Wastewater Treatment Facilities: A Source of Oil for Producing Biodiesel

Rafael Hernandez and Todd French
Mississippi State University
Dave C. Swalm School of Chemical Engineering
Biodiesel Industry: Present & Future Challenges

- Total US BD usage is ~80 Mgal/yr
- US uses ~75 Bgal/yr of Petro-Diesel
- Total oleochemical production capacity is ~500 Mgal/yr
- More than 70% of current biodiesel production cost is the feedstock
- There is a glut of crude glycerine in the market
- Current price of crude glycerine is ~ $0.01/lb compared to $0.60/lb in 2000.
- Many biodiesel producers are storing crude glycerine
DOE SERC Biofuels Research & Development at MSU

- Lipid Source Production
  - Plant Sciences
  - Biochemistry
  - Chemical Engineering

- Lipid Extraction
  - Chemical Engineering
  - Chemistry
  - Plant Sciences
  - Biochemistry

- Biofuel Production
  - Agricultural and Biological Engineering
  - Chemical Engineering

- Biofuel Market Development
  - Food Sciences
  - Chemical Engineering
  - Agricultural Economics
  - Mechanical Engineering
Technical Accomplishments/ Biodiesel from Sewage Sludge (~1 Bgallons oil)

Municipal Wastewater Treatment
Biosolids Generated for Use or Disposal in the United States

- 1998 - 6.9 M dry tons
- 2000 - 7.1 M dry tons
- 2005 - 7.6 M dry tons
- 2010 - 8.2 M dry tons

1 – “Biosolids Generation, Use, and Disposal in the United States”, EPA530-R-99-009, September 1999
Examination of the various transesterification methods shows that _in situ_ conversion of lipids to FAMEs provides the highest overall yield of biodiesel.

Assuming at 7.0% overall yield of FAMEs from dry sewage sludge on a weight basis the cost per gallon of biodiesel would be $3.11.

As transesterification efficiency increases the cost per gallon drops quickly, hitting $2.01 at 15.0% overall yield.
Biodiesel produced from primary sludge

✓ The experimental data indicated that the production of biodiesel by *in-situ* transesterification of primary sludge is second order, when the methanol:lipid molar ratio employed is in great excess compared to the stoichiometric requirement.

The cost per gallon of biodiesel from dry primary sludge would be $2.08. This is more cost effective compared to biodiesel from dry secondary sludge.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost per gallon ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifuge O&amp;M</td>
<td>0.22</td>
</tr>
<tr>
<td>Drying O&amp;M</td>
<td>0.64</td>
</tr>
<tr>
<td>Extraction O&amp;M</td>
<td>0.17</td>
</tr>
<tr>
<td>Biodiesel processing O&amp;M</td>
<td>0.60</td>
</tr>
<tr>
<td>Labor</td>
<td>0.10</td>
</tr>
<tr>
<td>Insurance</td>
<td>0.03</td>
</tr>
<tr>
<td>Tax</td>
<td>0.02</td>
</tr>
<tr>
<td>Depreciation</td>
<td>0.12</td>
</tr>
<tr>
<td>Capital P&amp;I service</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td><strong>2.08</strong></td>
</tr>
</tbody>
</table>

$0.15/lb
Saturated vs. Unsaturated Distribution in Sludge Sources

- Biosolids 1
- Primary Solids 1
- Secondary Solids 1
- Secondary Solids 2

- Polyunsaturated FAMEs
- Monounsaturated FAMEs
- Saturated FAMEs
The Yeast

*Rhodotorula glutinis*

- Means “red glutton”
- Aerobic, oleaginous (oil-producing) yeast
- High methyl ester yield\(^1,2\)
- Breaks down carbon oxygen demand (COD) in waste streams\(^2,3\)

Oleaginous Microorganisms Grown on Wastewater

- Oleaginous Yeast Grown on Wastewater with 0.1g/L of Dextrose
- Oleaginous Yeast Grown on Wastewater with 1g/L of Dextrose

- Optical Density (600nm)
- Time (hr)
- R. glutinis
- C. curvatus
- Pos. Control: R. glutinis
- Pos. Control: C. curvatus
- Negative control: wastewater
## Conversion of Lignocellulosic Biomass to Microbial Oil

<table>
<thead>
<tr>
<th>Sugar</th>
<th>Cell mass concentration in culture, mg/ml</th>
<th>Total Lipid production. % dry wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>artificial acid hydrolysate</td>
<td>4.12</td>
<td>22</td>
</tr>
<tr>
<td>Xylose</td>
<td>4.14</td>
<td>30</td>
</tr>
<tr>
<td>Dextrose</td>
<td>3.99</td>
<td>35</td>
</tr>
<tr>
<td>Switch Grass Hydrolysate</td>
<td>2.63</td>
<td>26</td>
</tr>
</tbody>
</table>
Envisioned Process: The New Biorefineries

- Sugars
- Lignocellulose
- Influent
- Grit Chamber
- Clarification
- Oxidation Unit
- Clarification
- Aerobic BioOxidation
- Belt Filtration
- Mixing
- Flow Splitting
- Lipid Accumulation Chamber
- Oily Sludge
- Liquid Effluent
Environmentally Sustainable Fuel Production

1. Sugars/Biomass
2. Water/Nutrients
3. Wastewater Treatment
4. Oil
5. Oil Refinery
6. CO₂
7. Hydrogen (H₂O)
8. Fuels
9. Intermediate Polymers/Specialty Chemicals
Benefits…

- Provides a profitable aspect to sewerage treatment
- Approximately 30% reduction in biosolids generation (note that biosolids management has become a big problem for cities – disposal costs >$50/dton)
- Greatly improved pathogen stabilization ( Produces Class A Sludge )
- Minimal impact to on-site treatment operations
- Minimal additional footprint requirements
- Provides cheap diesel source to city fleets
- Adds a fuel production incentive to third world countries to treat sewage
Summary

• The MSU Biodiesel Project integrates three key research areas associated with biodiesel production: feedstocks, oil extraction, and biodiesel processing technologies.

• Although the process for biodiesel production is relatively simple, specific feedstocks may require unique extraction and processing techniques to assure quality.

• The Sugar Platform, and current wastewater treatment, biodiesel, and fuel distribution infrastructure could be integrated to potentially generate 10 billion gallons of biodiesel (~10% diesel displacement).
Acknowledgements

- US Department of Energy
- USEPA-RARE
- PERC
- LS9
- Mississippi Technology Alliance
- MSDEQ
- Hilliard Fletcher Wastewater Treatment Plant, Tuscaloosa AL