



Getting to our future now. Biodiesel.



Alternative feedstocks for biodiesel production: Emerging technology and industry needs

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Community Fuels

OUTLINE

1. Introduction
2. Solid catalysts for cost and energy efficient biodiesel production
3. Algal biomass as feedstock for biodiesel production



Community Fuels

Facility at Port of Stockton, CA

Production capacity: 10 Mgal / yr
Multiple planned expansions



Production & Wholesale:

High quality biodiesel and crude glycerin

R&D: Process technologies and alternative feedstocks

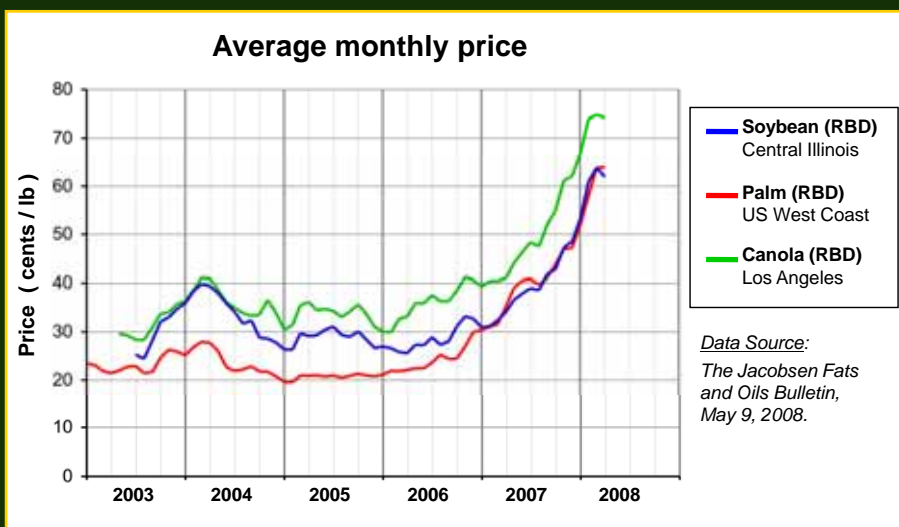
Experienced Team:

Expertise in fuels, chemical processing, regulatory compliance, renewable energy research, and commodity oils procurement



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Price of commodity feedstock oils



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Limitations of conventional feedstock sources

Social / environmental issues

- **Displacement of food crops**
 - Food vs. fuel debate
- **Environmental impacts of commercial agriculture**
 - Ecological damage from clearing natural lands (e.g., forests, grasslands) to create new croplands
 - Water consumption
 - Application of fertilizers and pesticides



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Feedstock sustainability

Life cycle analysis (LCA) indicates that biofuels produced from appropriate feedstocks result in immediate and sustained greenhouse gas reductions

- Biomass grown on marginal or abandoned lands
- ➔ – Utilization of waste materials

Focus on feedstock materials that do not compete directly with food crops for agricultural resources

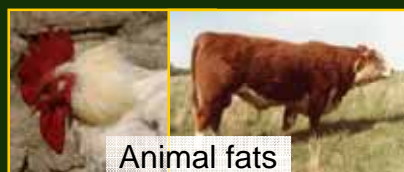
- Low-input crops grown on marginal lands

Developing viable alternative feedstock sources will be critical as the biodiesel industry continues to grow



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Other feedstocks



Rendering products:

Tallow, yellow grease, etc.

Wastes: IKG, trap grease, etc.



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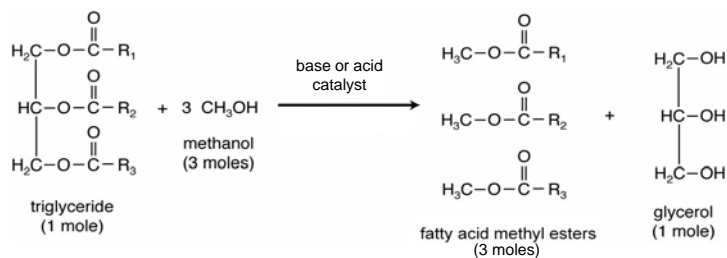
Solid catalysts for cost and energy efficient biodiesel production



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Side reaction of free fatty acids

Transesterification of triglycerides



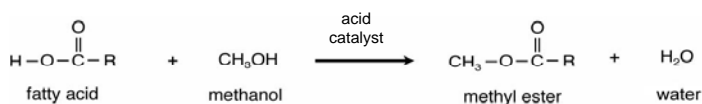
Saponification (reaction with base catalyst)



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Conversion of fatty acids to methyl esters

Esterification of fatty acids



acid treatment

base-catalyzed
transesterification



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Solid catalysts for biodiesel production

Solid catalysts offer several potential benefits over conventional liquid catalysts (e.g., sodium methoxide in methanol)

- Solid catalysts can be recovered and recycled after reaction
- Reduce/eliminate water washing of crude biodiesel product
- Higher quality glycerin byproduct
- **Ability to process high fatty acid feedstocks without additional pre-treatment steps**



Solid catalysts could significantly reduce the price of biodiesel production



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Solid catalysts for biodiesel production

Desired characteristics of solid catalysts

- High activity
- Stable, robust
- High surface-to-volume ratio
- Appropriate pore volume and size distribution (allows high diffusivity)
- Low expense and complexity of preparation

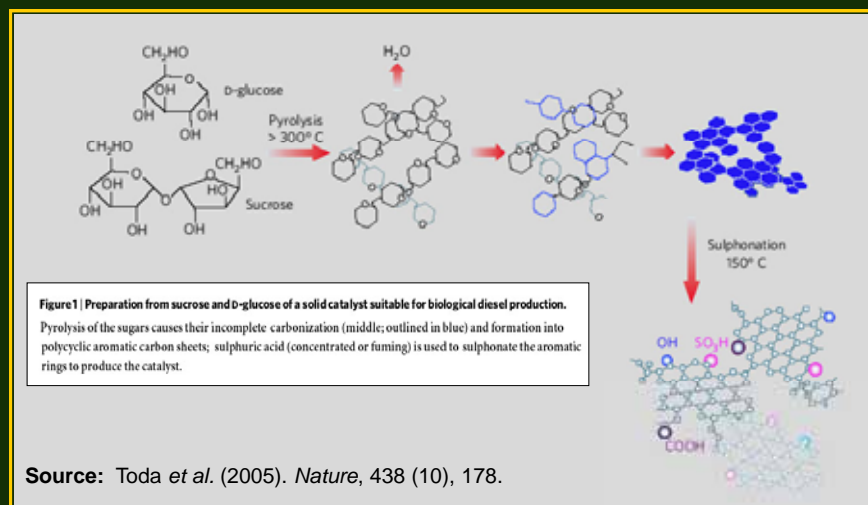
Examples of solid acid transesterification catalysts

- Zeolites
- Acidic ion exchange resins (e.g., Nafion and Amberlyst)
- Mixed metal oxides (e.g., Esterfip-H)
- Sulfated zirconia
- Sulfonated, partially carbonized sugars



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Development of novel solid catalyst materials



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Algal biomass as feedstock for biodiesel production



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Algae -- the ultimate feedstock?



Fundamental limitations of photosynthetic algal culture

- Cultures restricted to low cell densities
 - light limitation at high cell concentrations
- Dependence on local climate
 - solar insolation, temperature, etc.
- Requires large tracts of land (open ponds) or expensive equipment (photo-bioreactors)



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Benefits of heterotrophic algal culture

Some algal species can be grown *heterotrophically*

-- metabolic energy is derived from fermentation of reduced carbon compounds (e.g., sugars)

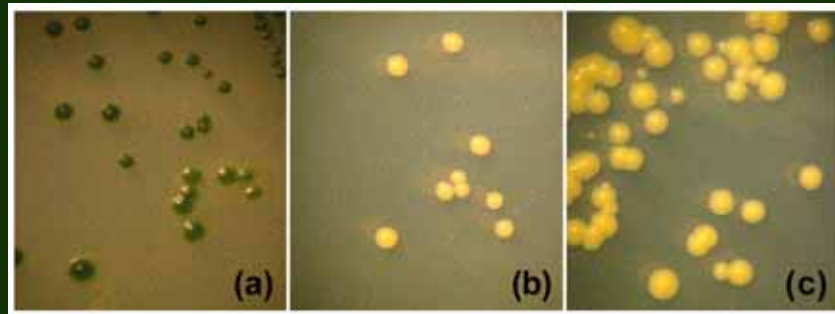
- High-density cultures possible
- Not reliant on local climate conditions
- Relatively small land requirements
- Uses robust, relatively inexpensive equipment that is already produced at large scales for mature industries
 - e.g., beer & wine making, ethanol, pharmaceuticals, etc.



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Results from prior work

- Investigation of appropriate strains
- Laboratory culture under heterotrophic conditions



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Results from prior work

Investigation of waste streams as nutrients for heterotrophic growth media


- Carbon sources
- Nitrogen sources
- Makeup water



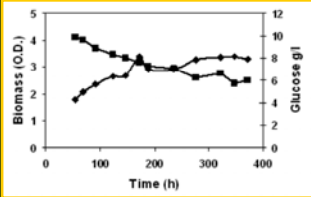
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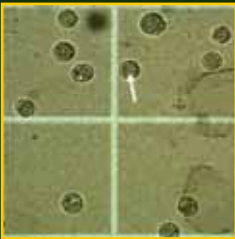
Results from prior work

Fed-batch runs using bench-scale bioreactor




A
2-liter bioreactor system





Cells at 1000x magnification



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Flow diagram for biodiesel production from heterotrophically cultured algal biomass

WASTE NUTRIENT SOURCES

↓

Pre-treatment

ALGAL CELL INOCULUM

↑

Heterotrophic growth (fermentation)

Dewatering algal biomass

→

Extraction of algal bio-oils

↓

Separation of algal biomass

EXTRACTED ALGAL BIOMASS

↓

Separation of glycerin

CRUDE GLYCERIN

Transesterification of algal bio-oils

↑

Purification of crude biodiesel


BIODIESEL FUEL

↑

Expensive, energy intensive

→

Major obstacle to viable process



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Algal cells must be lysed prior to extraction

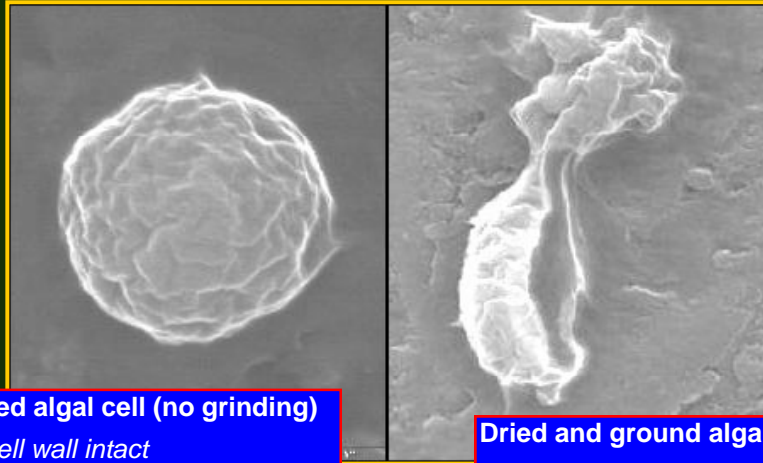
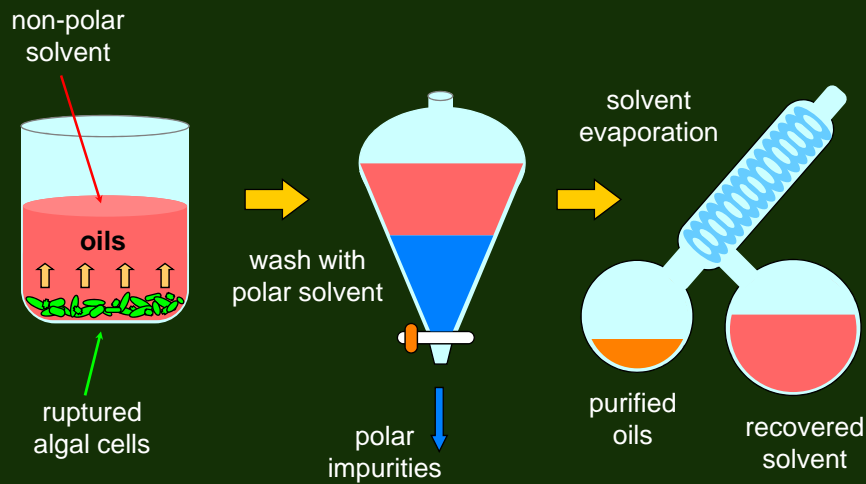


Image: Dr. Michael Cooney, University of Hawaii



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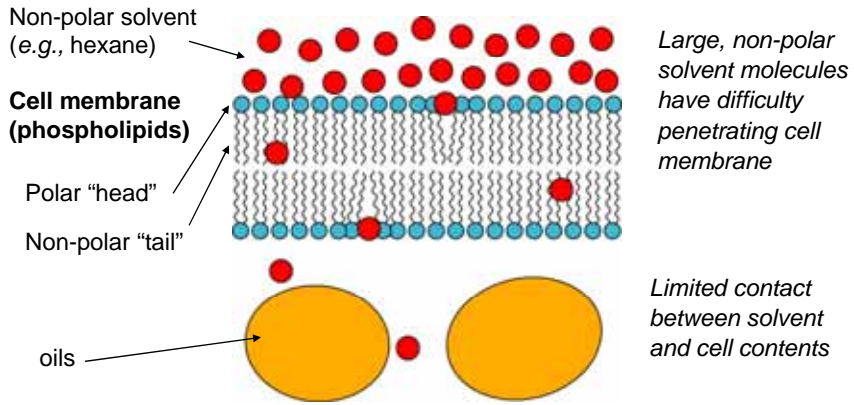
Solvent extraction



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Solvent extraction

Non-polar solvent by itself is often not effective



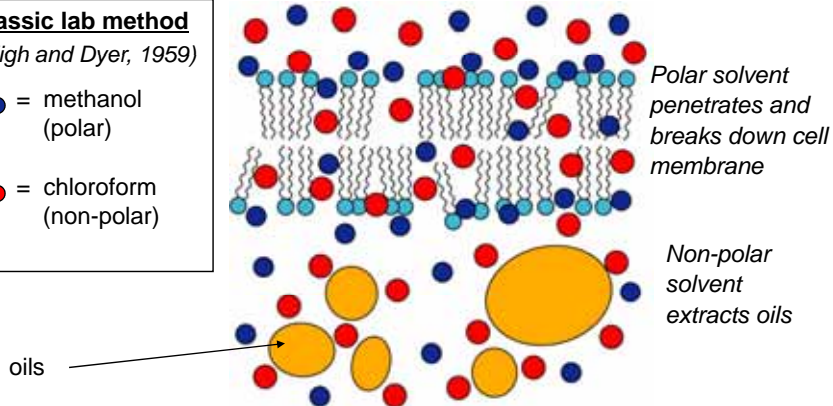
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Solvent extraction

High degree of extraction with polar/non-polar solvent mixture

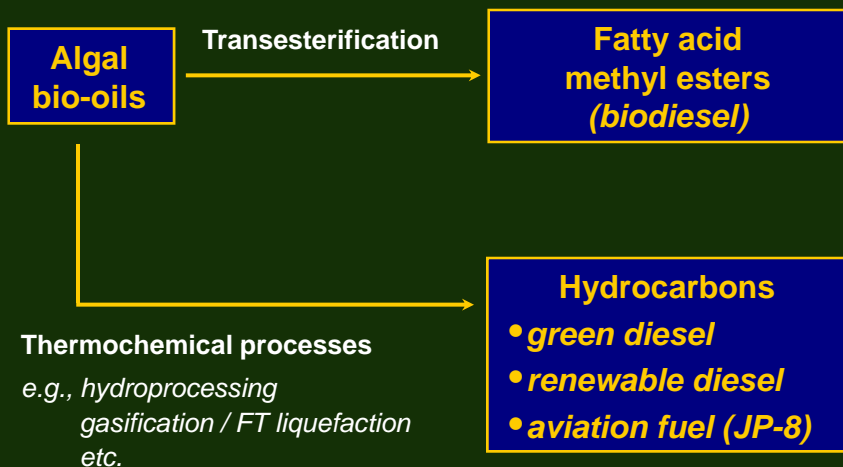
Classic lab method
(Bligh and Dyer, 1959)

- = methanol (polar)
- = chloroform (non-polar)



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Potential biofuels derived from algal bio-oils



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SUMMARY OF TECHNOLOGICAL NEEDS

Solid catalysts for biodiesel production

- novel catalyst materials
- system design (optimal size/shape of catalyst particles, binders, packed beds, regeneration, etc.)

Extraction/conversion of algal bio-oils to biodiesel

- efficient dewatering of cells
- novel solvent systems
- thermochemical processes



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