Another Biomass Resource: Natural Fats, Oils, and Waxes

Sources:

- Animal Fats (Lard, Grease)
- Vegetable Oils (e.g., Canola, Soy)
- Recycled Brown/Yellow Grease (e.g., from deep-fryer)

A Renewable Resource

A Byproduct of Food Industry

- Gathered for other purposes

Some Uses:

- Food Uses (fry/cooking oil)
- Direct Fuel Uses:
  - Diesel Fuel (Elsbett Co.)
- Base for fuels/lubricants

Direct Use of Fatty Acids & Oils as a Diesel Engine Fuel

Positive

- Cheap (no process cost)
- Proven
  - R. Diesel used peanut & other vegetable oils, & animal fats to fire his first engine
  - Elsbett Co. in Europe offers engine. URL:www.elsbett.com

Negative

- Poor Engine Efficiency
- Poor Engine Durability
- Poor Engine Performance
- Issues with the Fuel Itself
  - Fuel Gelling in Cold Temp.
  - Expensive

WHAT CAN WE DO?

DEFINITIONS:

LIPID-- water insoluble molecules from organic sources (hydrophobic);

FATTY ACID-- A main constituent of LIPIDS. Contains both hydrophobic and hydrophilic (water-loving) regions. Typically, fatty acids are 16 to 18 Carbons in length.

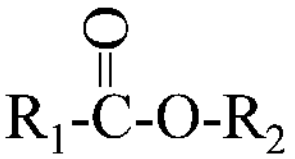
GLYCEROL-- A three-carbon (C_3) trihydroxy alcohol (3 [OH] groups).

TRIGLYCERIDE-- a simple lipid consisting of three fatty acids (hence the 'TRI') connected to a glycerol backbone.

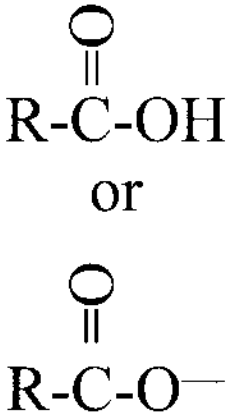
SATURATED- fully hydrogenated (each C has single bonds connected to H where possible)

UNSATURATED-not fully hydrogenated

ESTER- form:



ACID- form:



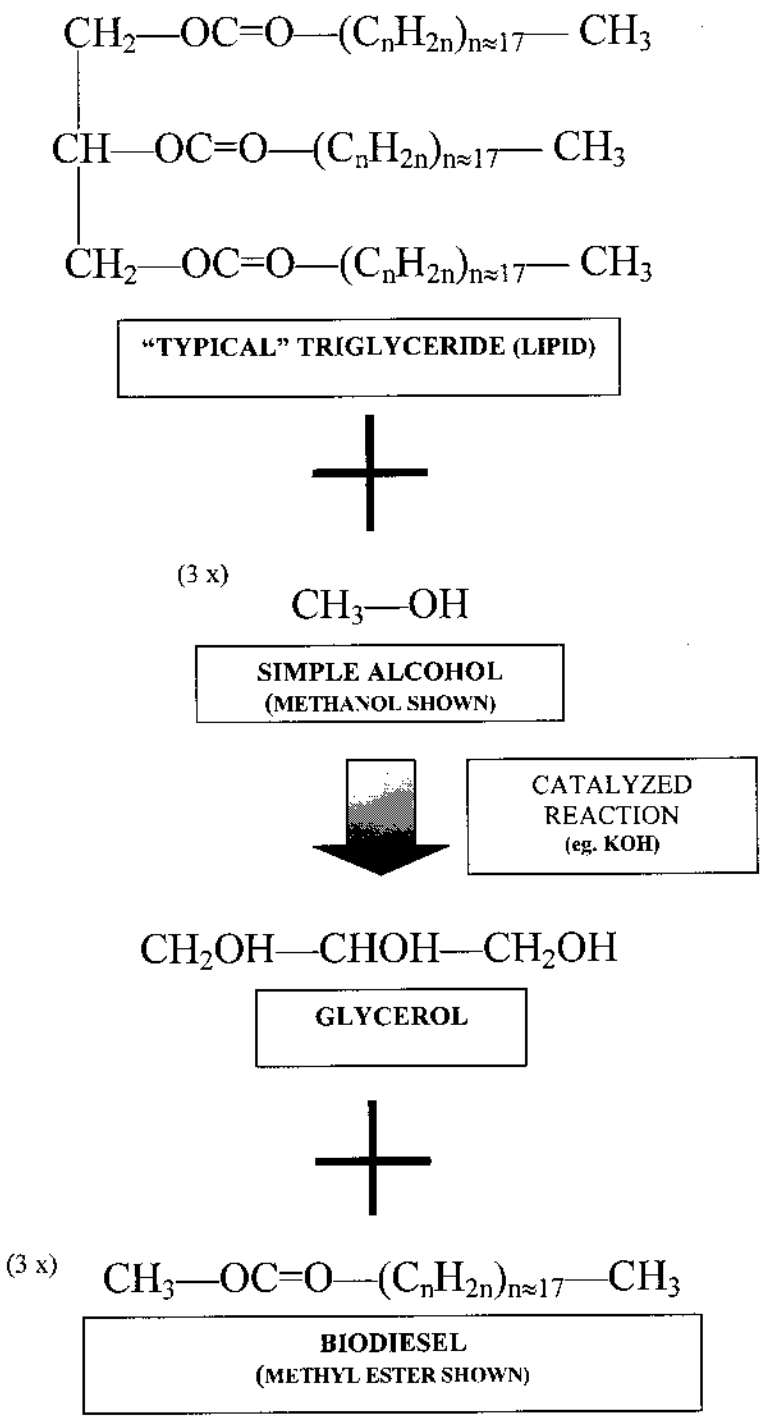


Figure 5.1 The Transesterification Process.

The above figure depicts the transesterification process used to make biodiesel.

Transesterification to BIODIESEL

"...[T]he mono alkyl esters of long chain fatty acids derived from renewable lipid sources"

--National Biodiesel Board

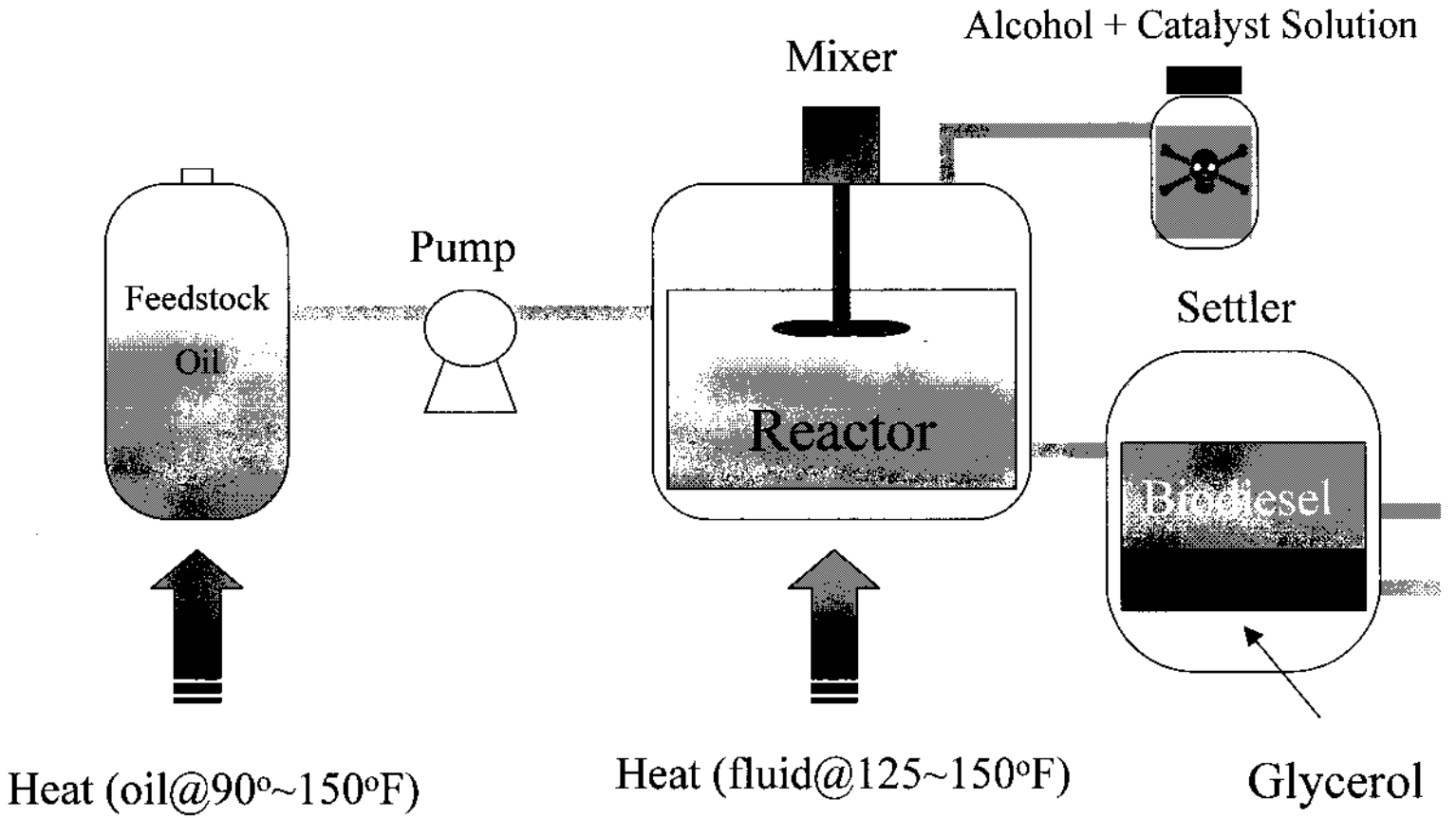
Advantages:

- Order of magnitude lower viscosity than natural vegetable oils
- Substantially similar to petroleum diesel fuel (petrodiesel). Can use biodiesel directly in Diesel engines with relatively no engine modification required.
- Slightly increased energy density
- Ease of transport and uniformity of fuel
- Higher performance fuel
- Emissions benefits

"Disadvantages":

- Process efficiency is 80.6% (loose 20%)
- 1 unit of fossil energy required per 3.215 units of fuel energy produced
- Typically $2.50 to over $5.00/gal. biodiesel. However, biodiesel from recycled fryer oil as low as $0.25 to $0.50/gal.
- Slight corrosivity to rubber/ elastomers.

Transesterification Reactor



Process first used 1853 by E. Duffy & J. Patrick-- Biodiesel first used in S. Africa before WWII to power heavy duty Diesel equipment

Comparison of Biodiesel to Feedstock Vegetable Oils

Property	#2 Diesel	Soy Oil	Soy Methyl Ester	Soy Ethyl Ester	Rapeseed oil	Rapeseed Methyl ester	Rapeseed Ethyl ester
Specific Gravity	**0.8495**	**0.92**	**0.886**	**0.881**	**0.91**	**0.880**	**0.876**
Viscosity @ 40 C, (cSt)	**2.98**	**33**	**3.891**	**4.493**	**51**	**5.65**	**6.17**
Sulfer, wt%	**0.036**	**0.01**	**0.012**	**0.008**	**0.01**	**0.012**	**0.014**
HHV, MJ/kg	**45.42**	**39.3**	**39.77**	**39.96**	**40.17**	**40.54**	**40.51**
HHV, MJ/L	**38.58**	**36.2**	**35.24**	**35.20**	**36.6**	**35.68**	**38.00**

Source: Klass, Biomass for Renewable Energy, Fuels, and Chemicals, 1998

Diesel Engine and Biodiesel vs. Petrodiesel

- Biodiesel Cetane Rating is 54 to 58 vs 50 to 54 for petrodiesel-- higher efficiency
- NOx generally increases
- Total hydrocarbons (THC) and carbon monoxide (CO) decrease
- Particulate Matter (PM) tends to increase at low load but decrease at high load-- Biodiesel PM is more easily broken down with a catalytic converter
- Lower visible smoke emissions
- Must use compliant fuel hoses and elastomers.
- Biodiesel VERY biodegradable w/fewer long term effects

Biodiesel in the World

United States

- Most US biodiesel from Soy or recycled oils.
- Biodiesel esters historically used for other purposes (e.g. Dawn,
- Overseeing National Biodiesel Board (www.biodiesel.org)
- University of Idaho (C. Peterson--premier biodiesel researcher in the world)
- Of the 94.6 million L methyl esters produced in '96--only 3.8 million L used for fuel

Asia

- Japan: Biodiesel used by public transport @ Nagano Olympics
- Some Tokyo buses f/Fryer Oil

Europe

- The three largest biodiesel consumers in the world are (in order):
  - France (all petrodiesel contains 1-5% vol. biodiesel)
  - Germany (over 350 gas stations offer biodiesel)
  - Austria
- Most biodiesel from rapeseed
- Uses 1135 L/yr
- Why Europe?
  - Incentives for non-food crops
  - High fuel price & fuel taxes
  - Environmental Benefit

Biodiesel Feedstocks and Potential

Feedstock	Average Yield (L/ha)	Potential Yield (L/ha)
Chinese Tallow Tree	NA	6270
Peanut	814	1780
Castorbean	449	1590
Winter Rape Seed	NA	1220
Sunflower	571	1030
Safflower	599	940
Flax	309	940
Soybean	383	650
Cotton	150	370

Data from Klass, Biomass for Renewable Eenrgy, Fuels, and Chemicals, Academic Press, London, Tokyo 1998 [Klass-1998]

US Feedstock Area Harvested

1997 Production of Certain Key Biomass Feedstocks in the US

Feedstock	US 1997 Production (Metric Tons)	Area Harvested (Hectares)	Yield (Tons/ha)
Canola	414,760	282,470	1.47
Cottonseed	6,290,960	5,370,240	1.17
Flaxseed	55,150	54,630	1.01
Mustard Seed	26,950	29,460	0.91
Peanuts	1,604,380	570,940	2.81
Rapeseed	880	610	1.44
Safflower	195,070	95,100	2.05
Soybeans for Beans	73,551,470	28,159,950	2.61
Sunflower	1,707,060	1,154,180	1.48
Corn (total for grain and silage)	321,269,540	32,163,960	9.99

Source: "Crop Production", National Agricultural Statistics Service, USDA, Washington D.C., Released 11 December 1998

Biodiesel Potential

- ~60 grams of glycerine produced per liter biodiesel (sells at ~$10/gallon; used in Food, Medicine, cosmetics, tobacco)
- Cost breakdown:
  - Seed cost: 70%
  - Oil extraction: 06%
  - Transesterification: 24%

Successful Biodiesel Applications

- **Idaho French-Fry maker**-- uses biodiesel from french-fryer oil to fuel potato trucks.
  - http://ehpnet1.niehs.nih.gov/docs/1995/103-2/forum.html#french
  - http://www.bioenergy.org/biologue/biomass-nw/index.html
- **Yellowstone 'Truck in the Park'**-- Used to 'Clean the Emission' of vehicles traveling through Yellowstone
- **Bryan Peterson**- '92 to '94 Circumnavigates the world in Diesel boat powered on biodiesel.
- **The Veggie Van**- Van driven 25,000 mi. across US on biodiesel made w/ batch reactor towed by van. Feedstock was Fast Food Restaurant fryer oil.
  - http://www.veggievan.org
  - Fuel ~$0.25/gal. (low qty.)
- **Channel Island NP, CA** Biodiesel to be used for sustainable energy promotion and lower environmental impact
- **City Busses**-Tokyo, Atlanta
- **Europe**- Underground Mines

Biodiesel--Thoughts for the Future

US Petrodiesel Consumption

- ~94.6 G L/yr

US Animal Fat/Veg. Oil Production

- ~10.4 billion kg/yr

@0.9kg/L biodiesel, this is:

- ~11.6 G L biodiesel
- ~12% of petrodiesel*

If all idle farm land used for oil crop production (2.5 times current food production) :

- 27% of petrodiesel could be displaced*

***Using ALL oils! None left for Food!**

The Chinese Tallow?

- High Yields per Hectare
- Grows in Arid Climate
- Doesn't compete w/ Food Crops
- BUT, lots of unknowns

US Annual Cooking Oil/Fat WASTE

- 1.13 to 1.59 billion kg/yr
- =up to 1.4 billion L of biodiesel
  - Several companies making biodiesel from this resource: for example Pacific Biodiesel in HI: www.biodiesel.com

Niche Applications:

- Underground Mines, Pristine Environments (esp. boating), Blending Agent (B20)