The Algalrithm

Turning Algae into Bio-surfactants

By: Catherine Brame, Katie Hopfensperger, Traci Reusser, and Mary Uselmann
Project Definition:

Utilize algae as a way to collect CO$_2$ emissions from industrial plants, then harvest the algae and extract the energy dense lipids. Our objective is to reduce the carbon footprint in the production of a bio-surfactant, and create this product with an economic and environmentally friendly process.
Commercial Uses of Algae

- Biogas
- Bioethanol
- Biodiesel
- Biobutanol
- Biofuel
- Cosmetics
- Nutraceuticals
  - Pharmaceuticals
  - Vitamins
- Food
- Bioplastics
- Feedstock
- Animal feed
- Fertilizer/nutrients
Bio-surfactants

• Bio-surfactants vs. traditional surfactants
  – Absence of toxicity
  – Biodegradability
  – Eco-friendly

• Bio-surfactants vs. Bio-based surfactants
  – Currently produced by:
    • Soybean, linseed, canola, sunflower, and rubberseed oils
Replace Chloroform with Dichloromethane

Palmitic acid
Stearic acid
Oleic acid
Linoleic acid
$\alpha$-linolenic acid

$\text{CH}_3\text{OH}:\text{HCl}:\text{CHCl}_3$, $(10:1:1, \text{v/v/v})$

Palmitic acid methyl ester
Stearic acid methyl ester
Oleic acid methyl ester
Linoleic acid methyl ester
$\alpha$-linolenic acid methyl ester

FAMEs: $30\% \text{ H}_2\text{O}_2$:toluene
$(1:10:5, \text{w/w/v}), 4 \text{ mol CHO0H}$

Possible side product

Plasticizer

Triepoxidized $\alpha$-linolenic acid methyl ester
Surfactant

Glycerol

Glycerol:NaOH (10:1, w/w)

Polyglycerol

Surfactant

Palmitic acid methyl ester

Stearic acid methyl ester

Monoepoxidized oleic acid methyl ester

Diepoxidiized linoleic acid methyl ester

Triepoxidiized α-linolenic acid methyl ester

Palmitic acid polyglycerol ester

Stearic acid polyglycerol ester

Monoepoxidized oleic acid polyglycerol ester

Diepoxidiized linoleic acid polyglycerol ester

Triepoxidiized α-linolenic acid polyglycerol ester
Business Opportunity
Wastewater

• Why use wastewater?
  – Cost effective
  – Low energy requirement
  – Production of chlorella algal biomass

• Agricultural, municipal, and industrial wastewaters
  – Agricultural WW is most common for algae cultivation

• Algal growth will depend on nutrients present in wastewater

• Permit for wastewater discharge will be needed
Business Opportunity and Plan

• Environmental Benefits:
  – Recycling wastewater
  – Reducing oil-based surfactants and introducing promising bio-surfactants without toxicity
  – Sequestering CO$_2$ from high-producing industrial power plants

• Carbon Tax
Bio-surfactants Process Design
Algae Cultivation and Lipid Isolation
Algal Lipid to Bio-surfactants
Design Alternatives
Algae Cultivation Method

- **Algae Fermentation Tank**
  - Heterotrophic growth (no sunlight, sugars required)
  - Controlled, sterile growth
  - More expensive, but greater efficiency and lipid yield

- **Open Pond System**
  - Autotrophic growth (requires sunlight, no sugars required)
  - Less expensive, variable production
Lipid Separation Method

• Mechanical Separation
  – Oil Press
  – Centrifuge

• Thermal Separation
  – Heater
  – Dryer

• Dissolved Air Flotation
Solvent Extraction

- Dichloromethane & Chloroform Extraction
- Potential Hazardous Byproducts
- Dissolved Air Flotation
  - Hexane Removal
Economics
Economics

• Assumptions:
  – 10 Photobioreactors, 1000m³ ---> 475 lbₘ/hr product
  – Projected market to sell at 98 ¢/lb
  – Utilities, equipment, miscellaneous costs

<table>
<thead>
<tr>
<th>Economics Summary ($MM)</th>
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<tbody>
<tr>
<td>Fixed Capital Investment</td>
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<tr>
<td>Start-Up Costs</td>
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<tr>
<td>Annual Revenue</td>
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<tr>
<td>Net Present Value (R= 12%)</td>
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<tr>
<td>Internal Rate of Return</td>
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<tr>
<td>Pay Back Period(yrs)</td>
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<tr>
<td>Minimum Acceptable Rate of Return</td>
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Opportunities for Improvement

• Realistic carbon tax as a source of revenue
• Room for improvement on:
  – Equipment costs
  – By-product revenue sources
  – Utility/heat duty costs from our unit ops
• Second part of process
  – Cost of chemicals, and permits for waste
The Future of The Algalrithm
Moving forward with Bio-surfactants

• End-product verification
  – Molecular analysis
  – Physical property analysis

• Detailed economic analysis
  – Current & future market analysis
  – Unit operations and operating conditions of Part II
Simulation Future Work

- **PBR**
  - Wastewater
  - Photosynthesis reaction
  - Separator for Vapor Stream
    - N₂ Gas
    - O₂ Gas
    - CO₂ Gas
    - Flare

- Water-Lipid Separation
  - Distillation Column

- Specifications of Part II
Acknowledgments

• Special Thanks
  – John Oakey
  – John Myers
Questions?