Biodiesel Production for On-Farm Use

A Curriculum for Agricultural Producers

Prepared by

For the

National Center for Appropriate Technology

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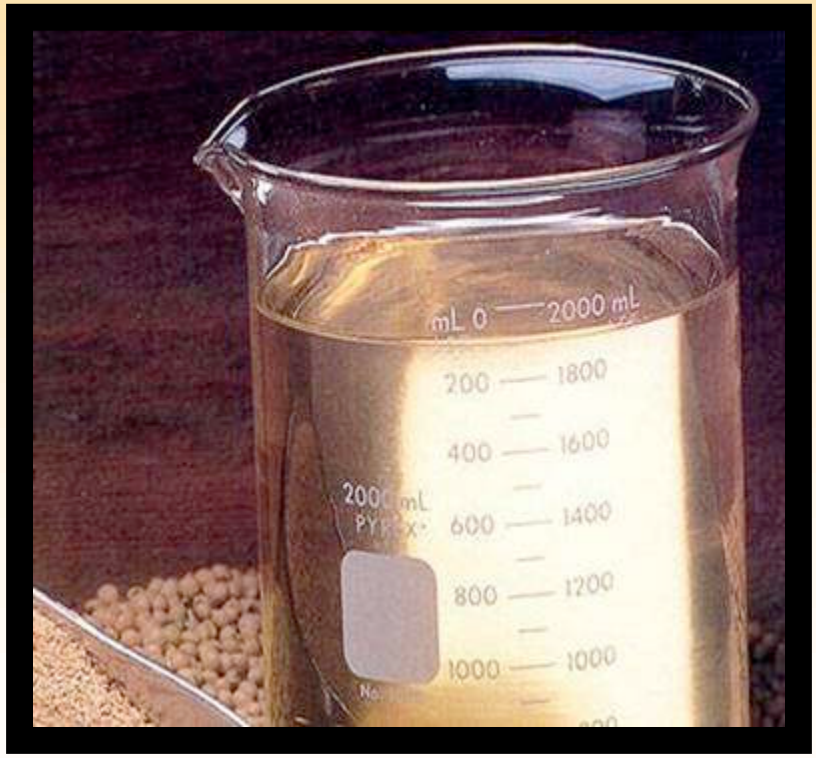
Overview

- Introduction
- The Chemistry of Biodiesel
- Advantages and Disadvantages
- Biodiesel Feedstocks
- Oil Processing
- Small Scale Biodiesel Production
  - On-farm Case Studies

Introduction: What is Biodiesel?

- A permanently thinned vegetable oil
- A diesel fuel replacement produced from vegetable oils or animal fats through the chemical process of transesterification
- Biodiesel can be used in any diesel engine in any proportion from 1-100% with little or no modifications to the engine



Biodiesel: What is it not?

Unprocessed Vegetable Oil

Mixtures of vegetable oil or alcohol with diesel fuel

Ethanol or E85

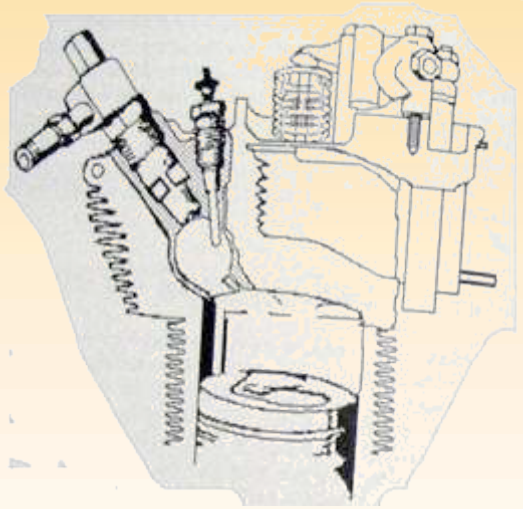
History of Vegetable Oil Based Fuels

- 1900 - Rudolph Diesel debuted the first diesel engine running on peanut oil at the World's Exhibition in Paris
  - He likely used peanut oil at the request of the French Government, who were interested in its use in their African colonies
- After Diesel's mysterious death in 1913, development focused on the use of petroleum-based fuels

The use of vegetable oils as engine fuels may seem insignificant today but the such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time.

-Rudolph Diesel, 1912

Why make biodiesel?



Diesel fuel injectors are not designed for viscous fuels like vegetable oil

Biodiesel

Glycerin (thick)

The Chemistry of Biodiesel

- All fats and oils consist of triglycerides
  - Glycerol/glycerine = alcohol
  - 3 fatty acid chains (FA)
- *Transesterification* describes the reaction where glycerol is replaced with a lighter and less viscous alcohol, e.g. methanol or ethanol
- A catalyst (KOH or NaOH) is needed to break the glycerol-FA bonds

Advantages of Biodiesel

- Biodegradable
- Non-toxic
- Favorable Emissions Profile
- Renewable
- Carbon Neutrality
- Domestic production

Advantages of Biodiesel

- Requires no engine modifications (except replacing some fuel lines on older engines).
- Can be blended in any proportion with petroleum diesel fuel.
- High cetane number and excellent lubricity.
- Very high flashpoint (>300°F) means greater safety
- Can be made from waste restaurant oils and animal fats

Biodiesel Reduces Toxic Emissions

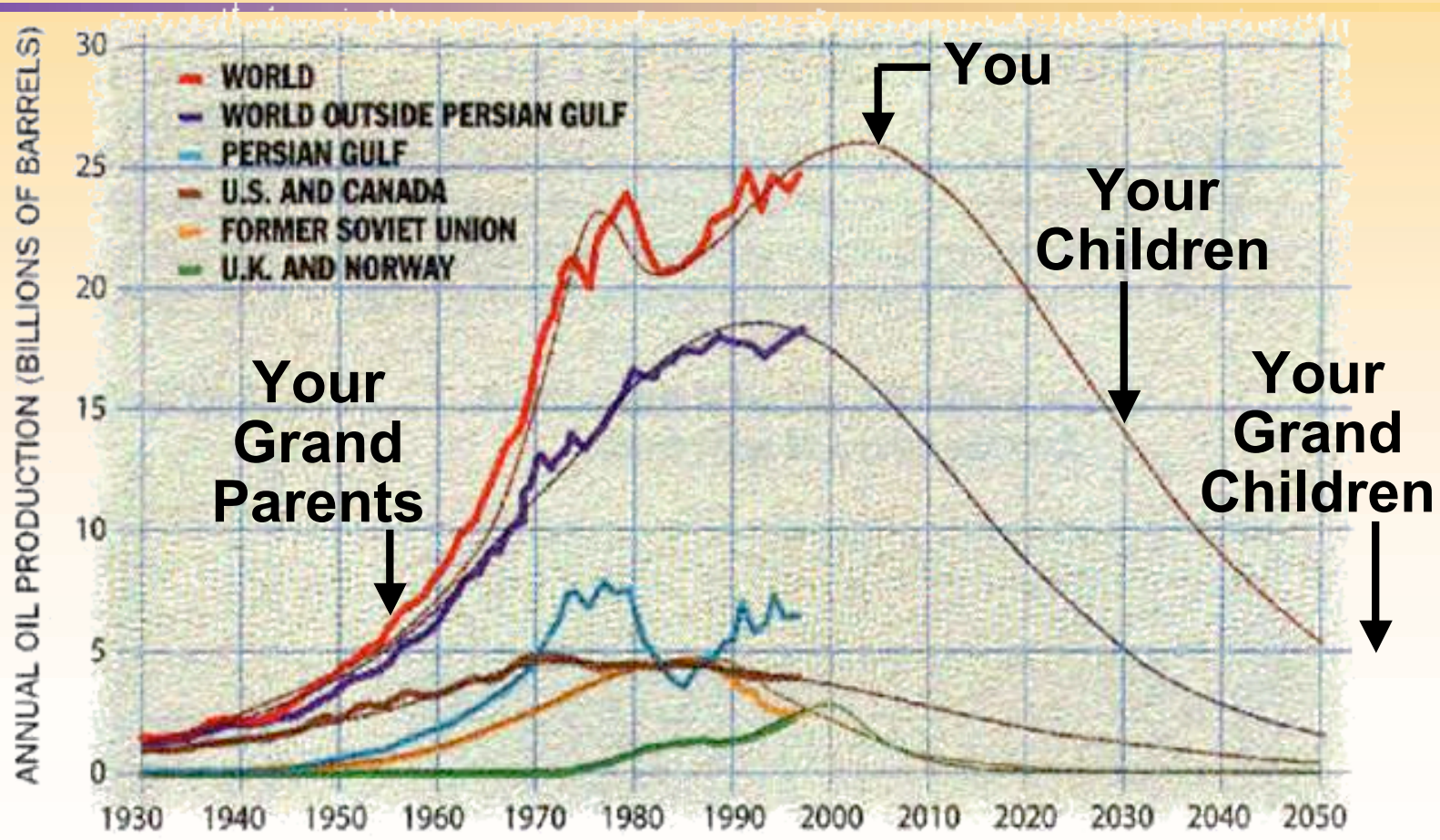
Sources: EPA, 2002 Biodiesel Emissions Database; McCormick, Bob, 2007, Presentation: The Truth about NOx Emissions & TxLED Update

Biodiesel vs. Petroleum Diesel		
Emission	**B100**	**B20**
Carbon Monoxide	-47%	-12%
Hydrocarbons	-67%	-20%
Particulate Matter	-48%	-12%
Sulfates	-100%	-20%
Nitrogen Oxides	+/- ??	+/- ??
Ozone formation (speculated HC)	-50%	-10%
PAH	-80%	-13%

Global Warming

- Biodiesel has a (nearly) closed carbon cycle
- Biodiesel yields a 78% carbon dioxide (CO_2) reduction compared to petroleum diesel under life-cycle analysis.
- Biodiesel has the most favorable energy balance of any liquid fuel
- 3.2:1 for soy biodiesel

World Oil – In Perspective



Source: Campbell, Colin J. and Jean H. Laherrere, "The End of Cheap Oil." *Scientific American*, March 1998.

Vegetable Oil as Feedstocks

- Oil-seed crops are the focus for biodiesel production expansion
- Currently higher market values for competing uses constrain utilization of crops for biodiesel production
- Most oil-seed crops produce both a marketable oil and meal
  - Seeds must be crushed to extract oil
  - The meal often has higher market value than the oil

U.S. Oil-Producing Crops

*Harvest yields from USDA NASS service, 2006 figures

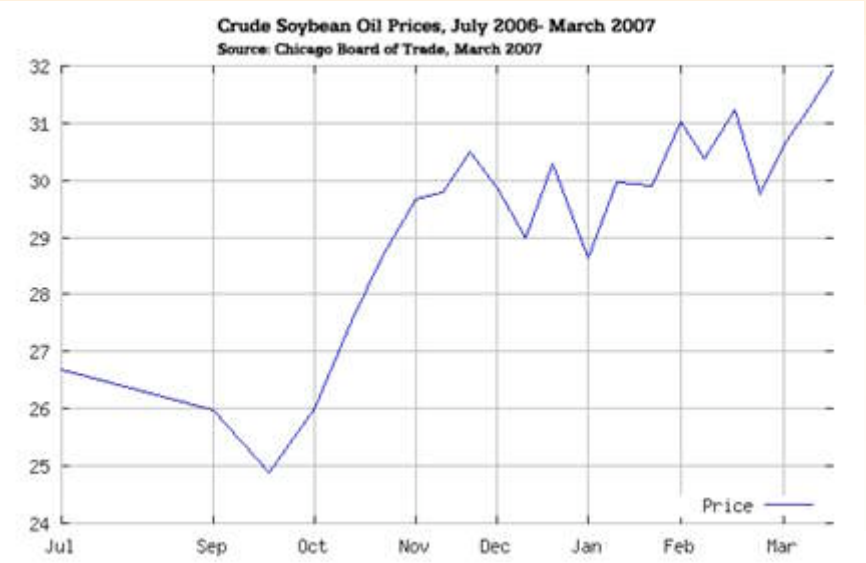
Land Crop Yields based on US average 2006			
Crop	**Avg Harvest (lbs)**	**Oil content % (avg)[2]**	**Gal/acre (approx.)**
Peanut	2874	47	175
Canola	1366	43	76
Soybean	2562	19	63
Sunflower	1211	40	63
Camelina[1]	1300	35	59
Safflower	1069	33	46
Corn	8946	4	46
Cottonseed	819	19	20

1 Biodiesel Magazine, Feb. 2007

2 O'Brian, Richard D. Fats and Oils: Formulating and Processing for Applications, 2004

Soybeans

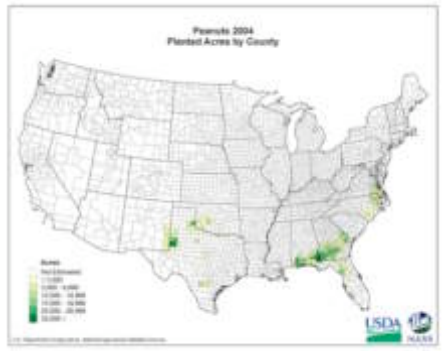
- Primary source for biodiesel production in U.S.
- Market value at $6.64-7.05 per bushel (60 lbs) range for conventional as of March 2007
  - $9+ per bushel for organic
- Approximately 75.5 million acres of soybeans in production (2006)
- Approximately 2 billion gallons of oil produced annually
- 85% of soybeans sold as meal for animal feed
- Oil is an added value to the meal
- Large, diverse market demand reduces availability for biodiesel
  - Meal valuable for livestock



Canola/Rapeseed

- Rapeseed is a member of the mustard family
- Canola is a variety of rapeseed bred to have low levels of erucic acid and glucosinolates (both of which are undesireable for human consumption)
- Both spring and winter varieties grown
  - Depends on geographical location
  - Winter crop in NC
- Good oil yield
- Premium cold flow properties

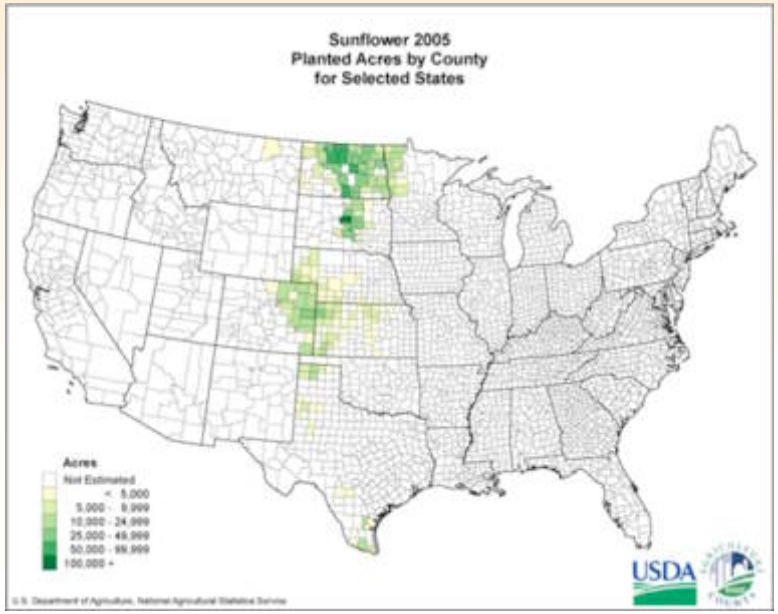
Peanuts



- Nearly 15% of peanuts are crushed for oil use in U.S.
- Value range of $0.23 -.30 per lb. of peanut depending on state, variety, production system (higher for organic)
- $.50 per gallon of oil obtained (on average)
- Market value for premium quality edible oil currently limits use in commercial biodiesel production
- Production limited to southern regions of U.S.
- Research on “industrial” peanuts—not suitable for human consumption—being conducted at the University of Georgia
  - Will potentially make peanuts more economically feasible as biodiesel source

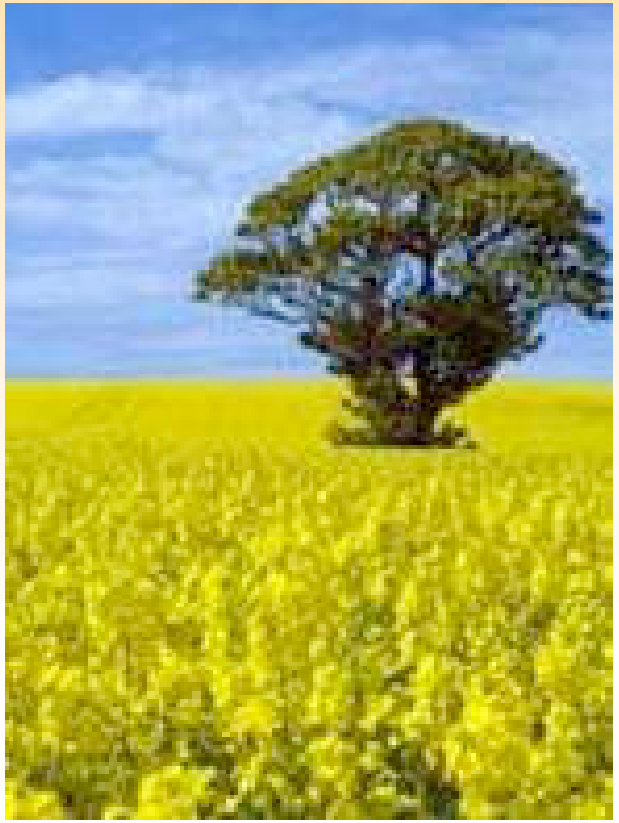
Sunflowers

- Wide geographical range for production
- Market value is high for edible oil and seeds, birdseeds
- $.08 -.12 per lb. market value
- University of New Hampshire project
- 1.86 million acres of sunflowers harvested in the U.S. in 2006



Camelina

- *Camelina sativa* is a member of the mustard family
- Summer annual crop suited to grow in semi-arid climates and northern U.S.
- Research on variety development and economic feasibility are being conducted at Montana State, North Dakota State, and Purdue University
  - The cost of camelina-based biodiesel would likely be $2 per gallon compared to 3$ per gallon for soy-based
- Variable and fixed costs are 1/3 - 1/4 the cost of canola
  - $45 to $68 per acre



Other oil crops

Oil Palm

- Up to 500 gallons/acre yield
- The most widely produced oil outside of the USA.
- Fruit grows in bunches, each weighing 22-110 lbs.
- Poor cold weather performance

Algae

- NREL Study (1978-1996) investigated using algae as a biofuel feedstock
- Theoretical yields of 10,000 gallons/acre
  - 250 times greater than soybean oil
  - GreenFuel Technologies - promising

Oil Processing

- Oil-seed crops must be crushed to extract oil
  - This can be done on-farm or at a crushing facility
  - Small scale systems use mechanical crushing
  - Commercial crushers often also use hexane extraction
    - Hexane is toxic but removes more than 99% of oil
- Before conversion, oil must be degummed:
  - Treat with phosphoric acid for 4-8 hours (300-1000 ppm for soy, 1000-3000 ppm for canola)
  - Water wash
  - Vacuum drying
  - Oil often purchased as “Crude, degummed.” RBD = Refined, Bleached, Deodorized

Disadvantages of biodiesel

- Lower Energy Content
  - 8% fewer BTU's per gallon, but also higher cetane #, lubricity, etc.
- Poor cold weather performance
  - This can be mitigated by blending with diesel fuel or with additives, or using low gel-point feedstocks such as rapeseed/canola.
- Stability Concerns
  - Biodiesel is less oxidatively stable than petroleum diesel fuel. Old fuel can become acidic and form sediments and varnish. Additives can prevent this.
- Scalability

Biodiesel Feedstocks

- Total annual production of U.S. fats and oils (2004)
- 35.3 billion pounds = 4.6 billion gallons of oil = 4.6 billion gallons of biodiesel

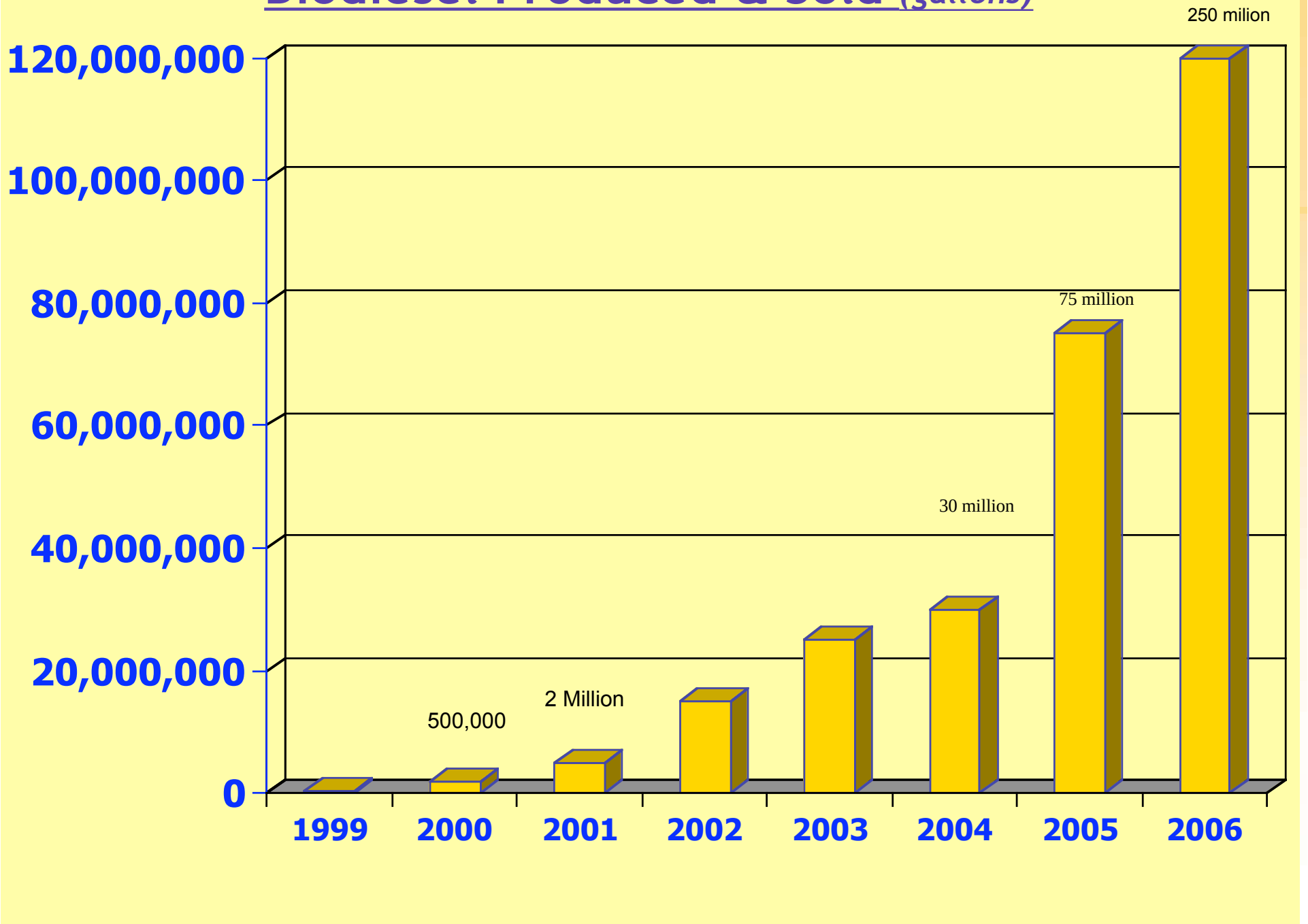
Vegetable Oil	(Billion lbs/yr)
• Soybean	18.340
• Peanuts	0.220
• Sunflower	1.000
• Cottonseed	1.010
• Corn	2.420
• Others	0.669
Total Vegetable Oil	23.659

Animal Fats/Oils	(Billion lbs/yr)
• Edible Tallow	1.625
• Inedible tallow	3.859
• Lard & Grease	1.306
• Yellow Grease	2.633
• Poultry Fat	2.215
Total Animal Fat	11.638

Diesel fuel consumption

- 2004 U.S. Diesel use = 62 billion gallons
  - On-road diesel use = 37 billion gallons
  - 4.6 billion gallons of biodiesel divided by 62 billion = 7.4%
- All vegetable oils and fats produced in the U.S. could only supply enough biodiesel to replace 5-10% of current consumption
- More feedstocks are needed to supply the growing biodiesel industry!
- Conservation is key

Biodiesel Produced & Sold *(gallons)*



Farm-scale oil presses

- Generally two types of mechanical oil presses are available
  - Screw and Hydraulic
- The presses use mechanical force to compress the oil out of the seeds.
- They are typically powered by an electric or diesel motor
- Presses vary in capacity (2-27 liters/hour) and cost ($400 - $13,000)

Examples of oil presses

- Taby Pressen (Sweden)
  - Electric powered screw oil presses
  - www.oilpress.com
- Komet (Germany)
  - Cold presses (i.e. no heat added)
- Mammoth (US)
  - Diesel powered oil press
  - Joel Koch (sawyer335@gmail.com)
- Kickstart (Kenya)
  - Ram press designed for “Better World Workshop
  - www.kickstart.org

Taby Press

Komet Press

Ram Press

On-Farm Biodiesel Production

Case studies

- BE Bioenergy/Steven Hobbs, Australia
- Piedmont Biofuels, NC
- Independence Valley, WA
- NC Zoo
- Gaston County, NC

On-farm/ off-road biodiesel

- Biodiesel used as off-road fuel is exempt from state or federal road excise taxes
- Fuel should meet the ASTM specification D 6751
- EPA registration is exempt for off-road fuel production
- Can be produced using either waste oils brought in or using locally grown energy crops such as canola, soy, sunflower, mustard, etc.

BE Bioenergy/Steven Hobbs

- Victoria, Australia
- Uses a 4% biodiesel blend in all on-farm diesel vehicles
- Currently grows a mixture of canola and mustard on farm, and press canola from neighboring farms.
- Plans to build small-scale biodiesel production plant using local feedstocks
- *www.bebioenergy.com*
  steven@bebioenergy.com

Piedmont Biofuels Biofarm

- Located in Moncure, North Carolina
- Powers two tractors and two farm pick-up trucks on 100% biodiesel (B100) produced at the farm
- Primarily uses waste vegetable oil as feedstock

- Have grown variety trials of canola, rapeseed and mustard radish.

North Carolina Asheboro Zoo

- Biodiesel is made from waste vegetable oil collected from zoo restaurants
- Restaurants currently provide about 1,500 gallons of used oil. 40% of diesel use is at B20 blend level
- Plans to replace all diesel fuel use with B100
- Biodiesel is used in zoo trams, buses, trucks, tractors and equipment

Independence Valley Farm

- Located in Rochester, Washington
- Received Western SARE Producer Grant for production development (2000)
- Utilized waste vegetable oil as feedstock for biodiesel
- Biodiesel replaced 330 gallons of petroleum-based diesel fuel
  - Two tractors
  - Market van

Gaston County, NC School Bus Garage

- Waste vegetable oil
- 12,000 gallons production in 2006
- Buses and fuel delivery truck
- Expansion to 60,000 gallons
- $150,000 savings over 2 years

Further Resources

- www.attra.org — Small scale oilseed processing guide, *Biodiesel: A Brief Overview*
- www.bebioenergy.com — Biodiesel, Farming for the Future
- www.landinstitute.org — Insights from Sunshine Farm
- www.folkecenter.dk — Cold-Pressing of Oilseeds, Organic Rape Cultivation, Pure Plant Oil (3 separate articles)
- www.wsare.usu.edu — On Farm Biodiesel Production with WVO
- www.green-trust.org — Sunflower Seed Huller & Oil-seed Press
- www.oilpress.com — Taby-pressen oil seed presses
- www.journeytoforever.org/biofuel_food.html — Food or Fuel?
- www.unh.edu/p2/biodiesel/index.html
- www.eere.energy.gov/biomass/publications.html
- www.bioproducts-bioenergy.gov/pdfs/bcota/abstracts/19/z347.pdf

National Biodiesel Board (NBB)

- National Soydiesel Development Board changed its name to NBB in 1995 and began to focus its efforts on addressing technical and regulatory needs to commercialize biodiesel.

  Two main accomplishments:

  1. Helped develop an ASTM specification for biodiesel
  2. Registered biodiesel with the EPA by completing Tier 1 and Tier 2 health data testing at a cost of over $2.2 million

- Annual NBB conference (Orlando, FL February 2008)

Contact Information

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