Physiological Optimization of Lipid Accumulation in Microalgae during Continuous Culture

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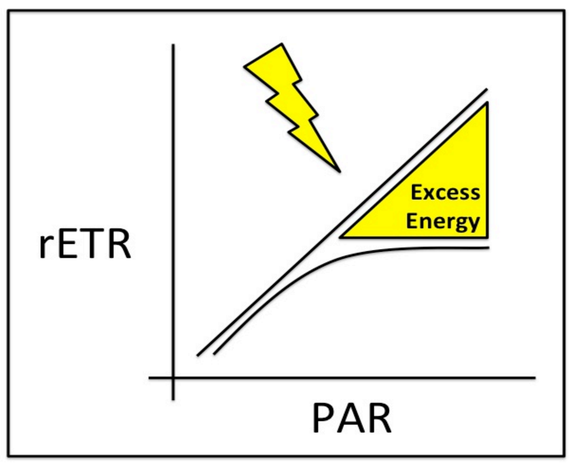
Abstract

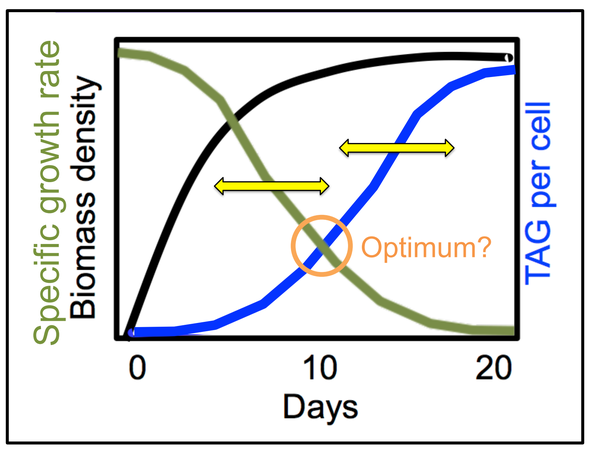
- Increasing microalgal lipid content via nitrogen limitation in batch cultures decreases photosynthetic efficiency and hinders cell growth. Physiological state is unbalanced or in the transient-state, making it difficult to correlate physiological patterns with nutrient concentration.
- In contrast, algae grown in continuous culture (CC) approximate physiological steady-state balanced growth. Recent studies indicate that lipid accumulation may coincide with a moderate growth rate under the appropriate CC nutrient regime, implying that this phenomenon resembles a continuum and not a switch. Thus, it follows that the degree of nitrogen limitation in CC may be modulated to obtain balanced growth states, which correspond to characteristic physiological states in regards to lipid content.
- We hypothesize that CC can be tuned to outpace **long-term mean batch lipid yield** by optimizing the balance between growth rate, photosynthetic efficiency and lipid content.



- Relative electron transport rate vs. photosynthetically active radiation

Conceptual Growth Model

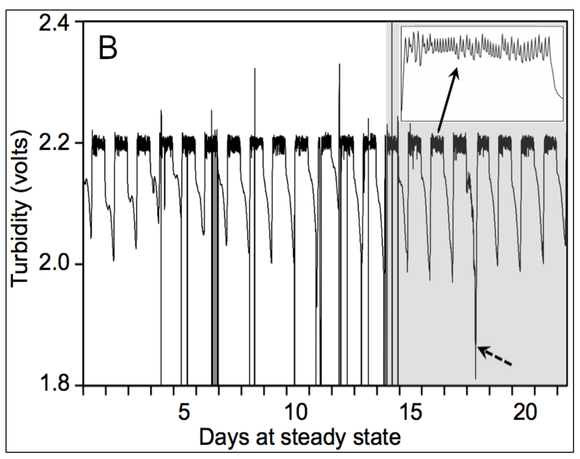
TAG per cell increases with decreasing growth rate, owing to differential photosynthate partitioning; biomass density will increase with time. Mean diel lipid yield is a function of all factors.



- Hypothetical model of batch growth. The *optimum* represents maximal TAG yield in continuous culture. Yellow arrows represent potential differences in strain and culture characteristics.

Nutritional Mode

- Batch
- Fed-Batch
- Semi-continuous
- Continuous
- Fed-Continuous

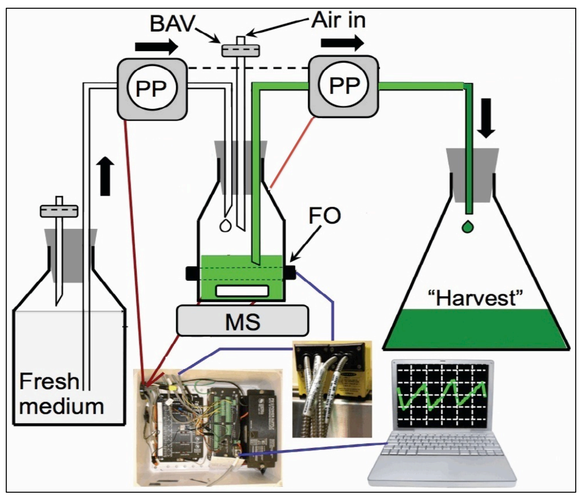


Batch Culture

- Down time, larger footprint
- Quality control concerns
- Maximize lipid **content**
  - Low growth rate

Continuous Culture

- Continuous production
- Uniform feedstock profile
- Maximize lipid **yield**
  - Growth v. torage



Batch v. Continuous
- Maximize Mean Diel Lipid Yield

Diel Patterns
- Cell division, starch v. lipid

Fed CC & Chl Fluorescence
- Energy Imbalance

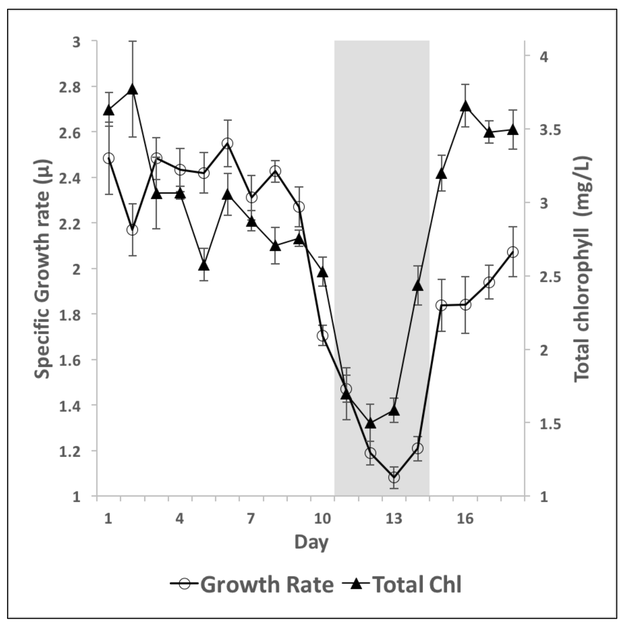
Predictive Model
- Nutrient & Redox Component

Optimization Strategy

Our approach is to decrement [N] in turbidostat cultures (n=4) under a 14:10 L:D cycle. Steady-state is indicated by less than ±10% change in growth rate, cell number or chlorophyll content for 3 days.

Uncoupling

- Growth and C fixation may be uncoupled when cell energy quota is exceeded.
- Excess energy dissipated by storing C as starch or lipid.
- This may be leveraged to maximize diel lipid yield.
- Photosynthetic carbon fixation must exceed the respiration at night.
- Growth must be limited without limiting C fixation.
- Excess energy is needed without damage.



Future Work

- N:P ratio experiment(s)
- Mutant and qPCR study
- Mixed culture & contaminant washout

References

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