

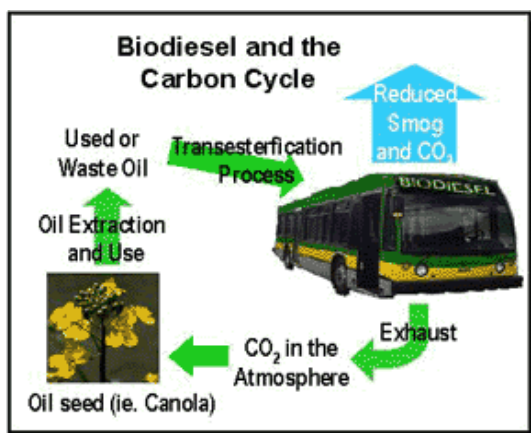


Cape & Islands Self-Reliance Guide To Biodiesel

Looking for information on Biodiesel? Want to learn how to make your first batch? This site is one of first hand knowledge and research to bring the basic, simple biodiesel production steps to you!

With ever-increasing fuel prices and degradation of the environment due to pollution, more and more people across the globe are searching for alternative means of meeting their fuel needs. Recently, many have turned to biodiesel as an answer, as biodiesel offers an immediate way to transform a fossil fuel burning machine into an environmentally and economically friendly vehicle. However, the benefits and technology of biodiesel have long been realized. Dr. Rudolf Diesel himself spoke of running the diesel engine on peanut oil. In 1911 Diesel wrote, "The diesel engine can be fed vegetable oils and would help considerably in the development of the agriculture in the countries which will use it" (Renewable Energy: Power for a Sustainable Future). A century ago there were very apparent benefits to using biodiesel, and time has only led to a larger list.

Environmentally speaking, biodiesel is a leading alternative fuel. "In 2000, biodiesel became the only alternative fuel in the country to have successfully completed the EPA-required Tier I and Tier II health effects testing under the Clean Air Act" (National Biodiesel Board). This means biodiesel significantly reduces practically all regulated emissions and is of no threat to human health. A study conducted by the U.S. Department of Energy, concluded that the production and consumption of biodiesel, when compared to petroleum diesel, resulted in a 78.5% reduction in CO² emissions (National Biodiesel Board). Finally, biodiesel provides a positive net energy balance, "as for every unit of energy that is required to produce a gallon of biodiesel, 3.24 units of energy are gained" (National Biodiesel Board).



Biodiesel produces economic and security benefits as well. The long-term price of fossil fuel is going nowhere but up, and prices for domestic agricultural commodities are low. Biodiesel will be part of the solution to freeing ourselves from the high prices of foreign fossil fuel, while boosting our homegrown agriculture commodities. "In 2001, the US Department of Agriculture reported that an average annual increase of 200 million gallons of soy-based biodiesel demand

would net total crop cash receipts by \$5.2 billion cumulatively by 2010" (National Biodiesel Board).



Biodiesel Basics

What is Biodiesel?

The National Biodiesel Board (NBB) states "Biodiesel is a domestic, renewable fuel for diesel engines derived from natural oils like soybean oil". The definition continues with "a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats". The latter leads to the nuts and bolts of what really biodiesel is: transesterification.



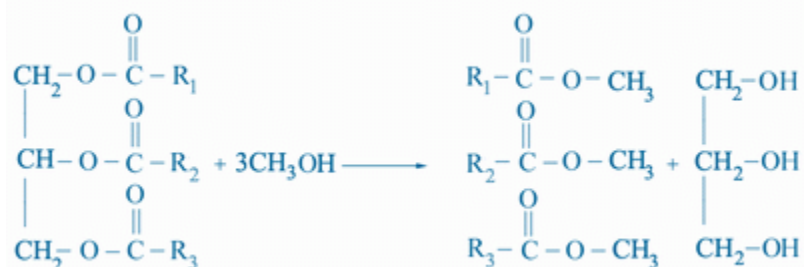
Photo courtesy of National Biodiesel Board

Transesterification

Some refer to the process of making biodiesel simply as transesterification, because it is the chemical process that achieves changing the triglycerides of vegetable oil into the mono-alkyl esters of diesel. However complicated this may sound, a degree in chemistry is not a prerequisite for making biodiesel.

All vegetable oils consist primarily of compounds known as triglycerides. Triglycerides are basically compounds comprised of three large organic fatty acid molecules (esters) combined with a glycerol (an alcohol). Diesel oil's main components are these esters freed from the glycerol and attached to another lighter alcohol. In biodiesel, the conversion of the esters is completed by adding methanol and the catalyst Sodium Hydroxide (NaOH). The catalyst is needed to break the bonds of the triglyceride

allowing the methanol to bond with the three free esters leaving methyl ester (mono-alkyl esters) and glycerol. This is actually a three-step process. One step for each glyceride: triglyceride to diglyceride; diglyceride to monoglycerides; monoglycerides to glycerol. A potential problem during transesterification is that before the reaction completes, converting all the triglycerides, the supply of methanol or sodium hydroxide is depleted. It is known that the quantity of methanol needed for virgin vegetable oil is 20% by volume of the vegetable oil. However, some biodiesel brewers will use up to 2 times that amount. The amount of Sodium Hydroxide used is .35% of the volume of virgin vegetable oil. If using Potassium Hydroxide the quantity is anywhere from .70% to .90%. As noted these numbers are for virgin vegetable oil not waste vegetable oil. For waste vegetable oil one needs more catalyst due to the presence of free fatty acids or FFA's.



Triglyceride → Methyl Ester + Glycerin

Picture from <http://www.me.iastate.edu/biodiesel/pages/biodiesel3.html>

Free Fatty Acids and WVO

Free Fatty Acids are fatty acids that are separated, due to heat or water, from the triglyceride. They are not esters and will attach to anything basic. Since transesterification is the changing of one ester to another ester, this process for making biodiesel cannot use free fatty acids, therefore they must be removed. If not, they will cause your fuel to be acidic and of poor quality. To do this, take advantage of the acidic nature of the FFA by neutralizing it with a base like Sodium Hydroxide. This is why WVO needs more of the catalyst than virgin or straight vegetable oil. How much more depends on the acidity of the WVO. One finds this by performing a titration.

Titration: Determining the Amount of Catalyst

A titration is done to determine how much catalyst is needed to neutralize the free fatty acids. "Titration is the act of determining the acidity of a sample of WVO by the drop wise addition of a known base to the sample while testing with pH paper for the desired neutral pH=7 reading" (wikipedia.org). Isopropyl alcohol is used instead of methanol because it does not react with the WVO. So that is the basic foundation that the process of making biodiesel rests on. Now let us make a batch.



Materials Needed

-Waste Vegetable Oil (WVO), Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH), Methanol or Ethanol, Isopropyl Alcohol

-One can obtain Waste Vegetable Oil (WVO) by contacting local fast-food restaurants or diners and asking for their waste vegetable oil. It is best if one can find a supplier who will strain or filter the WVO.

-Sodium Hydroxide or lye is a common household cleaning agent and can be purchased at many stores that sell household cleaning supplies. Potassium Hydroxide can be used instead of Sodium Hydroxide.

-Methanol or wood alcohol is the alcohol used in transesterification. Methanol is mostly produced from fossil fuels, though it can come from biomass, such as wood. Another alcohol one can use is Ethanol, which is usually derived from plants (soy beans, corn, etc.). The process of manufacturing quality biodiesel from Ethanol is of greater difficulty than Methanol. Try racetracks or bulk liquid fuel distributors to obtain methanol.

Caution: Some of the chemicals in the process of making biodiesel can be very harmful if not treated with proper care.

-Methanol is a corrosive, flammable liquid that can be absorbed through skin, by inhalation, or consumption. It can cause blindness and death if care is not taken. be careful not to inhale any vapors. MSDS on methanol: <http://www.bu.edu/es/labsafety/ESMSDSs/MSMethanol.html>

-Sodium hydroxide (Caustic soda, NaOH, lye) can cause severe burns and death. A thoroughly ventilated worksite is a must when completing the biodiesel process. MSDS on NaOH <http://www.proscitech.com.au/catalogue/msds/c200.pdf>

- Always wear long sleeved shirts, pants (no shorts), eye protection, and chemical proof gloves.

- Organic Cartridge-based respirators will not filter out methanol.

- Always have a source of running water immediately available.
 - Since methanol is flammable, always be aware of ignition sources. Remember, static charge can be a source of ignition, so make sure to ground when necessary.
 - Methanol dissolves rubber.
 - **When water is added to Lye it becomes very very hot and can cause serious burns, never clean up lye with water. If Lye gets on your skin use vinegar to neutralize the Lye.**
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Preparing the WVO

As previously mentioned WVO needs to be strained or filtered. If the provider does not filter or it is not filtered to acceptable standards, one can run the WVO through multilayered cheesecloth or a coffee strainer several times. One may find it necessary to heat the WVO until it becomes "pourable". The WVO also must be anhydrous, or absent of water. Unfortunately, most WVO will come containing some water and if not removed it will adversely affect the reaction (slow down and increase soap production). The simplest method of removing the water is to heat the WVO and let the water evaporate off.

Procedure

Step I. Measure volume of WVO. Pour filtered WVO into processor. If the WVO gets lumpy or solid, apply heat.

Step II. Calculate catalyst needed: **titration**. *Caution: Sodium hydroxide can cause burns; keep exposed skin to a minimum and wear proper gloves.*

- 1.) Dissolve 1 gram of Sodium Hydroxide in 1 liter of distilled water in a 1500ml beaker.
- 2.) Mix 1ml of the WVO with 10ml of isopropyl alcohol in a small beaker. Stir until the WVO is dissolved.
- 3.) Transfer some of the sodium hydroxide/water solution into a burette.
- 4.) Slowly release a ml of the sodium hydroxide/water into the WVO/alcohol solution.
- 5.) After each drop stir the WVO/alcohol solution and take pH reading. This can be done with litmus paper or a ph meter.

6.) Repeat 4 and 5 until you get a pH reading between 8 and 9. In most cases this won't be higher than 3-4 ml.

7.) The number of ml added to reach the pH is the amount of catalyst in grams needed per liter of WVO to neutralize the Free Fatty Acids.

8.) Add this number to the 3.5 grams of sodium hydroxide it takes to convert the triglycerides in one liter of WVO. So if it was 3 ml of solution to reach a pH of 8, your total amount of sodium hydroxide needed per liter of WVO would be 6.5 grams.

9.) If using Potassium Hydroxide instead of Sodium Hydroxide complete 1-8 but add 7-9 grams of Potassium Hydroxide per liter WVO instead of 3.5 when calculating total catalyst per liter WVO

Step III. Measure out appropriate methanol into a glass or plastic container. This is usually more than 20% of the volume of WVO. *Caution: Methanol is a corrosive, flammable liquid that can be absorbed through skin, by inhalation, or consumption. It can cause blindness and death if care is not taken. Be careful not to inhale any vapors.*



If making a large batch, try doing a test batch of a few liters first, so as not to waste WVO.

Step IV. Dissolve catalyst (sodium hydroxide or potassium hydroxide) into the methanol. Once dissolved this solution must be mixed with the WVO immediately. *Caution: Methanol boils at 65 °C, therefore never reach temperatures above 60°C when mixing.*

Step V. Mix the WVO with the methanol/catalyst solution. Depending on the amount of WVO, this could be anywhere from 15 minutes to an hour.



Step VI. Let the glycerin settle to bottom. This will take around 8 hours for larger batches. The rate of settling slows with time. Expect more than two thirds of the settling to be done within the first hour.

Step VII. If biodiesel is in a container with a stopcock, drain the glycerin until a tiny bit of biodiesel comes out. For processors with no stopcock, use a small pump (hand or water circulation pump) to pump out biodiesel.

Step VIII. Wash the biodiesel.

1.) There is debate whether biodiesel needs to be washed. Some sources encourage using unwashed biodiesel, because washing biodiesel is a time-consuming process. However, some alcohol, sodium hydroxide, and soap remain suspended throughout the biodiesel after the process is complete.

2.) **Why Wash?**

A.) Unwashed biodiesel will not meet ASTM (American Society of Testing and Materials) standards.

B.) Why not, if you have time and water, you can wash.

C.) Remember methanol is flammable, so unreacted methanol in the biodiesel fuel can result in fire. Many people know methanol is a desired for fuel in racecar engines. But your diesel engine is not a racecar engine; so do not feed it like one. Excess methanol in **unwashed** biodiesel will do harm to your car (read fuel injectors). So recover the methanol for re-use or wash it out of the fuel.

D.) Impurities in fuels are not good. Soap is an impurity and will reduce fuel lubricity and produce injector coking.

E.) Economics and Environment. When making large amounts of biodiesel, there can be washing and collecting the excess methanol can be a cost cutting measure and reduces the amount of methanol pollutant.

3.) **Washing Basics**

A.) Remove unreacted methanol: **not for novices.**

I. Unreacted alcohol (methanol) can be distilled from the biodiesel for use in additional batches.

II. Methanol can be driven from biodiesel by heating it; **do this outside or vent the methanol to the outside.**





a fine mist produced by the washing heads

B.) The process of washing biodiesel involves mixing it with water.

I. Water is heavier than biodiesel and absorbs the excess alcohol, sodium hydroxide, and soap suspended in it.

II. After washing and settling, the water and the impurities can be drained from the bottom of the container if you use a stopcock.

III. Don't worry if you must perform multiple washes, as this is common. The first wash water will be milky; the final should be pretty clear.

4.) **Test your unwashed fuel**

It is easy to test the quality of your fuel. After draining the glycerin from your biodiesel, place 150mL of settled, unwashed fuel into a glass container. Then add 150mL of water to the same container. Seal container and then violently shake for 10 to 30 seconds. Let settle for half an hour. Oil and water do not mix. You should have two layers: milky water and biodiesel. This is quality fuel.

However, if after 30 minutes you have what appears like mayonnaise or a thick white layer between the water and biodiesel your fuel needs improvement. Maybe there was an abundance of sodium hydroxide (titration error). Another possibility is that the reactions of transesterification did not complete and you now have mono- and diglycerides. These are emulsifiers.

5.) **Emulsion**

A.) Remember oil and water do not mix.

B.) Emulsifiers help make stable mixtures of oil and water. Emulsifiers in biodiesel hinder the ability of the water and biodiesel to separate.

Acid Wash to Rid Emulsifiers from www.journeytoforever.org

Typical quantities of acid used are: 8 milliliters of 5% vinegar per liter of wash water used (usually a quarter to half as much water as the amount of oil used); 2 milliliters of 10% phosphoric acid per liter of washing water; enough ("not much") 5% phosphoric acid to bring the pH down to 7 (neutral). (Other acids used are sulphuric, citric or acetic, all well-diluted.)

6.) Washing Techniques: Three techniques for washing biodiesel: **agitation washing**, **mist washing**, and **bubble washing**.

A.) **Agitation washing**- physical stirring of water into the biodiesel, letting it settle, and draining it off. Risky, as your fuel quality must be high.

I.) Mix the water/fuel mixture to the point of appearing homogenous for about 5 minutes.

II.) Let settle for 1 hour.

III.) Remove waste water and repeat steps I, II, and III for two more cycles.

B.) **Mist washing**- spraying a mist of water over the biodiesel. This is nice because there is no agitation. It is a slow process that uses lots of water.

I.) With mister device over biodiesel, turn on water. Should be a fine, gentle mist.

II.) Continue to mist until there is a significant amount of milky water at bottom of the processor. Drain this milky water off.

III.) Repeat, until the water you drain off is clear.

C.) **Bubble washing**- The University of Idaho developed the very popular bubble-washing. Water is added to the biodiesel. Then a bubble stone attached to a small air pump is placed in the biodiesel. The bubbles rise; coated with water that attracts impurities.

I.) Add water to the biodiesel in the wash tank (a quarter to a half as much water as biodiesel).

II.) The water should collect at bottom of the container.

III.) Place the bubble-stone down at the bottom of the processor with the water.

IV.) Turn on air pump that is connected to stone. Look for lots of little bubbles that travel up from water level into the biodiesel. If you get foam, turn air down.

V.) At least three washes will probably be required. Each wash should last six to eight hours. Drain and let settle for an hour between each wash.

Note: If you are going to wash make sure you complete the wash cycle or you will simply have added more water to the biodiesel and may have done more harm than good.

Step IX. Drying Washed Biodiesel

After the biodiesel is washed, it should be dried until it is clear. Some ideas for drying include: heat to roughly 120°F for a few hours (make sure you are in a well ventilated room as some fumes will be released) or uncover and let the sun do the work for a few days. Make sure to protect your biodiesel from rain and other moisture sources if you are going to let the sun dry it out.

Now you have biodiesel that is ready to be consumed by the diesel engine in your car. The process doesn't stop here; with every batch of biodiesel made, a new idea for improvement will be generated and soon you will become an expert in the production of biodiesel.



For more information and ideas on the production of biodiesel check out the website www.journeytoforever.org.

Links/Sources of Information Online:

<http://journeytoforever.org/biodiesel> A great site on just about everything that entails biodiesel.

http://www.ott.doe.gov/biofuels/pdfs/biodiesel_clean-green.pdf

<http://www.biodiesel.org/resources/fuelfactsheets/> Quick and simple information on biodiesel from the national biodiesel board.

<http://en.wikipedia.org/wiki/Biodiesel> A broad intro on biodiesel.

<http://www.me.iastate.edu/biodiesel/Pages/biodiesel1.html> A technical site on biodiesel.

<http://www.biodieselamerica.org/biosite/index.php?id=141,0,0,1,0,0>

Books:

From the Fryer to the Fuel Tank, by Joshua Tickell. A comprehensive reference about biodiesel and its production, including how to make it at home.

Renewable Energy: Power for a Sustainable Future. A textbook with a short read on biodiesel. Has a lot of introductory information on a lot of different renewable energy.