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Biodiesel: Do-It-Yourself Production Basics

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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.

Introduction

Biodiesel is an alternative to petroleum diesel. Biodiesel is permanently thinned plant- or animal-based oil, with a viscosity approximating that of standard No. 2 diesel fuel. The fuel is called biodiesel because it is made from mostly biodegradable materials and can be used as fuel in diesel engines. Biodiesel can also be used in boilers or furnaces designed to use heating oils or in oil-fueled lighting equipment. It can be used neat, meaning 100-percent biodiesel, or it can be blended with petroleum diesel.

The purpose of this publication is to describe how people can make biodiesel 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 petroleum diesel is.

Straight Vegetable Oil (SVO)

Under the proper conditions, either new or used vegetable oil such as cooking oil can be used as a fuel for diesel engines without processing the oil into biodiesel. Vegetable oil must be filtered to 5 microns or smaller and heated to at least 140 degrees Fahrenheit for use in diesel engines. Other common terms for unprocessed vegetable oil running in a diesel engine include pure plant oil (PPO), which is the same as SVO, and waste vegetable oil (WVO). Although SVO has some advantages over biodiesel, SVO has been shown to shorten engine life and cause other fuel-related problems. See the Further Resources section for more information about using SVO for fuel.

Materials for making a table-top batch of biodiesel. Photo: Ericka Dana

Biodiesel can be made in any quantity, from one cup to many gallons. The process described here is a batch process, which is appropriate for an individual farmer or rancher. Steady flow processes are more appropriate for biodiesel manufacturing plants. Because small mistakes are preferable to large mistakes, people interested in making biodiesel may want to start with small batches and work up to making larger batches.

Hazards

Making biodiesel is relatively simple; some say it is 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 nor anyone else associated with this publication is responsible for potential mistakes, injuries and damage. Do not rely solely on this publication for information about making biodiesel; carefully study other publications and start small.

Wear an appropriate respirator when making biodiesel. The only approved respirators for methanol are respirators with external air supplies. For information on obtaining a respirator, see the Further Resources section at the end of this publication. Other necessary equipment includes heavy rubber gloves, safety goggles, and clothing that will protect your skin from chemicals, especially methanol. Methanol can be absorbed through the skin and cause illness, blindness, and debilitation.

Heating the oil to remove the water and transferring the heated oil 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. Be cautious about using burners or electric heaters, just as if you were cooking. Hot oil will melt plastic buckets, creating a mess. Be careful to cool hot oil to below 120 degrees 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, when mixed with the proper amount of oxygen and an ignition source, can ignite with an invisible flame. When making biodiesel in larger quantities, make it outside or in a place where 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.

Storage of Chemicals and Biodiesel

Feedstocks and finished biodiesel must be properly stored. Methanol is a poison. Avoid all contact with methanol, including skin contact and breathing in fumes. Contact with methanol can cause irreversible illness, blindness, and death. Because methanol absorbs water, it should not be stored in any open container. Methanol should be stored in appropriate, sealed containers and containers should be clearly marked as containing methanol. Catalyst materials like sodium hydroxide (NaOH) and potassium hydroxide (KOH) are

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Basic Chemistry of Biodiesel

About Biodiesel

Biodiesel is made by chemically reacting vegetable oil or animal fat or a combination of oils and fats with alcohol, usually nearly pure methanol, denatured ethanol, or ethanol. The mixture is then combined with a catalyst—an alkaline chemical such as potassium hydroxide or sodium hydroxide, also known as lye. The oil is chemically acidic. The combination of the alcohol and catalyst, also known commonly as methoxide, 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. Because the biodiesel is not as dense as the glycerol, the biodiesel floats on top of the glycerol and may be poured or pumped off, or the glycerol can be drained off the bottom. The fuel can then be filtered and used in heating or lighting applications. Although some people use the fuel in diesel engines without further processing, it is strongly recommended that impurities such as soap, unreacted alcohol, and catalyst be removed first by a washing process. Unwashed biodiesel is caustic and incompatible with modern fuel-injection systems and use will lead to component failure. Modern diesel engines made after 2004 require high-quality fuel to avoid problems.

Anyone who has experience with diesel engines knows that diesel fuel will turn into a waxy gel at low temperatures. This is called the gel point and fuel at the gel point cannot be pumped until it is warmed up. The temperature at which the fuel will no longer pour is called the pour point. Biodiesel has a higher pour point than No. 2 petroleum diesel. This means biodiesel gels at a higher temperature. Some oil feedstocks, 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 gel point. Biodiesel is commonly blended with No. 1 petroleum diesel to lower the gel and pour points. 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 keep biodiesel above the gel point.

strong bases and extremely caustic. These chemicals also absorb water and will become unusable unless kept in a tightly sealed container.

Oil feedstocks can go rancid or even be rancid when acquired. 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, wet, or heavily used oil produces less biodiesel and may not even react enough to make biodiesel. Finished biodiesel can be safely stored for six months.

Improper storage of biodiesel, waste vegetable oil, and glycerol can attract rodents. Be careful to keep a clean workspace and dispose of waste quickly. Mice and rats can quickly chew through plastic containers, so be vigilant. Keep the work area secure from small children and pets, as the biodiesel can have an attractive, sweet smell. Biodiesel-soaked rags and paper towels can spontaneously combust and care must be taken to avoid this possibility.

Finished biodiesel should be stored in steel drums, poly totes, or yellow diesel cans, and these containers 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. Most petroleum fueling equipment can be used for biodiesel but the equipment degrades more quickly. For more information, see the ATTRA publication *Biodiesel Use, Handling, and Fuel Quality.*

Materials

As mentioned above, biodiesel production requires three inputs: oil or fat, alcohol, and a caustic, strong-base catalyst. Approximately 80 percent by volume of the feedstock of biodiesel is vegetable oil or animal fats and about 20 percent is methanol. Proper reaction of the raw oil requires 20 percent methanol. For example, a proper ratio is 10 gallons of oil to 2 gallons of methanol. The ratio of catalyst varies depending on materials used. One gallon of raw oil yields nearly 1 gallon of finished fuel.

New, degummed vegetable oil or waste vegetable oil from restaurants can be used for the oil component. The better the quality of the oil, the easier it is to make high-quality biodiesel. Oilseed farmers can press and degum oil or get pressed raw oil. See the ATTRA publication *Oilseed Processing for Small-scale Producers* for more information.

Methanol, or wood alcohol, was once made through pyrolysis of wood, but now methanol is made primarily from natural gas. It is used as a gas-line antifreeze and for racing fuel. Methanol is available from chemical suppliers. Methanol in 55-gallon drums is available from fuel dealers, auto parts stores, or speed shops. HEET gas-line antifreeze is 99-percent pure methanol and can be used to make small batches of biodiesel. Be sure to purchase HEET that is sold in yellow bottles. Iso-HEET, which is sold in red bottles, is isopropyl alcohol and will not work. Do not assume that fuel-line antifreeze is pure methanol unless it is labeled as such. Be sure to use nearly pure methanol.

For the catalyst, sodium hydroxide (NaOH, caustic soda, or lye) or potassium hydroxide (KOH, caustic potash) can be used. Until recently, sodium hydroxide was commonly sold as a drain cleaner in the form of Red Devil-brand lye and was available from hardware stores and many grocery stores. It has been discontinued by the manufacturer. If purchasing another brand of lye drain cleaner, make sure it is pure lye. Potassium hydroxide is less commonly available but can be purchased through chemical supply houses or farm chemical suppliers.

Avoid all contact with methanol, including skin contact and breathing in fumes. Contact with methanol can cause irreversible illness, blindness and death.

The amounts of methanol, potassium hydroxide, and raw oil used to make biodiesel are adjustable, as long as the following formula is followed: 1,000 milliliters of oil to 200 milliliters of methanol to 7 grams of potassium hydroxide. If you prefer to use sodium hydroxide, the correct amount in the formula would be 3.5 grams. For used oil, see the section on "How to do a Titration" on page 4.

Collecting Waste Vegetable Oil (WVO)

Although some biodiesel producers pay for waste vegetable oil, it is often available for free from restaurants. Shop around. Smaller restaurants may let producers pick up waste oil in buckets or drums, if the producer provides exchange buckets. Find out when the fryer oil is to be changed and pick it up warm if possible. To get the best oil, talk to the restaurant owner and, more importantly to the head cook, and inform them about the project and oil requirements. Most restaurant owners will be happy to work with producers who are conscientious and don't make a mess. Do not take oil from grease Dumpsters at the back of a restaurant. The oil may have excess water and be of poor quality. Taking oil may also constitute theft. Check with state and local governments for any necessary permits, as some jurisdictions charge fines for improper disposal of used oils.

Sodium Hydroxide Versus Potassium Hydroxide

Sodium hydroxide (NaOH) is the least expensive and most commonly used alkaline component in the small-scale biodiesel product ion process. However, in recent years, potassium hydroxide (KOH) gained popularity because of its superior catalyst properties. Potassium hydroxide dissolves more easily in methanol and is less sensitive to water. In addition, the glycerol, or glycerin by-product of processing with potassium hydroxide, remains liquid and is easier to dispose of.

The by-product can also more safely be added to compost piles, used in small quantities as a supplement to animal feed for ruminants or poultry, and applied as potassium fertilizer. Using sodium hydroxide contaminates the wash water with salts, rendering it inappropriate for land application. Sodium hydroxide glycerol does have advantages of its own: it makes a superior base for soap or degreaser.

Cost

In addition to the initial cost of the processing equipment, biodiesel production costs include the chemicals used in the reaction, gas or electricity expenses, and labor. Feedstocks can range from new food-grade cooking oil to animal fat renderings. The cost of the feedstock is very specific to the producer's location and operation. Waste oil from restaurants is becoming a valuable commodity, but many local restaurants are still willing to give producers waste oil for free. Farmers who grow oilseeds may be able to press oil at the farm for a relatively low cost.

Methanol costs fluctuated wildly in recent years, along with gasoline and natural gas prices. Expect to pay roughly 25 percent more for methanol than the current pump price for gasoline. Look in the phone book for fuel suppliers or speed shops. Catalyst costs start at about $2.50 per pound. Shop around to get the best price. Remember, hazardous chemical shipping costs can be significant for chemicals purchased over the Internet.

Currently farmers can expect to produce biodiesel from free, waste grease for between $1.20 and $2 a gallon, before accounting for labor, equipment and energy costs, and paying any applicable state and federal road tax.

How to do a Titration

As stated in the box on the next page, titration is a simple laboratory technique used to determine the level of free-fatty acids in used oil, and the amount of reactant chemicals that you will need to completely process your feedstock. Follow these instructions to determine the proper amount of catalyst before making each batch of biodiesel from waste oil.

Materials

1. One bottle of isopropyl alcohol. In the United States, Iso-HEET Premium Fuel System Dryer & Antifreeze, in a 12 fluid ounce red bottle, is available at auto parts stores and is about 100 percent isopropyl alcohol. Isopropyl alcohol is also available at pharmacies.

2. One bottle of phenolphthalein (preferred) or phenol red, available at hot tub stores and home centers.

3. One liter of 0.1-percent catalyst in distilled water

It is important to measure the catalyst very accurately. The accurate amounts are 1 gram of catalyst (sodium hydroxide or potassium hydroxide) dissolved in 1 liter of distilled water.

In the absence of a scale capable of measuring small amounts, one way of achieving precise measurements is to measure out 10 grams of catalyst 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 1 gram of catalyst in 1 liter of distilled water. A local pharmacist or high school science department can also do the measuring. Leftover solution can be stored in a sealed container for future test batches. Remember sodium hydroxide and potassium hydroxide are very caustic and even a very small amount can burn skin.

Equipment

1. A 1-cup jelly jar or other similar glass container. Remember to never use biodiesel production containers for food preparation.

2. Two 1-milliliter syringes with graduations marked on the side. Note that one syringe is for oil and one is for the lye-water mixture. Always use the same eyedropper for the same chemical; do not mix them up.

3. Safety glasses and rubber or nitrile gloves

Making Your First Batch of Biodiesel

There are many techniques for making biodiesel in batches from one cup to 90 gallons. Many kits are available for sale online, as well as do-it-yourself plans. Check the Further Resources section for links. Regardless of the scale of the operation, the same six basic steps apply.

1) Collect oil
There are many sources of oil, including growing oilseed crops and collecting waste oil. Some basic rules apply regardless of the source. Oil must be relatively free of solids and water. If collecting used cooking oil, work with establishments that change their oil regularly. This means at least once a week, depending on amount of use. The quality of the oil is important, too. Soy or canola oil is preferred because tropical oils and animal fats require more chemicals and produce a finished biodiesel with a higher gel temperature.

2) Test the oil
Waste vegetable oil contains free fatty acids (FFA), and the amount of free fatty acids in the oil is very important because it determines the quality and quantity of the fuel produced, as well as the amount of chemicals required and the cost per gallon. Titration is a simple technique used to determine the quantity of free fatty acids in oil. When using waste oil, try to use oil with a titration value of five or below. Titration is also discussed later in this publication.

3) Process the oil
The reaction between oil and the methanol-catalyst mixture, known as methoxide, can take place in a container of any size, but the container needs to be resistant to the corrosive nature of the oil and chemicals involved. On a small scale, a glass beaker or jar or a 1-liter plastic bottle are generally safe bench-top vessels. See the Making a table-top batch of biodiesel section of this publication for more information about producing biodiesel in a 1-liter plastic bottle. Some older literature refers to mixing biodiesel in a blender. DO NOT use a blender to mix a small batch of biodiesel. The reactants dissolve rubber gaskets, causing leaks. The violent mixing can also cause splashing of caustic chemicals. On a larger scale, a closed steel container is the safest option. See the section about batch processors for more information.

4) Remove glycerol
After the reaction, the glycerol by-product will settle to the bottom of the vessel. This glycerol must be removed before the biodiesel can be used. Most larger reactors include a drain at the bottom of the vessel that allows the denser by-product to be removed. In a bench-top situation, the biodiesel can be poured off or removed with a pipette or baster.

5) Wash and dry the biodiesel
Even after the reaction has taken place and the by-product has been removed, the biodiesel can contain impurities, including soaps and residual glycerol, methanol, and lye. Passing a small quantity of water through the biodiesel removes the impurities and stops any remaining chemical reaction.

6) Dispose of the glycerol
Proper disposal of the by-product is essential. The glycerol contains unconsumed methanol and catalyst, which can find their way into groundwater. See the section titled "Methanol Recovery" for more information on this process.

Procedure

1. Pour 10 milliliters of room-temperature isopropyl alcohol into the 1-cup jelly jar.
2. Add 2 or 3 drops of phenolphthalein to the alcohol.
3. Using one of the eyedroppers, add the 0.1-percent solution drop by drop until the alcohol just starts to turn red. Stir the alcohol while dropping in the 0.1-percent solution.
4. Using the other eyedropper, add exactly 1 milliliter of the oil to be titrated. Now, fill the eyedropper with 10 milliliter of 0.1-percent solution. Start dripping this solution into the mixture until it stays pink for at least 20 seconds.
5. Keep track of how many milliliters of 0.1-percent solution are needed for the liquid to turn and stay red.

The number of milliliters of 0.1-percent solution needed is equal to the number of extra grams of pure catalyst needed to produce the proper reactions to make biodiesel. For example, if it takes 3 milliliters of 0.1-percent solution to turn the oil and isopropyl alcohol solution to a base, add 3 grams of catalyst to the 3.5 grams of sodium hydroxide or 4 grams of potassium hydroxide needed for new oil, for a total of 6.5 grams of sodium hydroxide or 7 grams of potassium hydroxide.

Making a Table-Top Batch of Biodiesel

In the past, many biodiesel enthusiasts made demonstration batches using a kitchen blender. We strongly recommend that you DO NOT make biodiesel in a blender. The high speed of operation can cause splashing of caustic chemicals, and the rubber and plastic parts can degrade and leak. The easiest and safest method to try a small batch of biodiesel is the one originated by users at www.biodieselcommunity.org. Nicknamed the "Dr. Pepper Technique," it utilizes a 2-liter plastic soda bottle as a sealed mixing vessel to safely mix a small batch. Below is the author's adaptation of this method.

Before beginning this or trying any biodiesel processing at home, please refer to all hazards and safety precautions discussed in this publication as well in the articles listed in the Further Resources.

Before beginning, make sure that you have all of the equipment and materials you need to complete a batch.

Materials

- One liter of new vegetable (cooking) oil
- Catalyst, either sodium hydroxide or potassium hydroxide
- Methanol, commonly available as HEET fuel line treatment in the yellow bottle. DO NOT use Iso-HEET in the red bottle; this is isopropyl alcohol.

Equipment

- Clean, dry 2-liter soda bottle
- Measuring cup or graduated beaker
- Scale
- Glass jar to mix the methanol and catalyst to produce methoxide.
- Funnel
- Rubber gloves
- Safety glasses

Mixing the methoxide is the most potentially hazardous step in the biodiesel process. Make sure that you mix the methanol and catalyst in a clean glass jar with a tight fitting lid. DO NOT mix in a plastic container because the container may dissolve. Do your mixing in a well-ventilated area, as the methanol fumes are toxic.

Measure 4 grams of sodium hydroxide or 5.6 grams of potassium hydroxide using your scale. Add the catalyst to your clean glass mixing jar.

Measure 250 milliliters of methanol, using a graduated beaker or measuring cup. Add the methanol to the glass mixing jar with the catalyst.

Stir the methoxide mixture until the catalyst is completely dissolved. You can also cover the jar with a tight-fitting lid and mix the methoxide by swirling or shaking, but be very careful that your lid is screwed on tightly and completely free of leaks. It will take a few minutes for the catalyst to dissolve completely, so be patient. The mixture creates heat as the chemical reaction takes place and the jar will feel warm. This is normal.

Measure 1 liter of oil, and use your funnel to pour it into the 2-liter soda bottle. You will get a better reaction if the oil is warm. About 140 degrees Fahrenheit is ideal. You can heat the oil in a pan on the stove or just leave it in the sun for an hour. If you choose to pre-heat the oil, be very careful not to get the oil hotter than 140 degrees.

Add the methoxide solution to your oil. Use a funnel and be careful not to spill. If you spill, clean up the material immediately with paper towels and dispose of the contaminated paper towels safely.

Put the cap on the soda bottle and shake vigorously for about 30 seconds. Let the mixture settle and then shake again for about 10 seconds every 10 minutes; repeat this three times.

Allow the bottle to stand for an hour. The mixture will begin to clear almost immediately and a layer of darker liquid will begin to form on the bottom of the bottle.

The darker layer on the bottom of the bottle is glycerol, the by-product of the transesterification process.

You can now drain off the glycerol by taking off the bottle cap, covering the open mouth of the bottle with your thumb, and inverting the bottle. Wear gloves. Allow the glycerol to collect in the neck of the bottle and then use your thumb as a valve to drain the darker liquid into another container. Discard the glycerol by composting or use it as a degreaser. What remains in the bottle is useable biodiesel.

Photos: Ericka Dana

Choosing a Scale of Production

After trying a table-top batch, decide on a production system that is scaled to fit available space, available feedstock, and fuel needs. Batch mixing can be done on a variety of scales, and there are several system designs to consider. Batches of 10 gallons or less can be mixed with gentle agitation or stirred with a paint mixer. It is a simple, inexpensive process, but this type of paddle mixing can leave unreacted material and lead to lower-quality fuel. Mixing in an open-top container can lead to splashing chemicals and the release of dangerous and flammable methanol fumes. Most popular small-scale production systems currently in use are in the 30- to 50-gallon range and utilize circulating pumps to provide consistent mixing in a closed mixing container.

Although a small-scale mixer or crude paddle mixer may be inexpensive to build, remember that economies of scale apply. It can take the same amount of time to produce 10 and 30 gallons of biodiesel. Buying chemicals in bulk and mixing batches in a safe and efficient reactor saves time, money, and headaches in the long run.

There are many designs for building a processor and countless turn-key kits available. An in-depth discussion of processor design and construction is beyond the scope of this publication, but more information is available in the Further Resources section.

Washing Biodiesel

Unwashed biodiesel will not meet ASTM, formerly known as the American Society of Testing and Materials, standards. For more information about ASTM standards and testing and specifications for biodiesel and other diesel fuels, see the Further Resources section. Remember, equipment and engine manufacturers only warranty their equipment and engines for their material and manufacturer defects. Fuel manufacturers 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

The Appleseed Processor

For the last several years, many do-it-yourselfers chose to avoid the more-expensive kits on the market and opted to build their own processor using an electric water heater as the reactor. This water heater-based platform was developed by biodiesel home brewer Maria Alovert. Alovert, or Girl Mark as she is commonly known on Internet biodiesel forums, set out across the country in 2004 to share her open-source design through a series of workshops. Because Alovert spread her design like the nurseryman Johnny Appleseed spread apple seeds across Ohio, Indiana, and Illinois, her design became known as the Appleseed. Links to complete Appleseed plans are available in the Further Resources section.

The Appleseed design uses the water heater's existing tank, plumbing, insulation, thermostat, and heating element as the starting point for a remarkably simple, reliable, and inexpensive design. Although a used water heater can often be found for free, they can be problematic if they leak or contain large amounts of rust, limescale, or other impurities. A new electric water heater can be found on sale at home centers for as little as $200. The plumbing parts, pumps, and electrical supplies necessary for the completion of the unit can be purchased for about $150.

In this design, the oil is pumped into the water heater tank and brought up to a constant temperature of 130 degrees Fahrenheit using the built-in heating element and thermostat. While heating, the methanol and catalyst are premixed in a high-density polyethylene (HDPE) carboy or jug. The oil is circulated from the bottom of the tank to the top, and the methoxide is introduced slowly from the carboy through a permanent hose. This greatly reduces the risk of spilled chemicals and injury. After about an hour of mixing, the circulating pump is turned off and the glycerol settles to the bottom, where it can be drained off. The biodiesel can then be pumped out to another tank for washing and drying.

One of the beauties of this design is that, by using a series of bypass valves, the same one-half horsepower centrifugal pump can be used for filling, mixing, and emptying the reactor. This is also a very safe design appropriate for small-scale production.

Many variations on the design are available for free online, as well as designs for countless add-ons like standpipe wash tanks, drying systems, and methanol recovery systems. For the serious do-it-yourselfer who wants to produce high-quality biodiesel for the smallest investment, the Appleseed is a good design to explore.

biodiesel because washing biodiesel is a time-consuming process. However, some alcohol, catalyst 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 can also attack other engine components. Because the methanol and catalyst 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. In the small-batch scale described above, it is not feasible to reclaim the methanol. When making significant quantities of biodiesel, reclaim the unreacted methanol because the reclaimed methanol represents a significant cost savings and methanol is a pollutant in its own right.

Washing Techniques

There are several common techniques for washing biodiesel, including 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, catalyst, and soap suspended in the fuel. 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 catalyst in the biodiesel will form soap when mixed with water, and it takes awhile for the soap to settle out. Depending on the method used, it takes roughly 1 gallon of water per 1 gallon of biodiesel for a wash cycle. The mixing should be thorough and the water should be dispersed throughout the biodiesel. Agitation washing means 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. The rising bubbles are coated with water, which picks up impurities as the water travels up and then back down through the biodiesel.

Washing Your Test Batch

You can easily wash your 1-liter test batch by slowly and gently adding water to your bottle until it is full. Allow the water to settle to the bottom and then use the same technique used to remove the glycerol. Cover the mouth of the bottle with your thumb, invert the bottle, allow the water to settle, and then drain it off using your thumb as a release valve. Wear gloves. Repeat the process. After washing, the biodiesel will be cloudy with an appearance similar to orange juice. This is because of residual water trapped in the fuel. Do not use the fuel until you have allowed it to sit with the top off until it is clear. Then you know the fuel is dry.

Washing a Larger Batch

Building a basic washing system is simple. One option is to use a misting nozzle similar to those used in a grocery store produce department. Using an open-head 55-gallon drum or other container with a drain valve connected at the bottom, suspend the mist head over the barrel and plumb to a water supply with hard pipe or a garden hose. Fill the container about half full of biodiesel, and then turn on the water and allow the mist head to gently spray the surface of the biodiesel. In a short time, the water will fall to the bottom and be removed through the drain valve. For bubble washing, use an aquarium air pump, hose, and air stone. For a larger washing tank, a perforated pipe connected to an air compressor can be used. Gently add about one-third as much water as you have biodiesel to wash. Start the air pump or compressor and allow the bubbles to gently wash the biodiesel for several hours. Drain 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.

Drying Washed Biodiesel

After the biodiesel is washed, it should be dried until it is crystal clear. This can be done by letting the biodiesel sit uncovered in a sunny location for a few days, or it may be heated to about 120 degrees Fahrenheit for a few hours. Another popular technique is recirculating the biodiesel from the bottom of the drying tank through a shower head or sprayer suspended above the top of the open tank. This increased contact with air will dry biodiesel in about an hour, depending on humidity. 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. Although professional testing of fuel may be prohibitively expensive, simple home fuel test kits can be purchased for a reasonable price. One such kit, The Biodiesel pHLip Test, can be found at *www.phliptest.com.*

Methanol Recovery

Because much of the methanol used in transesterification remains in the by-product after reaction, it can be advantageous to recover the unused alcohol for several reasons. First, reusing the recovered methanol can save a considerable amount of money when producing significant volumes of biodiesel. Second, once the alcohol is removed the glycerol by-product becomes glycerin, a much more environmentally friendly product with countless uses.

Methanol recovery can be achieved through the distillation process by heating the glycerol to a temperature above the boiling point of methanol, 148 degrees Fahrenheit at sea level. This temperature is lower if the process is performed at a lower pressure. Attaching a vacuum pump to the distilling tank lowers the danger of explosion. The vaporized methanol must then be passed through a condenser, cooled, and recaptured as a liquid. Biodiesel researchers and enthusiasts are currently exploring several systems and links to more information can be found in the Further Resources section of this publication. Several methanol-recovery systems rely again on a water heater to provide a relatively safe, sealed tank to heat the glycerol and automotive condensers or homemade cooling towers. Because biodiesel made with sodium hydroxide will produce a glycerol that is more solid when cool, it is best to use potassium hydroxide if recovering the methanol, or pump the sodium hydroxide methanol directly in to the distilling unit while it is still hot.

One of the best ways to learn about making biodiesel is by joining a local biodiesel club or group.

Glycerol Disposal

One of the major issues to deal with in biodiesel production is the disposal of glycerol, the methanol-laden glycerin by-product of biodiesel product ion. While the methanol in the glycerol may biodegrade up to 97 percent within 72 hours, methanol-laden glycerol should be handled as a hazardous material. There is debate, though, as to the actual hazard posed by glycerol. Some people use small quantities as a dust suppressant, degreaser, or weed killer. Glycerol can be burned in a waste oil burner or added to a biodigester or a proper compost pile, where it can safely be converted to fertilizer. Glycerol has about the same feed value as corn and there are numerous university studies documenting its use as a feed supplement. Check local regulations before disposing of glycerol. NEVER dump glycerol in a ditch or waterway and DO NOT pour into drains or toilets, especially if you have a septic system.

Conclusion

This publication is meant as a starting point for making biodiesel. It is not a complete reference guide and you are encouraged to explore all of the additional information supplied in the Further Resources section. One of the best ways to learn about making biodiesel is by joining a local biodiesel club or group. Classes are offered in many areas through local clubs, community colleges, and farm groups. Make sure that you have as much information as possible before mixing your first batch, and always remember – SAFETY FIRST.

Further Resources

Unless noted, none of the biodiesel resources cited below are affiliated with NCAT.

Internet discussion groups

Joining these groups can be a great way to learn from those who are producing biodiesel. This is only a sampling of forums on topics like homebrew biodiesel, straight vegetable oil and home heating.

Biodiesel & SVO Discussion Forums
http://biodiesel.infopop.cc

Yahoo Biodiesel Group
http://groups.yahoo.com/group/biodiesel

Yahoo Biodiesel Basics Group
http://groups.yahoo.com/group/biodieselbasics

Frybrid Diesel/Vegetable Oil
www.frybrid.com/forum

Biodiesel cooperatives

Piedmont Biofuels Coop
www.biofuels.coop

Yoderville Biodiesel Collective
www.ybdc.org

Web resources

Journey to Forever
www.journeytoforever.org
Journey to Forever is a small, non-government organization based in Japan and involved in Third World rural development work. The Web site also offers a lot of information about other appropriate technologies.

MakeBiodiesel.Org
http://make-biodiesel.org/
MakeBiodiesel.org offers tips, procedures, safety information, and do-it-yourself guidance for biodiesel production.

National Biodiesel Board
www.biodiesel.org

Government agencies with biofuels information

Oak Ridge National Laboratories
www.ornl.gov

Biodiesel publications from the National Renewable Energy Laboratory
www.nrel.gov/vehiclesandfuels/npbf/pubs_biodiesel.html
This site offers PDF and HTML files about biodiesel production, handling and use; biodiesel quality, stability and compatibility; biodiesel emissions; and biodiesel fleet evaluations.

Standards and testing, chemical composition of biodiesel

National standards for biodiesel, from Journey to Forever
www.journeytoforever.org/biodiesel_yield2.html#biodstds

ASTM Standards
www.astm.org

Cetane Number Testing of Biodiesel
http://www.biodiesel.org/reports/19960901_gen-187.pdf

Glycerin uses

Glycerin, from Journey to Forever
www.journeytoforever.org/biodiesel_glycerin.html

Straight vegetable oil as diesel fuel, from Journey to Forever
http://journeytoforever.org/biodiesel_svo.html

Discussion forums

Biodeisel & SVO
http://biodiesel.infopop.cc/eve/forums/a/cfrm/f/898605551

Frybrid Diesel/Straight Vegetable Oil
www.frybrid.com/svo.htm

Reclaiming methanol

BioLyle's Biodiesel Workshop
www.biolyle.com/process/methanol.html

Safety

Biodiesel Safety and Best Management Practices for Small-Scale Noncommercial Use and Production, from Penn State College of Agricultural Sciences
http://pubs.cas.psu.edu/FreePubs/pdfs/agrs103.pdf

Make Biodiesel: Biodiesel Safety Tips and Videos
http://make-biodiesel.org/Biodiesel-Safety/

Occupational Safety and Health Administration
www.osha.gov

Respirator selection

National Institute for Occupational Safety and Health
Pocket Guide to Chemical Hazards
www.cdc.gov/niosh/npg/npgd0397.html

Making soap using biodiesel waste

Soap, from Journey to Forever
www.journeytoforever.org/biodiesel_glycerin.html#soap

Biodiesel as a home heating fuel

Bio Heat
www.bioheatonline.com

Heaters, burners and stoves, from Journey to Forever
http://journeytoforever.org/biodiesel_heaters.html

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