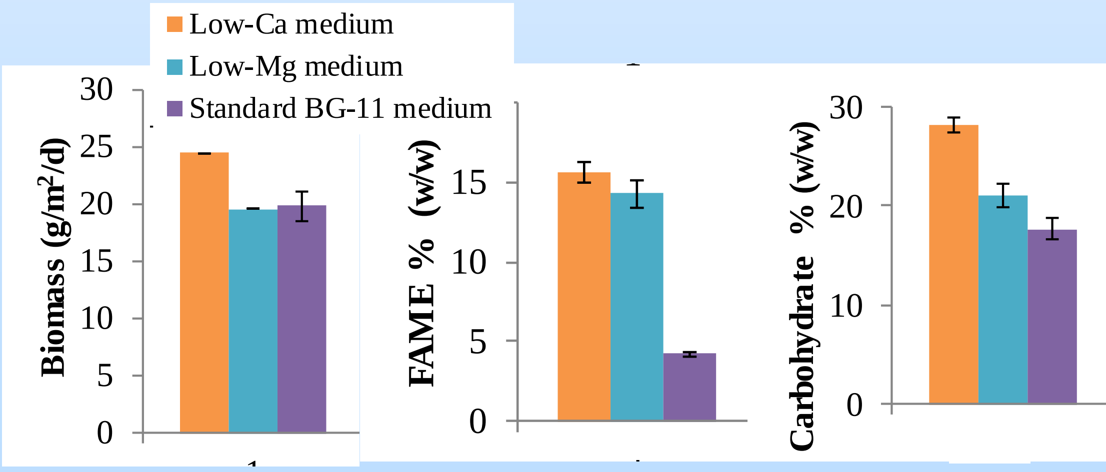


Progress and Current Status of Project

- Average annual productivity of strain SLA-04 meets BETO's FY20 targets without flue gas or concentrated CO_2 addition
- Alkaliphilic strain exhibits high productivities in all seasons
- Significant productivity improvements obtained by adjusting micronutrient compositions
- Robust culture – no crashes observed in over 2 years of outdoor cultivation studies

Season	Cultivation area of raceway pond (m^2)	Average ash-free dry weight productivity ($g/m^2/d$)
Fall	0.9 and 4.2	14.4
Winter	0.18	7.1
Spring	0.18	13.6
Summer	0.18	31.1

Avg. annual AFDW productivity = **16.5 $g/m^2/d$**



Opportunities for Collaboration

- Molecular toolkits
  - Fully annotated genome
  - Have > 19 phylogenetically characterized, bacterial isolates from SLA-04 cultures.
  - Developing genome editing methods for SLA-04
- Scale up and product development
  - Partnership with Ford and Sonoco for developing polymers and foams