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Biodiesel - A Primer

FARM ENERGY TECHNICAL NOTE

Abstract: This publication is an introduction to home biodiesel production. It includes lists of equipment and materials needed to make small batches of biodiesel. It describes biodiesel and includes cautionary notes and procedures for making test batches and 5-gallon batches. An extensive resource list is also provided.

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Introduction

Biodiesel is an alternative to petroleum diesel. It is called biodiesel because it is made from mostly biodegradable materials and can be used as fuel in diesel engines. It can also be used in boilers or furnaces designed to use heating oils or in oil-fueled lighting equipment. It can be used neat (100% biodiesel), or it can be blended with petroleum diesel.

The purpose of this publication is to describe how biodiesel can be made by an individual to provide fuel for diesel machinery on a farm or ranch. Please note that biodiesel used on public roads is subject to federal, state, and local taxes, just as is petroleum diesel. There are several processes that can be used to make biodiesel; this publication will describe one simple process. For information about other processes and other research done on biodiesel, see the **Resources** section. Note that there are a number of resources describing closed biodiesel processors, including how to make them at a low cost. A closed system processor mitigates some of the safety issues and can save money by reclaiming methanol, an expensive component of biodiesel.

Biodiesel can be made in any quantity, from a cup or so up to many gallons. The process described here is a batch process. Steady flow processes are more appropriate for biodiesel manufacturing plants than for the individual farmer or rancher. Since it is better to make small mistakes than big mistakes, I encourage people interested in making biodiesel to start with small batches and gradually work up to making larger batches.

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NCAT

Feedstocks

Either new or used vegetable oil (cooking oil) can be used as a fuel for diesel engines under proper conditions. Vegetable oil must be filtered to 5 microns and heated to at least 140°F for use in diesel engines. See **Resources** for more on using waste vegetable oils for fuel.

HAZARDS!

Some words of caution: Making biodiesel is relatively simple, easier than making beer. However, there are caustic, toxic, volatile, and flammable chemicals involved. The potential for personal injury and property damage is very real. Neither the author of this publication, the National Center for Appropriate Technology, nor anyone else is responsible for the mistakes you make. Do not rely solely on this publication for information about making biodiesel; carefully study other publications and start small. Wear an appropriate respirator (note that the only approved respirators for methanol are respirators with external air supplies; see **Resources**), heavy rubber gloves, safety goggles, and clothing that will protect your skin from chemicals, especially methanol. It can be absorbed through the skin and cause illness, blindness, or debilitation.

Heating the oil to remove the water and transferring the oil to buckets are two potentially dangerous steps in the process of making biodiesel. When heating the used oil, be careful to keep it from spattering and making the floor slippery. You also need to be cautious about using burners or electric heaters, just as if you were cooking. Hot oil will melt plastic buckets, and you will have a mess. Be careful to cool hot oil to below 120°F before pouring it into a plastic bucket. Do not use anything that comes in contact with biodiesel or the chemicals used to make biodiesel for food production.

Making biodiesel requires a well-ventilated area to reduce the danger of fire and explosion and exposure to methanol. Methanol can vaporize, and given the proper mix with oxygen and an ignition source, it can ignite with invisible flame—that's why to make it safer oil companies had to put 15 percent gasoline in it so the flames could be seen. When making biodiesel in larger quantities, make it outside or somewhere there is no chance of a spark or flame coming in contact with the methanol. Any wiring in indoor areas where methanol is used must be explosion proof.

About Biodiesel

Biodiesel is made by chemically reacting vegetable oil or animal fat (or combinations of oils and fats) with alcohol (usually nearly pure methanol or denatured ethanol) and a catalyst (sodium hydroxide, or lye). The oil is chemically acidic; the alcohol is chemically a base. This chemical reaction breaks the fat molecules in the oils into an ester, which is the biodiesel fuel, and glycerol. This reaction is called transesterification. Since the biodiesel is less dense than the glycerol, it floats on top of the glycerol and may be pumped off, or the glycerol can be drained off the bottom. The fuel can then be filtered and used in heating or lighting applications. Some people use it in diesel engines without further processing, but others recommend removing impurities (soap, un-reacted alcohol, and sodium hydroxide) by a washing process.

Almost any variety of oil or grease — from new food-grade vegetable oil to used cooking oil or trap grease to waste water treatment-plant grease — can be turned into biodiesel. We do not recommend using waste water treatment-plant or trap grease for home production, because of potential cross-contamination with hazardous materials such as pesticides, herbicides, and toxic cleaners. A 2001 survey showed that waste-water treatment grease picked up a number of bad compounds (including benzene, toluene, arsenic, and lead) from other sources on its way to the plant. Even trap grease from a restaurant had contamination problems. If you have access to inexpensive oil or grease, such as a by-product of some process, it may be quite cost-effective for you to manufacture your own fuel from these by-products. The amounts of reactants (oil, methanol, and sodium hydroxide) vary to some degree, depending on what oil you use. The amount of methanol and sodium hydroxide must be sufficient to react with the vegetable oil, but you should not use excessive amounts of these reactants. The cost of the methanol and sodium hydroxide is significant, and you do not want to waste them. Just as an engine requires excess air to be sure that all the fuel burns, it takes excess methanol to be sure all of the oil reacts. As you develop your own expertise, you will be able to adjust the amounts used to optimize your process and minimize how much of the reactants you use.

Anyone who has experience with diesel engines knows that diesel fuel will turn into a waxy gel at low temperatures and cannot be pumped until it is warmed up. The temperature at which the fuel will no longer pour is called the *pour point* or *gel point*. Biodiesel has a higher pour point than No. 2 petroleum diesel (biodiesel gels at a higher temperature). Some oil feed-stocks, such as coconut oil or animal fats, result in biodiesel that will gel at relatively high temperatures, whereas biodiesel made from canola or rapeseed oil will have a lower pour point. Additives can lower the pour point in cold weather, or biodiesel can be mixed with No. 1 petroleum diesel to lower the pour point. Biodiesel should be stored at above-freezing temperature, and temperature controlled heaters can be installed on tanks and fuel lines in diesel vehicles. Some vehicles have heated fuel filters that also help.

Storage of chemicals and biodiesel

Feed stocks and finished biodiesel should be properly stored. Methanol is a poison. You should avoid all contact with it, including getting it on your skin or breathing the fumes, because contact with methanol can cause irreversible illness, blindness, and death. Methanol absorbs water, and so should not be stored in any open container. Methanol should be stored in appropriate sealed containers, and these should be plainly marked as containing methanol. Sodium hydroxide is caustic (a strong base). Sodium hydroxide also absorbs water and will become unusable unless it is kept in a tightly sealed container. One step in making biodiesel is the making of sodium methoxide. Do not mix up and store methoxide in advance. React the methoxide with the oil as soon as possible.

Oil feed stocks can go rancid (smell bad) or even be rancid when you get them. Avoid rancid oils. Used oil should be turned into biodiesel as soon as possible, in order to keep it from going rancid and increasing the amount of free fatty acids. Rancid oil produces less biodiesel and may not even react to make it. Finished biodiesel has a long shelf life. Finished biodiesel should be stored in yellow diesel cans, and these should be clearly marked as containing biodiesel. Biodiesel is a good solvent. It will dissolve rubber and some plastics, remove paint, oxidize aluminum and other metals, and has been reported to destroy asphalt and concrete if spills were not cleaned quickly. Keep it off items you care about.

Materials

As mentioned above, biodiesel production requires three inputs: oil or fat, alcohol, and sodium hydroxide (caustic soda or lye). Approximately 80% percent by volume of the feed stock of biodiesel is vegetable oil (and/or animal fats) and about 20% is methanol. For the oil component, you may use new, de-gummed vegetable oil or get waste vegetable oil from restaurants. If you are an oilseed farmer, you can press and de-gum your own oil or get pressed raw oil. Food-service suppliers sell new oil in 5-gallon or larger containers. Methanol, or "wood alcohol," is made primarily from natural gas. It is used as a gas line antifreeze and for racing fuel. You can get methanol from a chemical supply house, and once you get serious about making biodiesel, you can get methanol in 55-gallon drums from racing-fuel supply stores or auto parts stores. HEET fuel antifreeze is 99% pure methanol and can be used for small text batches. Do not assume that a fuel line antifreeze is pure methanol unless it is so labeled. You will want to use nearly pure methanol. Sodium hydroxide in the form of Red Devil Lye is commonly used as a drain cleaner and is available from hardware stores and many grocery stores.

Although you may have to pay for waste vegetable oil, as a rule you can often get it free from restaurants. Shop around. Smaller restaurants may let you pick up waste oil in buckets, if you provide exchange buckets. Find out when the fryer oil is to be changed, and pick it up warm if you can. To get the best quality oil, talk to the restaurant owner and, more importantly, to the head cook, and let them know what you are doing and what you need. If you do not make a mess and are conscientious, most restaurant owners will be happy to work with you. It is not recommended that you take oil from the back of the restaurant. First, it may have excess water and be of poor quality. Second, you could get arrested for theft. Check with your state and local governments for any necessary permits, as some jurisdictions charge fines for improper disposal of used oils.

Cost

Besides the initial cost of the processing equipment, biodiesel production costs include the cost of the chemicals used in the reaction, gas or electricity expenses, and labor (your time). Feed stocks can range from new food-grade cooking oil ($2.30 or more per gallon) to animal fat renderings. The cost of the feed stock is very specific to your location and operation. Waste oil from restaurants may cost as much as $0.15 per pound (or about $1.20 per gallon), or you may be able to get it for the cost of the replacement buckets and your time to pick it up. Farmers who grow oilseeds may be able to press oil at the farm for a relatively low cost. Near pure methanol costs about $2.36 per gallon in bulk (2004). Note: The cost of methanol varies significantly, depending on where you get it. Almost all methanol is manufactured from natural gas and is really an industrial by-product. Shop around to get the best price you can. Remember that methanol is a hazardous chemical, and shipping costs can be significant. Eighteen ounces of sodium hydroxide (Red Devil Lye) costs about $7.00.

Small Batch v. Large Batch:
Sample Cost Comparisons

Note: These examples do not account for the cost of equipment. The equipment needed to make 5 gallons of biodiesel is relatively inexpensive and easy to get. The equipment to make 250 gallons of biodiesel is more involved. Also, the examples are intended to compare the cost of a small batch with the cost of a large batch.

Example 1: Say you go to a restaurant and get 5 gallons of waste vegetable oil from the deep fryer, at no cost. You go to Sunoco Racing Fuels and buy a gallon of methanol for $15.24. You find by doing a titration (see procedure below) that you need 3½ ounces of sodium hydroxide, costing $1.36. You end up with 5 gallons of biodiesel and a little more than a gallon of glycerol. The cost of the biodiesel is $3.32 per gallon, not including appropriate road taxes.

Example 2: Say you go to a restaurant and purchase 250 gallons of used oil for $182.00. You go to Sunoco and buy 50 gallons of methanol for $118.00. You need 18 ounces of sodium hydroxide at a cost of $7.00. The total cost is $307.00. You end up with 250 gallons of biodiesel at a cost of $1.23 per gallon, before taxes.

Making a Small Batch Using New Vegetable Oil

Equipment

There are several suppliers of biodiesel kits (see **Resources**). Before purchasing any kit, research the kits carefully, and be comfortable with making small batches. Some farmers will already have all of the equipment. For safety, a completely closed system is best. There are several how-to references available for making a closed-system biodiesel reactor. This publication describes a simple open-system method to be used by a responsible adult with proper safety equipment.

To make a small batch of biodiesel from new oil, you will need the following.

A blender with a glass jar. (These are available at second-hand stores for a few dollars) or a glass jar with a tight fitting lid to use to shake the reactants. Note: After using the blender or jar to make biodiesel, do not use it for any food preparation. Also note that the biodiesel will dissolve any natural rubber. The seals that come with the second-hand blender will probably not last too long. You can cut new seals out of Teflon sheeting available from auto parts stores.

A scale that can weigh 0 to 50 grams to the nearest 0.1 gram.

One quart jar.

One-cup liquid measuring cup (glass or plastic compatible with methanol).

A hand pump. (Inexpensive pumps are available at cleaning supply stores.)

Vegetable oil.

Methanol.

Sodium hydroxide (lye).

Method

Have all the materials warm, room temperature at the coolest, 130°F at the warmest. Put on the respirator, goggles, and gloves (See **Hazards!** box). Place 1 fluid cup of methanol in the blender. Measure out 3.5 grams of sodium hydroxide from a new container and place it in the methanol in the blender. Put the top on the blender and blend on low speed for about five minutes. Shut off the blender. The mixture in the blender is now sodium methoxide, a strong base. Avoid getting this on anything, especially yourself.

Measure one quart of new vegetable oil and pour it into the sodium methoxide in the blender. Put the lid on (you may now take off the respirator, gloves, and goggles) and blend at low speed for a half hour. Let the mixture settle at room temperature for at least eight hours. The mixture is now composed of light-colored methyl esters (biodiesel) floating on top of heavier, darker glycerol. Using the hand pump, pump the light biodiesel off of the glycerol.

The resulting biodiesel can be used in oil-fired heating equipment or some oil lamps. Some people use biodiesel at this stage in diesel engines; I

recommend washing the biodiesel (see **Washing Biodiesel**, below). The glycerol can be used to make soap, or it can be poured into a pan, left to dry-out for a week or so, and then put into a compost bin. Glycerol can also be burned as a fuel; see Glycerin Uses in the **Resources** section.

If you were not successful, make sure you follow the recipe exactly, and try again. Unsuccessful batches can show up in a variety of ways, but if you are using new oil, a batch can fail because you didn't use almost pure methanol, you used old sodium hydroxide, you did not mix the solutions long enough, or the temperature was too low. If you do not have two distinct layers in the blender, you probably did not use enough sodium hydroxide. If you have a solid white material in the blender, this is soap. Study the How-To Resources for help in figuring out what went wrong and how an unsuccessful batch may be remedied. Get comfortable making small batches before moving up to a larger batch.

Making a Small Batch Using Waste Vegetable Oil

Waste or old oil is more acidic than new oil, since free fatty acids form in oil with use. Because of the high content of free fatty acids, more sodium hydroxide catalyst is required for making biodiesel from waste oil than from new oil. As described below, when using waste oil, you will need to perform a titration to determine how much additional catalyst is needed.

While some resources recommend making multiple small batches of biodiesel, varying the quantity of sodium hydroxide until the reaction works, titration is simple enough that, overall, it will save you time and materials. Different titration methods are presented in various references. One simple method is presented below, using a chemical indicator called phenol red. This titration method should give you an accurate indication of the additional amount of sodium hydroxide needed to neutralize the free fatty acids in the waste vegetable oil. Other titration methods are similar except for the method used to determine when a solution that you prepare changes from an acid to a base.

How to do a titration

Materials

One bottle of isopropyl alcohol. (In the U.S., Iso-HEET® Premium Fuel System Dryer & Antifreeze, 12 fl. oz., in the red bottle, is available at auto parts stores and is about 100% isopropyl alcohol. Isopropyl alcohol is also available at pharmacies.

One bottle of phenol red from the hot tub store.

One liter of 0.1% sodium hydroxide in distilled water—which is another way of saying 1 gram sodium hydroxide (lye) dissolved in 1 liter of distilled water.

Since you might not have particularly accurate scales, one way of achieving this is to measure out 10 grams of lye and dissolve it into 1 liter of distilled water. Now take 100 milliliters of this water and mix it with 900 milliliters distilled water. You now have pretty close to the 1 gram of lye in 1 liter of distilled water. You can also go to your local pharmacist or high school science department and ask them to do the measuring for you.

Equipment

One one-cup jelly jar.

Two glass 1 milliliter eyedroppers with graduations marked on the side. Note that you will use one for oil, one for the lye-water mixture. Always use the same eyedropper for the same chemical; do not mix them up.

The procedure

1. Pour 10 milliliters of room-temperature isopropyl alcohol into the one-cup jelly jar.

2. Add 2 or 3 drops of phenol red to the alcohol.

3. Using one of the eyedroppers, slowly, drop by drop, add the 0.1% lye solution until the alcohol just starts to turn red. Stir the alcohol while dropping in the 0.1% lye solution.

(continued next page)

4. Using the other eyedropper, add exactly 1 milliliter of the oil to be titrated.

5. Now, filling the eyedropper with exactly 1 milliliter of 0.1% lye solution, start dripping this solution into the medicine measure while stirring.

6. Keep track of how many milliliters of 0.1% lye solution are needed for the liquid to turn and stay red.

The number of milliliters of 0.1% lye solution needed is equal to the number of extra grams of pure sodium hydroxide catalyst needed to produce the proper reactions to make biodiesel. For example, if it takes 3 milliliters of 0.1% lye solution to turn the oil and isopropyl alcohol solution to a base, you will need to add 3 grams of sodium hydroxide to the 3.5 grams for new oil, or 6.5 grams total per liter of waste oil.

Once you have determined how much sodium hydroxide you need by titration, make a small batch of biodiesel in the same way you made it with new oil, but use the total amount (new oil plus titration result) of sodium hydroxide.

One thing you may notice in your small batch is more than two layers. A white layer between the biodiesel and the glycerol is soap, and it will be present if there is any water in the waste vegetable oil or the other reactants you started with. Warming the oil will cause the water to sink to the bottom of the container, and the oil can be poured or pumped off of the top. After warming the oil, allow it to cool below 130°F, and pump the oil into another bucket. Filter the warm oil through a filter paper. A paper coffee filter, a funnel, and patience will work for small batches.

If there is a layer of unreacted vegetable oil, you didn't use enough lye. You might make a gel soap if you use too much lye. Study the **Resources** for clues to what went wrong and how to remedy it. You can heat the oil to help get rid of the water before reaction with the methanol. It is best to heat the oil to a fairly low temperature (200°F) and hold it there, rather than heating it to a high temperature; it takes less energy and makes fewer free fatty acids (FFAs).

If you have a good separation between the layers of biodiesel on top and glycerol on the bottom, pump the biodiesel off of the top into another container, being careful not to bring any glycerol or visible soap along with it.

Quality Testing

Soap, methanol, and lye will still be suspended in your biodiesel. You can test for these because they are chemical bases. The pH of unwashed biodiesel will be above 8, and you want your finished fuel to be pH 7, neutral. If the pH is high, you can use less lye. If you shake up some of the biodiesel with water and it won't settle out, you have soap and other impurities in the biodiesel.

Making a Larger Batch Using New Oil

Materials

One 7-gallon plastic bucket. You can find these at a homebrew supply store, where you can also get a valve that you will need to install as close to the bottom of the 7-gallon bucket as possible. The homebrew supply will have buckets with the valve already installed, but it is usually placed farther up on the bucket than you want for draining impurities. Also, the bucket must have a lid with a hole in it for the shaft of the mixer. The ones from the homebrew supply store have a hole in the center, but it is usually too large. Get a new lid and cut a small hole in it for the shaft of the mixer. The smaller the hole the better.

Electric drill. If you are very patient, you can stand there with the drill in your hand and mix the reactants, but you will probably want to fabricate something to hold the drill. There are some suggestions in the How-To Resources.

Paint stirrer that will fit in the drill.

A scale that can measure 0 to 100 grams in 0.1 gram increments.

A drill pump and a 5-micron diesel filter.

Five gallons of new or de-gummed vegetable oil.

One gallon of nearly pure methanol.

Sixty-six and one-half grams (2.34 ounces) sodium hydroxide.

Procedure

Have all the materials warm, room temperature at the coolest, 130°F at the warmest. Put on gloves, respirator, and goggles. In a well ventilated area place 1 gallon of methanol in the bucket. Measure out 66.5 grams of sodium hydroxide from a new container and place it in the methanol in the bucket.

Put the lid on the bucket and mix with the paint mixer for about five minutes. Remove the lid. What is in the bucket now is sodium methoxide. Avoid getting this on anything, especially yourself.

Measure out 5 gallons of new vegetable oil and pour it into the sodium methoxide in the bucket. Put the lid on (you may now take off the respirator, gloves, and goggles) and blend at low speed for one half hour.

Let the mixture settle in a well-ventilated area at room temperature for at least eight hours. What you have now is light-colored methyl esters (biodiesel) floating on top of heavier, darker glycerol. Using a small pump (a drill pump will work for this) pump the biodiesel through the diesel filter into another container for washing, being careful to get just the biodiesel layer into the wash container.

Making a Larger Batch Using Used Fryer Oil

Used fryer oil is a little different from new oil. Used oil probably has water and food particles in it. Used oil also contains free fatty acids caused by cooking with it. Remember that the titration will give you the number of additional grams of sodium hydroxide per liter of waste oil, so you must multiply the number of additional grams of sodium hydroxide by the number of liters of waste oil you are using.

Use the same equipment as you did making a 5-gallon batch with new oil. There is a handy chart in *From the Fryer to the Fuel Tank* (see **Web-Based How-To Resources**) for the amount of sodium hydroxide to use for various quantities of oil and various titration numbers.

Procedure

Perform a titration on the waste oil, to determine how much sodium hydroxide is needed for the reaction (in addition to the 3.5 grams per liter of new oil). Have all the materials warm, room temperature at the coolest, 130°F at the warmest. To filter waste vegetable oil, warm it in a stockpot, and pour it through a filter paper. These and the filter basket are available from restaurant supply stores. If the oil is very warm, let it cool to 120°F. Filter the oil and remove water as described above.

Follow the directions above for making a 5-gallon batch using new oil, but using the amount of sodium hydroxide called for by the titration.

Washing Biodiesel

Unwashed biodiesel will not meet ASTM (American Society of Testing and Materials) standards. For more information about ASTM standards, and testing and specifications for biodiesel and other diesel fuels, see **Resources**. Remember, equipment and engine manufacturers only warranty their equipment and engines for their material and manufacturer defects. Fuel manufacturers (in this case, you) assume responsibility for any damage caused by the fuel. Washing biodiesel is easy to do, and requires only water and time.

Why wash biodiesel?

The biodiesel produced with the process described above will work in some heating and lighting equipment and may be used to fuel diesel engines. Most impurities settle out into the glycerol layer—including unfiltered particulates, methanol, and glycerin. 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 transesterification is complete. Water in biodiesel can lead to biological growth as the fuel

degrades. Unreacted methanol in the biodiesel fuel can result in fire or explosion and can corrode engine components. The catalyst, sodium hydroxide, can also attack other engine components. Since the methanol and sodium hydroxide are chemical bases, unwashed biodiesel is caustic and may damage diesel engine components. Soap is not a fuel and will reduce fuel lubricity and cause injector coking and other deposits. At the 5-gallon batch quantity described above, it is not feasible to reclaim the methanol. If you begin making significant quantities of biodiesel, you should reclaim the unreacted methanol, because the reclaimed methanol represents a significant cost savings, and methanol is a pollutant in its own right.

Minimize contamination

To minimize impurities in the biodiesel, filter the oil before you mix it with methoxide. Remove all the water from waste vegetable oil by heating it before it is processed into biodiesel. Do not use any more methanol or sodium hydroxide than is needed to have an efficient reaction.

Most of the unreacted sodium hydroxide ends up in the glycerol layer and can be discarded or used to make soap (see ***Soap Making Using Biodiesel Waste)***. Most soap (if there is any water and FFA in the oil you started with) ends up in a white layer between the glycerol and the biodiesel. Drain this layer off with the glycerol before washing the biodiesel.

Remove unreacted methanol

Unreacted alcohol may be distilled from the biodiesel and reclaimed for use in future batches (more than one quarter of the methanol in the recipe will end up unreacted). Although alcohol reclamation is beyond the scope of this publication, note that methanol boils at 148°F at sea level. Methanol can be driven from biodiesel by heating it; do this outside or vent the methanol to the outside. Never breathe methanol fumes. A much better and safer solution is to use a vacuum pump to lower the pressure of a closed tank. The methanol can be collected and re-used. See the **Resources** section on methanol reclamation.

Washing Techniques

There are three techniques for washing biodiesel: agitation washing, mist washing, and bubble washing. The process of washing biodiesel involves mixing it with water. Water is heavier than biodiesel and absorbs the excess alcohol, sodium hydroxide, and soap suspended in it. After washing and settling, the water and the impurities in the water can be drained from the bottom of the container. Several wash cycles are generally needed. The first water drained off the bottom of the biodiesel will be milky, and the final wash water drained off will be clear. Excess sodium hydroxide in the biodiesel will form soap when mixed with water, and it takes a while for the soap to settle out. Depending on the method you use, it takes roughly as much water as biodiesel for a wash cycle. Initial washings must involve gentle mixing to minimize the formation of soap that will take time to settle out. However, you want the mixing to be thorough and for the water to be dispersed throughout the biodiesel. Agitation washing amounts to stirring water into the biodiesel, letting it settle, and draining it off. Mist washing is spraying a fine mist of water over the surface of the biodiesel. Tiny droplets of water fall through the biodiesel and pick up impurities on the way down. Bubble washing is done by putting a bubbler in a layer of water beneath the biodiesel in a container. As the bubbles rise they are coated with water, which picks up impurities as it travels up and then back down through the biodiesel.

Washing a Small Batch (courtesy of "Squire Tilly")

This is a simple, nearly foolproof method for washing small test batches of biodiesel, and I have often washed a sample of biodiesel in less than an hour using this method.

Be aware that unwashed biodiesel contains soap. If you agitate your first few washes too vigorously, the water, soap, and biodiesel will likely form an emulsion that may take days or weeks to separate.

Prior to washing, let the unwashed biodiesel settle for at least eight hours and possibly as long as a week to get rid of as much excess sodium hydroxide as possible.

In addition to unwashed biodiesel, you will need water, and a container about twice the volume of the biodiesel you are washing (you may use the container in which you reacted the biodiesel, but this ties up that container, so you will probably

want to use another container).

The three important things to remember in washing are GENTLY GENTLY GENTLY.

Washing Technique

Pour 1 liter of biodiesel into a 2-liter plastic soft drink bottle. Gently pour about 500 milliliters of lukewarm water into the bottle. Seal with a cap that will not leak. GENTLY rotate bottle end for end for about 30 seconds. After 30 seconds place the bottle upright.

If you have been GENTLE, the water and biodiesel will separate immediately.

You will notice the water is not clear.

Wearing rubber gloves, remove the cap, and using your thumb as a valve, turn the bottle upside down and drain the water. Drain the water into a bucket and allow it to evaporate. Discard any residue.

Repeat the process of adding 500 milliliters of lukewarm water, gently shaking, and draining off the water four or five times. Each time that you repeat the process, you should shake the mixture a little more vigorously and for a little longer, until by the fifth washing you are shaking the mixture very strongly for about a minute or a little more.

Washed biodiesel is VERY CLOUDY, much lighter in color than the original biodiesel, and looks terrible. After a day or two of settling and drying it will clear.

Washing a Larger Batch

Agitation Washing

Gently mix equal parts water and unwashed biodiesel and let settle until clear. Repeat several times, until the water is clear. Pump the biodiesel off of the top of the water (or drain the water off the bottom), dry the biodiesel for a few days in the sun.

Bubble Washing

An air pump, hose, and air stone can be bought from an aquarium supply store. Put the weighted air stone in the bottom of your bucket along with the biodiesel. Then gently add about 1/3 as much water as you have biodiesel to wash. Start the air pump and allow the bubbles to gently wash the biodiesel for several hours. Drain off the milky water, and repeat this process, letting the air pump run longer during each washing cycle, until the water remains clear. If the bubbles cause foam to form, use less air. You want to start out GENTLY. After the last water drained is clear, dry the biodiesel (see below) and it is ready to be used as diesel engine fuel.

Mist Washing

Purchase a misting nozzle from a pet store (these are used to keep reptiles cool) or from a drip irrigation company and connect it to your domestic water faucet. Turn the water on to make a fine, gentle mist, and allow the mist to float over the surface of the biodiesel. Keep the misting nozzle above the biodiesel. Mist the biodiesel until you have several gallons of milky water in the bottom of the container, then drain it off. Repeat this process several times, until the water you drain off is clear. Dry the biodiesel until it is clear, and you can use it for diesel fuel.

Drying washed biodiesel

After the biodiesel is washed, it should be dried until it is clear. This can be done by letting the biodiesel sit (covered) in a sunny location for a few days, or it may be heated to about 120°F for a few hours. Reacted, washed, and dried biodiesel may be used in any diesel engine. It should have a pH of close to 7, or chemically neutral, and it should have no methanol left in it.

How to Use Biodiesel

Biodiesel can be mixed with petroleum diesel in any proportion. To prevent gelling in cold weather, blend your biodiesel with Number 1 petroleum diesel. Biodiesel can be mixed with heating fuel and used in oil-fired heating equipment, and it can be used in some lamps designed to burn kerosene. Your biodiesel's cold weather performance depends upon what you use for

oil. Canola or rapeseed oil-based biodiesel will have better cold weather flow characteristics than biodiesel made from coconut oil or animal fat.

Resources

Books

Note: Unless noted, none of the biodiesel resources cited below are affiliated with NCAT and may not be associated with any other resource cited.

Biodiesel Homebrew Guide: Everything you need to know to make quality alternative diesel fuel out of waste restaurant fryer oil. Version 9—May 8, 2004. By Maria "Mark" Alovert.

For sale on-line from www.veggieavenger.com/store/propaganda.shtml

Small-scale Oilseed Processing. ATTRA Publication. 2001. By Janet Bachmann. National Center for Appropriate Technology, Fayetteville, AR. 21 p.

Get a free printed copy by calling 1-800-346-9140, or download from the ATTRA Web site:
HTML
www.attra.org/attra-pub/oilseed.html
PDF
www.attra.org/attra-pub/PDF/oilseed.pdf

Biodiesel Development: New Markets for Conventional and Genetically Modified Agricultural Products. 1998. By James Duffield, Hosein Shapouri, Michael Graboski, Robert McCormick, and Richard Wilson. United States Department of Agriculture Economic Research Service, Washington, DC. 31 p.

Available for download free of charge from www.ers.usda.gov/publications/aer770/ or by phone at 1-800-999-6779 (Stock Number: ERSAER770) for $25.50 + handling.

From the Fryer to the Fuel Tank: The Complete Guide to Using Vegetable Oil as an Alternative Fuel. By Joshua Tickell. Tickell Energy Consulting (TEC), PMB 223, 1350 Mahan Dr. E-4, Tallahassee, FL 32308.

Available on-line in hard copy or as an e-book on CD.
www.joshuatickell.com/products/publications/ or *www.Veggievan.org*

Web-Based How-To Resources

www.mississippi.org/programs/energy/Biodiesel%20Study/Eng_AspectsCh1.pdf

A general introduction to biodiesel and making biodiesel. Read this first.

www.journeytoforever.org/biodiesel_make.html#start

Journey to Forever is a small NGO (Non-Government Organization) based in Japan and involved in Third World rural development work. There is also a lot of information about other appropriate technologies on the Journey to Forever Web site.

www.journeytoforever.org/biodiesel_mike.html

Located on the Journey to Forever Web site, Mike Pelly's biodiesel recipe is widely accepted as being a good method for making biodiesel.

www.woodgas.com/Unlinked/biodiesel.htm

A good description of how to make small batches of biodiesel – for demonstrations.

www.kenneke.com/~jon/Kenneke76.pdf

Another description of how to make biodiesel.

www.eline2000.com/eline/articles/biodiesel/biodiesel.htm

A good article on making biodiesel.

www.eline2000.com/eline/video/2003.htm

On-line videos of making biodiesel.

www.biodieselgear.com/documentation/index.htm

A good resource list for people interested in making biodiesel.

www.biodieselgear.com/documentation/MistWashingBiodiesel.pdf

About mist washing biodiesel.

Other Processes (High Free-Fatty-Acid Conversion)

www.journeytoforever.org/biodiesel_

aleksnew.html
This is a description of a different process to make biodiesel.

http://biodiesel.infopop.cc/eve/ubb.x?a=tpc&s=447609751&f=629605551&m=519609261
This is a similar acid/base process described on an Internet discussion group web site.

Internet Discussion Groups

(Joining these groups can be helpful for problem diagnoses.)

http://groups.yahoo.com/group/biodiesel

http://groups.yahoo.com/group/biodieselbasics

http://wwia.org/mailman/listinfo.cgi/biofuel
The Biofuel mailing list is for anyone who is making or has an interest in making biofuels. All aspects of biofuels use are covered. On-farm energy is often discussed.

Web Resources

National Biodiesel Board
www.biodiesel.org

DOE Alternative Fuels Data Center
www.afdc.doe.gov/altfuel/biodiesel.html

University of Idaho
www.uidaho.edu/bae/biodiesel/

DOE Office of Transportation Technologies
www.ott.doe.gov/

DOE Energy Efficiency and Renewable Energy Network
www.eren.doe.gov/RE/bio_fuels.html

Veggie Van Home Page
www.veggievan.org/biodiesel/

Berkeley Biodiesel Collective
http://bapd.org/gbeeve-1.html

Pacific Biodiesel, Inc.
www.biodiesel.com

Sustainable Solutions Caravan
www.sustainablesolutionscaravan.org/englishIndex.html

National Biodiesel Board
www.biodiesel.org

Government Agencies with Biofuels Information

Oak Ridge National Laboratories
www.esd.ornl.gov/bfdp or bioenergy.ornl.gov/

National Renewable Energy Laboratory
www.afdc.nrel.gov

Department of Energy
www.eren.doe.gov or www.eere.energy.gov/biomass/renewable_diesel.html

Chemistry of Biodiesel Resources
http://koal2.cop.fi/leonardo/
An interesting page about vegetable oil transesterification and other vegetable oil chemistry.

Standards and Testing, Chemical Composition of Biodiesel

National Standards for Biodiesel
www.journeytoforever.org/biodiesel_yield2.html#biodstds

Biodiesel Chemical Properties
www.chanco.unima.mw/physics/biodieselanaly.html

ASTM Standards
www.astm.org/cgibin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/D6751.htm?L+mystore+dlra2970+1083877590

Cetane Number Testing of Biodiesel
www.biodiesel.org/resources/reportsdatabase/reports/gen/19960901_gen-187.pdf

Methanol Composition and MSDS
www.bu.edu/es/labsafety/ESMSDSs/MSMethanol.html

Glycerine Uses
www.journeytoforever.org/biodiesel_glycerin.html

Research Sites and Papers

www.me.iastate.edu/biodiesel/

www.uidaho.edu/bae/biodiesel/

Other general information

www.allpar.com/ed/biodiesel.html

www.veggieavenger.com

Using Vegetable Oils for Fuel

Using vegetable oil in diesel engines
www.oilpress.com/drive_your_diesel.htm

Using vegetable oil in diesel engines
www.rerorust.de/

Using vegetable oil in diesel engines, conversion kits
www.biofuels.ca/

Conversion Kits
www.greasel.com/
www.greasecar.com/

Economic Feasibility of Producing Biodiesel in Tennessee
web.utk.edu/~aimag/pubs/biodiesel.pdf

Reclaiming Methanol

www.home.swbell.net/scrof/Biod_Proc.html

www.journeytoforever.org/biodiesel_processor2.html

www.journeytoforever.org/biodiesel_processor8.html#press

Respirator Selection

www.cdc.gov/niosh/npg/npgd0397.html

Soap Making Using Biodiesel Waste

www.eline2000.com/eline/articles/barsoap/barsoap.htm

www.journeytoforever.org/biodiesel_glycerin.html#soap

www.eline2000.com/eline/video/2003.htm

Biodiesel as a Home Heating Fuel

www.biodiesel.org/markets/hom/default.asp

The electronic version of Biodiesel - A Primer
is located at:
HTML
http://attra.ncat.org/attra-pub/biodiesel.html
PDF
http://attra.ncat.org/attra-pub/PDF/biodiesel.pdf

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