Biodiesel Basics

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Biodiesel

Using converted vegetable oils and animal fats as an alternative to Petrol-Diesel fuel has been around for decades. The original Diesel engine was designed to run on cheap vegetable oils. The engine was commonly demonstrated running on peanut oil.

The process of converting vegetable oils into Biodiesel is called Transesterification. An alcohol and a catalyst is mixed with the oil in order to "crack" the oil into Esters and Glycerol. During this process, the catalyst allows the alcohol to substitute itself for the Glycerin, and the heavier Glycerin falls out of the mixture, leaving alkyl esters. The Glycerol is removed and what remains is the "alkyl esters of fatty acids" commonly known as Biodiesel.

Biodiesel can be made from a wide range of easily renewable plant oil sources and animal fats even waste oils thrown away by most restaurants.

Vehicle manufacturers already provide vehicle warranties covering the use of 100% Biodiesel and Biodiesel has been in use for some time in Europe. Germany has over 900 fuelling stations that supply Biodiesel cheaper than petrol-diesel. France is the world's largest producer of Biodiesel where almost all petrol-diesel fuel sold there contains 5% Biodiesel. The USA has a few suppliers and the number is increasing. The US made Biodiesel, at present, is more expensive than petrol-diesel because it is mostly made from expensive fresh virgin soybean oil. As the number of plants making waste-oil biodiesel increases and the demand rises, the prices should drop.

One thing that is overlooked by a large number of people is the fact that quality Biodiesel can easily be made by almost anyone in their back yard, garage or shed. Once you've made your first batch of Biodiesel, you will be able to enjoy the benefits of this clean burning, non-toxic, biodegradable fuel.

What's more, Biodiesel can be home made for less than $0.50 per gallon! That's something we all can understand right?

The down side of home making Biodiesel is the process requires the use of some dangerous chemicals! If you follow directions and you are very careful, design your equipment properly, it is quite safe.

The two most commonly used chemicals in Transesterification are Methanol and Sodium Hydroxide. These chemicals are used in their highest purity and can be very dangerous if you do not know what you are doing or if your equipment is not designed and built safely.

Needless to say, we recommend you obtain material safety data sheets (MSDS) for all chemicals used and use all necessary precautions at all times. Material Safety Data Sheets for most of the chemicals described herein are available on our web site at http://www.biodieselgear.com/documentation/.

Properties of Various Oils

The properties of vegetable oils vary according to the plant it comes from. A fuel made from one kind of oil is likely to have slightly different characteristics than a fuel made from another kind of oil. These characteristics normally won't adversely affect its suitability as a fuel but there are a couple characteristics that are important to the potential Biodiesel producer. Cloud Point and Gel Point seem to be very important.

The following chart conveys the yields of various oil producing plants per acre.

Crop	lbs oil/acre	US gal/acre	Crop	lbs oil/acre	US gal/acre
corn	129	18	sunflowers	714	102
cashew nut	132	19	cocoa (cacao)	771	110
oats	163	23	peanuts	795	113
cotton	244	35	opium poppy	873	124
hemp	272	39	rapeseed	893	127
soybean	335	48	olives	910	129
coffee	345	49	castor beans	1061	151
linseed (flax)	359	51	pecan nuts	1344	191
hazel nuts	362	51	jojoba	1365	194
pumpkin seed	401	57	brazil nuts	1795	255
mustard seed	430	61	avocado	1980	282
sesame	522	74	coconut	2018	287
safflower	585	83	oil palm	4465	635
rice	622	88			
tung oil tree	705	100			

Oils solidify at varying temperatures. Some begin to solidify at higher temperatures than others. If you live in a cold climate, Biodiesel made from certain oil producing plants may solidify at the slightest dip in temperature.

Plants like Coconut, Palm Nut produce large volumes of oil per acre but the oil tends to solidify at a high temperature. Biodiesel made from this oil will also tend to Cloud or Gel at a higher temperature than oil from other sources.

Look at the following chart. It details the properties of various common oils.

Ester Characteristics					
Type of Oil	**Melting Point (Deg C)**			**Iodine number**	**Cetane number**
	Oil / Fat	**Methyl Ester**	**Ethyl Ester**		
Rapeseed oil	-5	-10	-12	110 to 115	58
Sunflower oil	-18	-12	-14	125 to 135	52
Olive oil	-12	-6	-8	77 to 94	60
Soybean oil	-12	-10	-12	125 to 140	53
Cotton seed oil	0	-5	-8	100 to 115	55
Corn oil	-5	-10	-12	115 to 124	53
Coconut oil	20 to 24	-9	-6	8 to 10	70
Palm kernel oil	20 to 26	-8	-8	12 to 18	70
Palm oil	30 to 38	14	10	44 to 58	65
Tallow	35 to 40	16	12	50 to 60	75

As you can see Coconut and Palm kernel oil would become difficult to handle below 30C (86F) and Tallow and Palm oil would be difficult to handle below 40C (104F). This should not inhibit their use but be prepared to put significant energy into keeping it warm enough to keep it liquid. Biodiesel made from these oils will not gel at the same temperature as the oil does, but as you can see from the chart Esters of Palm oil and Tallow have melting points above freezing (0C or 32F). The oils that perform the best at low temperatures seem to be Rapeseed, Sunflower Soybean and Corn.

In the cold climates, standard diesel winter additives can be used to keep the Biodiesel liquid at low temperatures. You should follow the same procedures you would in your petrol-diesel when it comes to very low temperatures if you are using fuel that tends to cloud at low temperatures.

Now lets look at some fuel properties of a few Esters.

Below is a chart showing some fuel properties of various Esters and number 2 Diesel fuel.

Fuel-related physical properties of esters of oils and fats						
Ester	**CN**	**HG** (kJ/kg)	**Viscosity** (mm2/s)	**CP** (deg C)	**PP** (deg C)	**FP** (deg C)
Rapeseed	54.4	40449	6.7 (40deg)	-2	-9	84
Safflower	49.8	40060	-	-	-6	180
Soybean	46.2	39800	4.08 (40deg)	2	-1	171
Sunflower	46.6	39800	4.22 (40deg)	0	-4	-
Tallow	-	39949	4.11 (40deg)	12	9	96
#2 Diesel	47	45343	2.7 (38 C)	-15.0	-33.0	52

Here we can see Cetane Number (CN), Cloud Point (CP), Plug Point (PP) and Flash Point (FP) of a few Methyl Esters and #2 Diesel Fuel. It is no wonder Rapeseed is used so heavily in Germany and in other parts of Europe and Canada. Rapeseed Methyl Esters make a great fuel.

The Process Overview

Animal fats and vegetable oils are basically triglycerides, containing glycerine. The catalyst and alcohol are mixed together to form Methoxide, which is mixed vigorously into the oil for a period of time. This process “breaks” the oils into esters and glycerin. The heavier glycerin, soaps and waxes sink to the bottom while the Biodiesel floats to the top where it is siphoned or decanted off and the Glycerin is purified.

We can use either ethanol or methanol in our process. Ethanol is less dangerous but Methanol is usually less expensive so most people use Methanol over Ethanol.

We can use either sodium hydroxide (caustic soda, NaOH) or potassium hydroxide (KOH) as our catalyst. Sodium hydroxide is generally easier to get and cheaper.

CAUTION:
Sodium Hydroxide (Lye, NaOH, caustic soda) is dangerous. It can cause severe burns to the skin and should never be handled with out appropriate protection.

Methanol (wood alcohol, MeOH) is also dangerous. Exposure is cumulative. Methanol can cause blindness and even death. You don't have to drink it for it to kill you! Don't breathe the fumes either! It should not be handled with out appropriate protection.

Only use Polyethylene, Polypropylene, stainless steel and glass containers for these chemicals.

Making Biodiesel from Fresh Oil

Making Biodiesel from virgin oil is the easiest but is also the most expensive. The following will describe the basic process for making a batch of Biodiesel from fresh vegetable oil. A Biodiesel Discovery Kit is available from http://www.biodieselgear.com/ that includes a couple graduated beakers, funnel, scale for accurately weighing the catalyst and full color instruction manual.

1. Prepare your methoxide in a suitable container. This typically consists of 20%-25% methanol by volume of oil and 4.0 grams sodium hydroxide per liter of oil mixed together well.

   (The difference between making Biodiesel from fresh oil and making it from waste oil lies in the amount of catalyst used. *See **"Making Biodiesel from Waste Oil"** in the next section.*)

   Note: Make sure ALL the sodium hydroxide is dissolved before proceeding.

2. Pour your oil into your reaction vessel
3. Warm to approx. 50C (122F)
4. Pour the methoxide in on top of the oil
5. Agitate the mixture vigorously for about 30 seconds
   (Continuous gentle stirring for the next hour is recommended.)
6. Stop stirring and let the mixture settle and separate overnight
7. You should now have a reactor vessel containing lighter colored biodiesel on top of a layer of darker glycerin.
8. Continue on to ***Washing***.

More detailed and practical instructions are available in the Biodiesel Discovery Kit available at http://www.biodieselgear.com/equipment/demokits.htm.

Making Biodiesel from Waste Oils

The following will describe the general process for making a batch of Biodiesel from waste vegetable oil. A Biodiesel Discovery Kit is available from http://www.biodieselgear.com/ that includes a couple graduated beakers, funnel, scale for weighing the catalyst and full color instruction manual.

Making Biodiesel from waste oil differs from fresh oil in that measures must be taken to ensure the oil contains no water and it requires excess catalyst to convert.

To dry the oil, pour your oil into a suitable vessel and heat the oil to approximately 130F and hold it there for 15 – 20 minutes then remove the heat. The water will drop out and settle to the bottom. Pour the warm, dry oil into your reaction vessel for the rest of the reaction.

A procedure called ***Titration*** is used to determine how much catalyst to use. This means determining the pH -- the acid-alkaline level -- of the oil. An electronic pH meter is easy to use best, but not entirely necessary. Many use a chemical indicator solution such as Phenolphthalein or a "high range" aquarium pH indicator. Litmus paper is not accurate enough to do this job unless it's a narrow range paper designed for between 8 and 10.

Titration

- Dissolve 1gram of Sodium Hydroxide (catalyst) in 1 liter of distilled water (0.1% lye solution). This is the reagent solution.
- In a smaller container, dissolve 1 ml of oil in 10 ml of alcohol (you may use methanol or isopropyl but it must be 95% pure. This is the test solution.
- Add the appropriate number of drops of indicator solution to the test solution. (usually 5 or 6 drops). If you are using an electronic pH meter, you don't need an indicator solution.

Important: You need a dropper that is graduated in milliliters or fractions thereof. It is important to know exactly how much reagent was added during the test.

1. Using the same dropper or syringe, add reagent solution 1milliliter at a time to the test solution, stirring all the time, until the solution turns and stays the proper indicating color (pink for phenolphthalein, consult your test kit) for at least 10 seconds.
2. Keep account of how many ml you add to the test sample. Add 4.0 to this number. This will be the number of grams of catalyst you'll need to convert each liter of this batch of oil.

The Process!

1. Prepare your methoxide in a suitable container. This typically consists of 20%-25% methanol by volume of oil and 4.0 grams plus titration amount of sodium hydroxide per liter of oil mixed together well.

(Use *4.0g Sodium Hydroxide for pure fresh oil. Use titration for waste oils.*)

Note: Make sure ALL the sodium hydroxide is dissolved before proceeding.

2. Pour the methoxide on top of the oil.
3. Agitate the mixture vigorously for about 30 seconds.
   (Continuous gentle stirring for the next hour is recommended.)
4. Let the mixture settle and separate overnight
5. You should now have a reactor vessel containing lighter colored biodiesel on top of a layer of darker glycerin.
6. Continue on to ***Washing***.

More detailed and practical instructions are available in the Biodiesel Discovery Kit available at http://www.biodieselgear.com/equipment/demokits.htm.

Washing

For commercial use, Biodiesel must be washed to remove any remaining methanol, glycerin, catalyst, soaps and other impurities. For private use, it's up to you. Some of the pioneers insist washing is not necessary and that they routinely use their product filtered but unwashed.

We highly recommend washing Biodiesel.

There are three ways to wash biodiesel.

- Mix Washing
- Bubble Washing
- Mist Washing

These are too much involved to cover here but here is the basic premise behind washing.

1. Pass water droplets through the esters to allow soluble material, excess catalyst and other impurities to stick to the water and be settled to the bottom of the vessel.
2. The water should be removed from the vessel periodically
3. Wash until the wash water drained out is clear or the pH of the biodiesel becomes relatively neutral (approx 7.0).

Detailed documentation of each of these wash methods can be found on our web site at http://www.biodieselgear.com/documentation/

Drying

Washing sometimes leaves the biodiesel looking a bit cloudy. This means there's still a little water in it. Heat the Biodiesel up slowly to 50C(122F) and hold it there for a little while (15 or 20 Minutes). Let the water settle out. Let the mixture sit a couple days if you have to.

Filtering

Obviously for a micro batch it may not be worth filtering but your Biodiesel should be filtered down to 10 micron before you use it. Either, filter it as you put it in the storage container/tank or filter it as you dispense from storage into the vehicle. It is highly recommended to do both; filter your Biodiesel as you send it to the storage container and then again when you dispense it to the vehicle fuel tank. Filtering should be done while cold to further remove anything that might tend to solidify or cloud the fuel at ambient temperature. This makes for much better fuel. A standard diesel engine fuel filter assembly works well for this.

Storage

Biodiesel can't be stored for super-long periods of time, as its biodegradability will cause it to break down in less than 12 months. Store your Biodiesel in any suitable dry sealed container. Many people utilize a steel storage tanks and steel drums for larger quantities.

Uses

One obvious use is you can burn it in your diesel automobile or truck engine with no trouble at all. Retarding the injector timing about 1.5 degrees will make the engine run smoother with fewer emissions.

Biodiesel is commonly used as a fuel additive in petrol-diesel to increase its lubricity as well as to decrease its emission output.

Biodiesel can be used as a wood treatment, and an excellent lubricant. It has been used as a chainsaw bar oil to allow the sawdust to be usable in compose bins. It has heating uses, and can be used in some oil-fired furnaces, boilers and water heaters. Many multi-fuel stoves will also run on biodiesel. It has lighting uses in some of the multi-fuel lanterns (See below)

The BriteLyt Petromax multi-fuel lantern works just fine on biodiesel.
http://www.britelyt.com/ or http://store.britelyt.com/

Processing Equipment

Obviously if you are going to make Biodiesel on a larger scale, you will not want to use a 2 liter bottle or a 5 gallon bucket as your reaction vessel. No cost effective commercially made processing equipment designed for the home or farm has been available…until now! (For more information on the first manufacturer to do it, see http://www.biodieselgear.com/)

So far Biodiesel processing equipment falls into two categories. You either produce Biodiesel in a batch or continuous process. Continuous processes are currently only used by commercial producers putting it out of the scope of this discussion. So, we will be discussing the batch processing equipment.

Batch processing equipment is either manual or "touchless".

Manual Processors

This is the most common type because it is easier to make ones self out of inexpensive or scrap parts.

The most basic processor is a tank of some kind, a mixing device, a means of heating the mixture and a means of dispensing the product. An electric hot water heater can easily be modified to work as a processing vessel due to the built-in heating and its insulated exterior.

A 20, 30 or 55 gallon drum works well also but with more modification. Most builders weld angle iron legs on it to get it up off the ground to provide room for dispensing the product into other containers with out having to pump it.

If you don't have a vessel with a cone type bottom, you will need two valves for draining the two layers of product. One should be welded on as close to the bottom as possible and the other should be welded on a few inches above the bottom one. Use the bottom valve to drain the glycerol to a point below the top valve. Then use the top valve to drain the Biodiesel. This allows you to not get any byproduct in your Biodiesel when you drain it.

To heat the mixture, you can employ electric heat, hydronic (hot water) heat or flame heat directly to the bottom of the drum (remember methanol is highly explosive).

Electric Heat
For electric heat you will need to use commercially available hot water heater heating elements. Most of them are available in 1000-3500 watt, 120-volt “screw-in” type. They screw in to a standard 1” pipe thread. Cut a 1” steel coupling in half and weld on the side of your tank, about 2 inches off the bottom of the tank. Wire it to a switch allowing you to turn it off and on as needed.

Hydronic Heat
For hydronic heat, you will need to install a coil of copper tubing into the bottom of the tank and attach it to a hot water source that can be metered and turned on and off readily. Some have constructed a small passive solar water heater to do this job. You don’t need heat for this process to work but in most cases it is desirable to warm it up to melt any tallow that normally solidifies at ambient temperature. Heat makes the process work much faster.

Flame Heat
Some people are using flame heat. We don’t recommend it because of the flammability of methanol fumes. Since methanol is lighter than air theoretically the flame should not be a problem but it only takes one time you know…

With any heating system you will need a suitable thermometer to monitor the temperature of your batch. Don’t forget safety devices, like a thermostat and an over temp cut out!

One of the most important things your processor needs is a mixer of some sort. Either you use a propeller type mixer or you use a pump to mix your batch.

Mechanical Mixer
Many people attach a motor to a post attached to the side of the tank and affix a shaft to the end of the motor shaft. Attach a propeller (one from an outboard boat motor works well) to the end of the shaft so that when it runs, it pushes the liquid from bottom to top.

Pump Mixer
The pump type is more energy efficient and only requires a pump to draw from the bottom and pump it in on top of the mix. This action is usually sufficient to provide the proper mixing action.

As with any process, the parts you choose may affect the time necessary to get full conversion. Tests will need to be run until you are confident with the results.

Touchless Processors
The touchless processor is quite complicated and has many expensive parts.

First of all you need a strong, closed vessel that is capable of withstanding a vacuum or pressure. A vacuum pump or air compressor is used to move the various materials into and out of the processor and a pump is used to provide the mixing action.

A series of valves are used to control the movement of the base oil into the processor through a set of filters, then to control the introduction of the methoxide into the oil. Then after the process is finished and the glycerol is drained away, vacuum is again used to recover any remaining methanol into an appropriate vessel to be reused. Then finally vacuum and/or compressed air can be used to transfer the biodiesel into an appropriate washing tank in order to keep water out of the main reaction vessel.

This type of system requires a very tight system with no leaks and is almost impossible to cover well in detail here. For a description of a "touchless" system go to http://home.swbell.net/scrof/Biod_Proc.html or http://www.veggiepower.org.uk/page301a.htm