Biodiesel or Fatty Acid Alkyl Ester (FAAE) Production

Reactions involved:

- **Triglyceride** + **Alcohol** $\rightarrow$ Biodiesel (or FAAE) + **Glycerol**
- **FFA** + **Alcohol** $\rightarrow$ Biodiesel (or FAAE) + **H$_2$O**

- **Chemical approach**
  - Transesterification: Alkaline (solid or liquid)
  - Esterification: Acid (solid or liquid)

- **Enzymatic approach**
  - Lipase for two simultaneous reactions

**Alcohol reactant**
- Primary: Methanol, ethanol or higher alcohols
- Secondary: Isopropanol or higher alcohols
Why Enzymatic Approach?

**Major Characteristics:**

- Specific reaction
  - NO side product
- Environmentally friendly
  - Low temp. and pressure
- No acidic, basic or toxic chemicals involved
  - NO chemical disposal, no toxic chemical waste
- Water-free
  - NO waste water
- Multiple sources
  - Sources of enzymes are abundant

*An enzymatic process is “green” by nature.*

Concerns with the Enzymatic Process

- Lipase cost
- Reaction rate, i.e., lipase activity
- Life span

Lipase total cost contribution
= $f(\text{lipase cost, lipase activity, life span})$

Unless all concerns are addressed, it can’t be a cost-effective process.
Factors Affecting Lipase Cost

- Lipase source: dominant
- Carrier: insignificant
- Immobilization cost: insignificant

Source cost can be significantly reduced through mass production.

Factors Affecting Reaction Rate

- Lipase source
- Immobilization process

Both are important and correlated.

An amount lower than 3% per stream day is now attainable, i.e., 100 T/D of biodiesel, ≤ 3T immobilized lipase.
Factors Affecting Life Span

- Lipase source
- Lipase deactivation

Deactivation can be due to methanol, ethanol, glycerol and natural aging.

Glycerol deactivation can be eliminated through the use of inert solvent.

Life Span: Natural Aging

- Tests done at room temp.
- Immobilized lipase

Retention = \frac{\text{hydrolytic ability}}{\text{initial hydrolytic ability}}

SBC (2012)
Glycerol Effect on Column Operation

Glycerol deactivation is independent of reactor type: Packed bed or CSTR

The ET Process®

Simplified flowsheet of ET Process, Sanho Biodiesel (US 7473539, US 7666666)
Typical Product Quality

Reactants: Soybean oil and methanol

<table>
<thead>
<tr>
<th>Biodiesel Component</th>
<th>Composition, wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid methyl esters</td>
<td>99.46</td>
</tr>
<tr>
<td>Monoglyceride</td>
<td>0.44</td>
</tr>
<tr>
<td>Diglyceride</td>
<td>0.03</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>0.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Glycerol Composition, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
</tr>
<tr>
<td>Methanol</td>
</tr>
</tbody>
</table>
Cost Savings from the ET Process®

**Saving in feedstock**  Big, f(oil source, FFA)

**Profit from glycerol**  Medium

**Saving in operating cost**  Small

**Total savings USD 0.251/Kg of biodiesel**

Basis: CPO 8% FFA, USD 681.5/t (Dec. 2008)

Advantages

- **With the ET Process®, government subsidy is not necessary for business sustainability.**
- **Biodiesel price can be lower than diesel, still with significant profit**
- **Payback: far less than 1 year**

SBC (2012)
Further Profit and Advantage for Biodiesel Production

**Can preserve nutraceutical compounds**
like **carotenoids, tocotrienols, tocopherols, sterols, etc. in crude oil**

**They can easily be separated from biodiesel during downstream processing.**

Extended Applications

- **High value-added products**
  Reactions with higher alcohols
  - Isopropyl myristate, isopropyl palmitate, etc.
  - Biolubricants

- **Pure glycerol can be used for production of pure monoglyceride, i.e., biobased materials.**
  \[ RCOOR' + \text{Glycerol} \overset{\rightleftharpoons}{\longrightarrow} \text{MG} + R'OH \]
Reactions with Higher Alcohols

Not much difference in reaction times for primary alcohols, e.g.,
- Methanol
- Ethanol
- n-butanol
- iso-butanol
- 2-ethyl-hexyl alcohol
- Lauryl alcohol, etc.

Longer reaction time is required for secondary alcohols, e.g., isopropyl alcohol.

Fatty Acid Alkyl Esters

Soybean oil + IPA \( \rightarrow \) Fatty acid isopropyl esters + Glycerol

High-Value End Products:
- Isopropyl myristate
- Isopropyl palmitate
- Glycerol monostearate
- Isopropyl oleate and/or isopropyl linoleate

SBC (2011)
Feedstocks containing a high amount of artificial trans-fats and trans-fatty acids, such as PFAD (Palm Fatty Acid Distillates), and deodorized distillates, are problematic.

Trans-fats and trans-fatty acids can't be converted by the lipase now available.
Conclusions

The ET Process® provides a solution that overcomes all the problems associated with the conventional chemical process.

To achieve a sound business and long-term sustainability, biodiesel should be coproduced with other products, such as glycerol, phytochemicals or high value-added products like pure monoglycerides, by an integrated design.

The enzymatic approach can pave the way to an eco-environmentally conscious society that uses renewable oil sources to produce biofuels and biobased materials, i.e., lipid-based biorefinery society.

Thank you!

Questions may be sent to gc@sunhobiodiesel.com

www.sunhobiodiesel.com