Biofuel Technologies and their Implications for Water and Land Use
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Sao Pablo - BRASIL

BIODIESEL PRODUCTION – TECHNOLOGIES
ALTERNATIVE RAW MATERIALS

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Competition with food production is unavoidable, but can be minimized by maximizing efficiencies.

Transform disadvantages in opportunities.

Integrated processes should be a key objective.

Basic science is needed.

Engineering solutions to technological problems are required.
To warm up……

- Biodiesel production in large scale
- Biodiesel production in very low scale: self consumption
- Use of ethanol to transesterify the vegetable oil/fat
- Develop the algae technology…
- RVO: recycled vegetable oils
- Other raw materials…..jatropha…. 
**BIODIESEL PRODUCTION PROCESS**

**Water consumption**

**Methanol**

**Oil**

**Catalyst**

**Reaction**

**Phase Separation**

**Purification Neutralization Washing**

**Methyl Ester**

**Water**

**Wet Methyl Ester**

**Biodiesel**

**Drying**

**Fractioning**

**Glycerine**

**Water**

**Methanol**

**Crude Glycerine**
Glycerol Processing: Technical Grade

Crude
Glycerol

Acidification
pH=4
HCl 36%

Fatty Acids

Neutralization
pH=7
NaOH 50%

Evaporation
Glycerol
Technical
Degree

Water
Methanol
Neutralization//Washing Continuous Equipment

CLEAN BIO

WATER

ACID

BIO IN

WATER OUT
PLANT: 250,000 TON/YEAR - Refined Oil

**WATER: MASS BALANCE**

1000 kg Oil
Methanol 98 kg
NaCH₃O 16.7 kg
HCl 36% 12 kg
NaOH 50% 1.5 kg
Water: 4 kg

1000 kg FAME
117 kg Glycerine
5 kg Fatty acid

**WATER CONTENT**

7-8%
1-2%
PLANT: 250,000 TON/YEAR
Refined Oil

1000 kg Oil

Electric energy: 13 kWh
Steam: 250 kg (10 bar)
Cooling water: 150,000 kcal

Effluents:
4 kg water 0.3% methanol

vent absorption
Dry Purification: ADSORBENTS

Eliminates soaps and glycerine, but methanol remains

MUST BE ELIMINATED BY EVAPORATION

Glycerine has to be purified: needs water.
Dry Purification:
ADSORBENTS: EXCHANGE RESINS

\[
\text{Soap} + \text{Resin}^{\text{H}^+} \rightarrow \text{Free Fatty Acid} + \text{Sodium Resin}^{\text{Na}^+}
\]

ONLY LOW LEVELS OF SOAPS ARE ADMITTED BY THIS ADSORBENT
Dry Purification: ADSORBENTS

SILICAGEL

GLYCERIN ADSORPTION ON SILICA
Low level of energy is used to obtain biodiesel

Water is recirculated, thus no water input is needed.

Very low level of effluents are generated, and are due to vents treatments.
Small Scale Production
SELF CONSUMPTION: ENERGY (LAND AND WATER) SAVINGS?

ENERGY SAVING? -> LAND AND WATER PROTECTION
Example: 3000 lts Biodiesel/day
8000 ha farm
Santa Fe- Argentina

Plant in operation since 2006

Consumes 100% biodiesel

370 km away from the port
25 m

Expeller

Raw Material

2 x 60

Glycerine Tanks

2 x 12 m

Methanol Tanks

2 x 12 m

Oil

Biodiesel

Balanced feed Plants

Electricity Generator

Glycerine Tanks

2 x 12 m³

Methanol Tanks

2 x 12 m³

Biodiesel Tanks

3 x 12 m³
REACTION

Water with Methanol

GLYCERINE

SETTLING

Methanol with water 3000 ppm

NEUT/WASHING

Water with Methanol

Efluentes.... Glycerine?

RESINS

DRYING

EVAPORATION

Reaction goes back!!

Process for small plants...
PRESSING
RAW MATERIAL AND EXPELLER STORAGE
METHANOL TANKS
BALANCED FEED PRODUCTION
Free and Total Glycerine analysis by volumetric procedure developed in our lab.

Agricultural producers need assistance to select the technology and to set-up simple procedures to assure the quality.
Ethyl Ester Production

Ethanol: renewable safer to handle ethylester better cold properties
no reliable information available for production at any scale!!
ETHYL ESTER PRODUCTION

ETHANOL: RENEWABLE - BETTER COLD PROPERTIES

LESS REACTIVE THAN CH₃O⁻!!!
Different Phase Diagram: complicate the process!!

Ethanol

NO PHASE SEPARATION

NOTE THE AMOUNT OF GLYCEROL PHASE

FAME

GLYC

Methanol distribution: higher concentration in Glycerine
Several issues complicates the process design

ETOXIDE is not as good catalyst as METOXIDE

METOXIDE is more adequate

Mixture of methyl and ethyl esters

Higher solubility of glycerol in biodiesel phase

Higher tendency to form soaps....
Cold Properties

Ethylesters: refined tallow
5°C lower pour point and cloud point

Ethanol  Methanol
Algae Production

photosynthesis

Air

sunlight

nutrients

water

carbon dioxide

Surface Area

oxygen

sugars

lignin/cellulose

starches/protein

lipids
Algae...... a very interesting alternative

Capture CO$_2$ from Power Plants

Do not use agricultural lands

carbon dioxide is in most cases the limiting factor
Photosynthesis

Approximate chemical reaction:
\[ n \text{CO}_2 + n \text{H}_2\text{O} + 7n \text{photons} + \text{nutrients} \rightarrow C_{nH_{2n}O_nN_xS_y} + n \text{O}_2 \]

Solar Incidence is 4 to 7 kWh/m\(^2\), but only 47% is in the right frequency range for photosynthesis.

Other inefficiencies and plants’ internal energy usage make that less than 10% of available sunlight is actually converted into usable biomass.

Green algae are the most efficient, converting 7-8% of total sunlight into usable biomass with a maximum theoretical yield of 140 ton DM/acre/year of which 40% could be available as lipids (15,000 gallons/acre/year).

By comparison, soy beans yield only 1.5 ton DM/acre/year containing only 20% oil (90 gallon/acre/year), while sugarcane typically yields 15 ton DM/acre/year for 800 gallon/acre/year of ethanol.

From: Integrated Biorefineries- Thomas Gieskes
Integrated Biorefinery is an integration of processes that combine the efficiency of algae cultivation with a renewable source of carbon dioxide from a complementary renewable fuels process.
Tropical and subtropical regions range from 10 to 30 Mega grams (Mg = 10^6g) dry biomass ha\(^{-1}\) year\(^{-1}\)

To increase yields may be growing micro-algae in water that has been saturated in CO\(_2\) derived from power plants

Maintaining desired algal cultures in such ponds has turned out to be difficult
Why Algae?

- Much greater productivity than their terrestrial cousins
- Non-food resource
- Use otherwise non-productive land
- Can utilize saline water
- Can utilize waste CO₂ streams
- Can be used in conjunction with waste water treatment
- An algal biorefinery could produce oils, protein, and carbohydrates
Inexpensive culture systems using shallow (10 cm deep) ponds stirred with paddle wheels in areas of high solar insolation

More intensive cultivation systems becoming available

Algal cultivation can be 50x more productive than traditional crops

Potential for culture in areas not used for crop production Desert land Ocean
## Comparing Potential Oil Yields

<table>
<thead>
<tr>
<th>Crop</th>
<th>Oil Yield Gallons/acre</th>
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<tbody>
<tr>
<td>Corn</td>
<td>18</td>
</tr>
<tr>
<td>Cotton</td>
<td>35</td>
</tr>
<tr>
<td>Soybean</td>
<td>48</td>
</tr>
<tr>
<td>Mustard seed</td>
<td>61</td>
</tr>
<tr>
<td>Sunflower</td>
<td>102</td>
</tr>
<tr>
<td>Rapeseed/Canola</td>
<td>127</td>
</tr>
<tr>
<td>Jatropha</td>
<td>202</td>
</tr>
<tr>
<td>Oil palm</td>
<td>635</td>
</tr>
<tr>
<td>Algae (10 g/m²/day at 15% TAG)</td>
<td>1,200</td>
</tr>
<tr>
<td>Algae (50 g/m²/day at 50% TAG)</td>
<td>10,000</td>
</tr>
</tbody>
</table>
Resource Requirement: Water

Water with few competing uses

Water resources show many areas of intersection with cheap land and CO₂ sources

“Produced water” from oil wells potential source

Seawater available in many parts of the world
Resource Requirement: LAND
60 billion gallon/year

10 g/m²/day
at 15% TAG
(~1,200 gal/acre-yr)
48,000,000 acres

50 g/m²/day
at 50% TAG
(~10,000 gal/acre-yr)
6,000,000 acres

32,000,000 acres
### Resource Requirement: CO₂ and Water

**Basis: algal oil needed for 60 billion gal/yr biodiesel**

<table>
<thead>
<tr>
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<th>10 g/m²/day at 15% TAG</th>
<th>50 g/m²/day at 50% TAG</th>
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<tbody>
<tr>
<td><strong>CO₂</strong> Usage (ton/year)</td>
<td>1.4 billion</td>
<td>0.9 billion</td>
</tr>
<tr>
<td>% of US Power Plant Emissions</td>
<td>56%</td>
<td>36%</td>
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</tbody>
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**Water Usage (trillion gallons/yr)**

- 120
- 16

*Compare to ~22 trillion gal/yr saline water extracted in 2000 in U.S. (primarily for power plant cooling) (USGS), and to >4000 trillion gal/yr of water used to irrigate U.S. corn crop (USDA).*
Vast Areas of the Globe Are Not Suitable for High Levels of Terrestrial Agriculture

Agricultural Suitability

Completely Suitable
Significant R&D is required to optimize yields in order to realize realistic scenarios of land and water use.

Technology has contributed so far in large extend to this goal, but still there are many problems to be solved.

There are many options, in different scales. All can contribute in order to provide renewable energy.

Interdisciplinary work is needed, and cooperation among countries must be intensified in order to find the best solutions to the energy and food requirements.

and that is why we are here......!!
THANKS FOR YOUR ATTENTION!!