Search the Journey to Forever website – click HERE

Please support Journey to Forever: Make a donation

日本語

En español Biocombustibles, biodiesel

Navigation

Biofuels
Biofuels Library
Biofuels supplies and suppliers

Biodiesel
Make your own biodiesel
Mike Pelly's recipe
Two-stage biodiesel process
FOOLPROOF biodiesel process

New! Build a 3-inch ethanol still – Click HERE

Make your own biodiesel

Spanish version -- Versión en español

Anybody can make biodiesel. It's easy, you can make it in your kitchen -- and it's better fuel than the petro-diesel the oil companies sell you.

Your diesel motor will run better and last longer on your home-made fuel, and it's much cleaner -- better for the environment and better for health.

If you make it from used cooking oil it's not only cheap but you'll be recycling a troublesome waste product that too often ends up in sewers and landfills instead of being recycled.

Best of all is the GREAT feeling of freedom, independence and empowerment that making your own fuel will give you.

Biodiesel processors
Biodiesel in Hong Kong
Nitrogen Oxide emissions
Glycerine
Biodiesel resources on the Web
Do diesels have a future?
Vegetable oil yields and characteristics
Washing
Biodiesel and your vehicle
Food or fuel?
Straight vegetable oil as diesel fuel
Heaters, burners, stoves

Ethanol
Ethanol resources on the Web
Is ethanol energy-efficient?

Biogas

Wood gas as motor fuel
Home
What people are saying about us
About Handmade Projects

Free heating!

Roger Sanders has updated his popular improved version of the Mother Earth News waste oil heater with a great deal of new information and new options.

This waste oil heater solves all the problems that made the original MEN version difficult to use.

Roger's design is simple and reliable -- it's easy to build and easy to use, it's quiet, it uses no electricity, it's easy to light, easy to clean and easy to control, it has a wide heat range, and it runs on waste vegetable oil (WVO) just as well as on used engine oil. It can save you thousands of dollars in heating bills.

The Second Edition is available as a pdf e-book, price $22.50. Complete DIY instructions -- buy it **HERE**.

Spanish

Spanish-language version **HERE**.

Here's how to do it -- everything you need to know.

Three choices

There are at least three ways to run a diesel engine on vegetable oil:

- Mix it with petroleum diesel fuel, or with a solvent, or with gasoline;
- Use the oil just as it is -- usually called SVO fuel (straight vegetable oil) or PPO fuel (pure plant oil);
- Convert it to biodiesel.

The first two methods sound easiest, but, as so often in life, it's not quite that simple.

1. Mixing it

Vegetable oil is much more viscous (thicker) than either petro-diesel or biodiesel. The purpose of mixing or blending straight vegetable oil (SVO) with other fuels and solvents is to lower the viscosity to make it thinner, so that it flows more freely through the fuel system into the combustion chamber.

If you're mixing SVO with petro-diesel you're still using fossil-fuel -- cleaner than most, but still not clean enough, many would say. Still, for every gallon of SVO you use, that's one gallon of fossil-fuel saved, and that much less climate-changing carbon dioxide in the atmosphere.

People use various mixes, ranging from 10% SVO and 90% petro-diesel to 90% SVO and 10% petro-diesel. Some people just use it that way, start up and go, without pre-heating it (which makes veg-oil much thinner). Some even use pure vegetable oil without pre-heating it.

You might get away with it in summer time with something like an older '80s Mercedes 5-cylinder IDI diesel, which is a very tough and tolerant motor -- it won't like it but you probably won't wreck it

resources on the Web

Contact us

To Keith Addison
keith@journeytoforever.org
To Midori Hiraga
midori@journeytoforever.org
Homepage
http://journeytoforever.org/

Handmade Projects
Journey to Forever

tolerant motor -- it won't like it but you probably won't wreck it. Otherwise, it's not wise.

To do it properly and safely you'll need what amounts to a proper SVO system with at least fuel pre-heating. (See next.) In which case there's no need for mixes, you can just use 100% SVO.

Blends of SVO with various solvents, such as mineral turpentine (white spirit), or with various "secret" ingredients, such as naphthalene (mothballs) and xylol (paint-stripper), or with unleaded gasoline, are experimental at best -- little or nothing is known about the effects of these additives on the combustion characteristics of the fuel or their long-term effects on the engine. Not recommended -- use such blends at your own risk.

Higher viscosity is not the only problem with using vegetable oil as fuel. Veg-oil has different chemical properties and combustion characteristics from the petro-diesel fuel that diesel engines and their fuel systems are designed to use. Diesel engines, especially the more modern, cleaner-burning diesels, are high-tech machines with precise fuel requirements (see **The TDI-SVO controversy**). They're tough, but they'll only take so much abuse.

There's no guarantee of it, but using a blend of up to 20% veg-oil of good quality with 80% petro-diesel is said to be safe enough for older diesels, especially in summer. Otherwise using vegetable oil as fuel requires a professional SVO solution -- or convert the veg-oil biodiesel.

Mixes and blends are generally a poor compromise. But mixes can have an advantage in cold weather: as with biodiesel, some winterised petro-diesel mixed with straight vegetable oil lowers the temperature at which the SVO starts to gel. (See **Using biodiesel in winter**)

More about fuel mixing and blends.

2. Straight vegetable oil

Straight vegetable oil fuel (SVO) systems can be a clean, effective and economical option.

Unlike biodiesel, which runs in any diesel without modification, you have to modify the engine to use SVO. The best way is to fit a professional single-tank SVO system with replacement injectors and glowplugs optimised for vegetable oil, as well as fuel heating. With the Elsbett single-tank SVO system you can use petro-diesel, biodiesel or SVO, in any combination. Just start up and go, stop and switch off

like any other car. Journey to Forever's Toyota TownAce van has an Elsbett single-tank SVO system.

There are also two-tank SVO systems which pre-heat the oil to make it thinner. You have to start the engine on ordinary petro-diesel (or biodiesel) in one tank and then switch to SVO in the other tank when the veg-oil is hot enough (i.e. thin enough), and switch back again to the petro-diesel tank before you stop the engine, or you'll coke up the injectors.

Much more information on straight vegetable oil systems **here**.

3. Biodiesel or SVO?

Biodiesel has some clear advantages over SVO:

- It works in any diesel, without any conversion or modifications to the engine or the fuel system -- just put it in and go.
- It also has better cold-weather properties than SVO (but not as good as petro-diesel -- see **Using biodiesel in winter**).
- Unlike SVO, it's backed by many long-term tests in many countries, including millions of miles on the road.

Biodiesel is a clean, safe, ready-to-use, alternative fuel, whereas it's fair to say that many SVO systems are still experimental and need further development.

On the other hand, biodiesel can be more expensive, depending on how much you make, what you make it from and whether you're comparing it with new oil or used oil. And unlike SVO, it has to be processed first.

But the large and rapidly growing worldwide band of biodiesel homebrewers don't mind that -- they make a supply every week or once a month and they soon get used to it. Many have been doing it for years.

Anyway you have to process SVO too, especially WVO (waste vegetable oil, also called UCO, used cooking oil), which many people with SVO systems use because it's cheap or free for the taking. With WVO, food particles and impurities and water must be removed, and it probably should be deacidified too.

Biodieselers say, "If I'm going to have to do all that I might as well make biodiesel instead." But SVO types scoff at that -- it's much less processing than making biodiesel, they say.

To each his own.

	Needs processing	Guaranteed trouble-free	Engine conversion	Cost
Biodiesel	Yes	Yes*	No	Smaller outlay
SVO/ WVO	Less	No	Yes	Cheaper in the long-run
* Fuel filters might need changing in the first couple of weeks; fuel hoses or seals on some older diesels might need changing. See **Biodiesel and your vehicle**				

Costs and prices: Most people in the US use about 500 gallons of fuel a year (about 10 gallons a week), costing about US$1,200 a year at the fuel pump (December 2008 prices).

Petro-diesel costs at least twice as much in the other industrialised countries (in the UK in December 2008 it cost the equivalent of US $5.74 for a US gallon of petro-diesel), but drivers in those countries generally use less fuel than drivers in the US do.

Biodiesel homebrewers using waste vegetable oil as feedstock make biodiesel for 50 cents to US$1 per US gallon, so their 500 gallons a year costs them $250-500, while a good processing system can be set up for around $100 and up.

An SVO system costs from about $500 to $1,200 or more. So, if the vegetable oil is free, with an SVO system you'll probably be saving on fossil-fuel prices within a year, not a long time in the life of a diesel engine. But you'll probably still be saving less than the biodieselers.

Will the engine last as long with SVO? Yes, if you use a good system. Recommendations, and much more, **here**.

Biodiesel

Converting vegetable oil to biodiesel is probably the best all-round solution (or we think so anyway).

You could simply buy your biodiesel. Most major European vehicle manufacturers now provide vehicle warranties covering the use of pure biodiesel -- though that might not be just any biodiesel. Some

manufacturers insist on "RME", rapeseed methyl esters, and won't cover the use of soy biodiesel, because soy biodiesel fails the EU biodiesel standard, EN 14214.

Germany has thousands of filling stations supplying biodiesel, and it's cheaper there than petro-diesel fuel. All fossil diesel fuel sold in France contains between 2% and 5% biodiesel. EU laws will require this throughout Europe. Some states in the US now have similar requirements. The number of biodiesel suppliers in the US is growing and sales are rising fast. In the UK biodiesel is available and it's taxed less than petro-diesel.

However, there's a lot to be said for the GREAT feeling of independence you'll get from making your own fuel.

If you want to make it yourself, there are **good recipes** available for making top-quality biodiesel, and they say what we also say: some of these chemicals are dangerous, take full **safety** precautions. If you burn/maim/blind/kill yourself or anyone else, that will make us truly sad, but not liable -- it's nobody's responsibility but your own.

On the other hand, nobody has yet burned, maimed, blinded or killed themselves or anyone else making homebrewed biodiesel. Large numbers of ordinary people all over the world are making their own biodiesel, it's been going on for years, and so far there have been NO serious accidents. It's safe if you're careful and sensible.

"Sensible" also means not over-reacting, as some people do: "I'd like to make biodiesel but I'm frightened of all those terrible poisons." In fact they're common enough household chemicals. Lye is sold in supermarkets and hardware stores as a drain-cleaner, there's a can of it under the kitchen sink in most households. Methanol is the main or only ingredient in barbecue fuel or fondue fuel, used at the dinner table, and often sold at supermarkets and chain stores as "stove fuel"; it's also the main ingredient in the fuel boys use in their model aero engines.

So get it in perspective, there's no need to be frightened.

See **Safety** and **More about methanol** for details.

Learn as much as you can first -- lots of information is available, right here -- keep reading! -- and at **other websites**.

Where do I start?

Start with the **process**, **NOT** with the processor. The processor comes later.

Start with **fresh unused oil**, **NOT** with waste vegetable oil (WVO), that also comes later.

Start by making a small, 1-litre test batch of biodiesel using fresh new oil. You can use a spare blender, or, better, make a simple **Test-batch mini-processor**.

Keep going, step by step. Study everything on this page and the next page and at the links in the text. There are checks and tests along the way so you won't go wrong.

Once you've mastered small test batches with new oil that pass the quality control checks provided, you'll learn how to make test batches with used oil (WVO) that also pass the quality checks.

Then you'll be ready to move up to production of full-sized batches of top-quality fuel.

Get some methanol, some lye and some new oil at the supermarket and go ahead -- it's a real thrill!

What's next?

Learn, one step at a time. It's all quite simple really, very few biodiesel homebrewers are chemists or technicians, there's nothing a layman can't understand, and do, and do it well. But there is quite a lot to learn.

You'll find everything you need to know right here. It's not just us who say so, it's largely the result of a collaborative effort over 10 years involving thousands of people worldwide -- it's what works.

We've made it as easy for you as possible. You start off with the simplest process that has the best chance of success and move on step by step in a logical progression, adding more advanced features as you go.

This way you'll get a "feel" for the process -- you'll soon be making your own fuel, and you'll be able to do your own trouble-shooting (and you'll have much less trouble in the first place).

- "I am a pipe welder who knew nothing about chemistry but I have learned a lot from this website. It's set up for someone who has never had a chemistry class (me). If I can understand

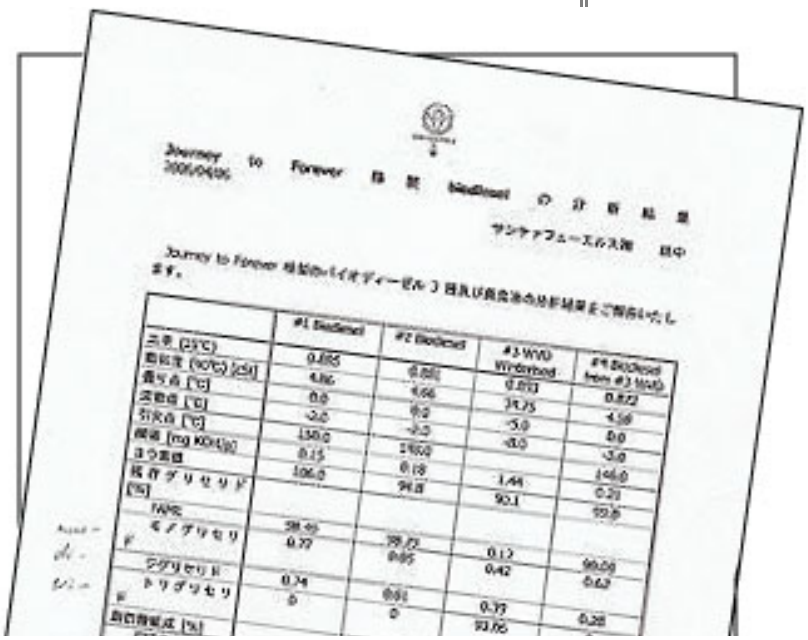
this anyone can." -- Marty, Biofuel mailing list

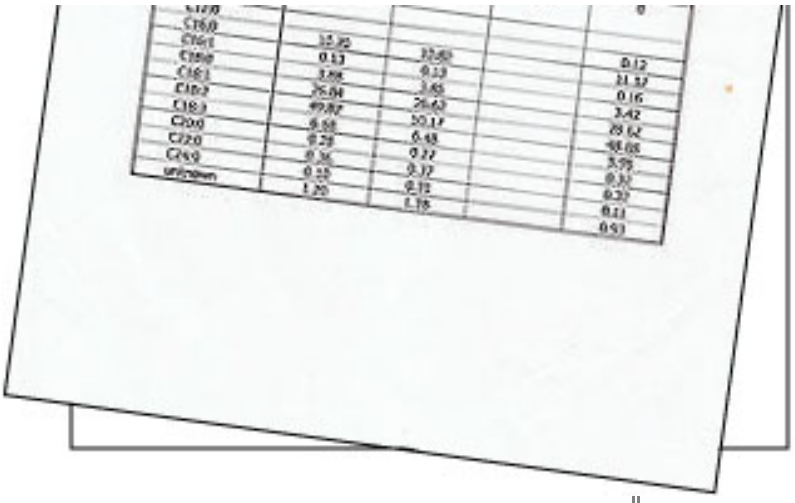
- "For anyone starting out or still in the R&D phase of scaling up and tweaking the process to improve quality, disregard anything other than the tried and tested directions at Journey to Forever. Print them out. Read them and then re-read them. Follow the instructions, don't add or subtract anything and you will be making quality biodiesel." -- Tom, Biofuel mailing list

- "My best advice is to follow explicitly the instructions at the Journey to Forever website starting from the beginning and you will do just fine. In my own journey of discovery I learned this. You cannot afford to cut corners. Don't be tempted to use less than accurate measures and think that it will be alright. There is no cheating." -- Joe, Biofuel mailing list

- "I started producing biodiesel with much help from Mr Addison's excellent website Journey to Forever, and cut my teeth in bio from information harvested there. I am now producing and distributing to other local contractors like myself approximately 3,000 gallons of B100 per week and am very happy with our switch to biofuel. I figure I have replaced over the last couple of years over 100 thousand gallons of petroleum diesel with biodiesel derived from waste cooking oil collected in New England and New York City. Just wanted to share that with you all." -- Kelly, Biofuel mailing list

Top quality





We had biodiesel we made in our 90-litre processor tested with a Gas Chromatograph at the chemistry department lab at a technical university in Tokyo. GC tests cost thousands, but we got it for nothing via a biofuels company we were helping. This was ordinary, production-run biodiesel from several different batches. The lab used the EU biodiesel quality standard, EN 14214, which is tougher than the US standard and is the de facto world standard. All our samples passed the minimum standards by a good margin: completion (the most important one) ranged from 98.49 to 99.09%, against the EN 14214 requirement of minimum 96.5%. The comment on the lab's report sheet was "Very clean biodiesel!" The cleanest they'd seen, they said – how did we make such good biodiesel from WVO? You can do it too – it's proof that the step-by-step instructions you'll find here and Journey to Forever's backyard brewers' cheapo kitchen-sink quality tests will indeed guide you to a top-quality product that will make any diesel engine happy, and keep it that way.

Thousands of ordinary people have done this without any other help, and so can you. You don't need anyone to show you how, and you don't need to find another biodieseler in your area first so you can see their set-up in action. Not all biodiesel brewers are the same, not all make quality fuel (though they might think they do). There's a fair chance you'd just be picking up someone else's bad habits.

Comment from a visitor to our site: "We got hold of two gentlemen who are running seminars on making biodiesel. Neither of them is

making quality biodiesel, in fact they are teaching everyone else how to make poor-quality biodiesel. One didn't even know what the methanol test was. It is certainly a poor picture of what's going on with biodiesel here..."

It's not unusual.

Do it yourself, you'll be just fine.

NOTE: This is a standard World Wide Web document, which means it's hyperlinked. This is how it works (comment from a Biofuel list member):

- "Your website is very well done. I appreciate the layers of technical complexity. You have progressively more technical information layered in an escalating and logical fashion. I like the links as each new item is introduced, the user can click for more specific information on a topic and it opens in a new window. This eliminates the tediousness of having to constantly backtrack to where the new concept was introduced."

Close the new window when you're finished with it and you're back where you were. Keep going.

The process

Biodiesel is made from vegetable and animal oils and fats, or **triglycerides**. Biodiesel cannot be made from any other kinds of oil (such as used engine oil).

Chemically, triglycerides consist of three long-chain fatty acid molecules joined by a glycerine molecule. The biodiesel process uses a catalyst (lye) to break off the glycerine molecule and combine each of the three fatty-acid chains with a molecule of methanol, creating mono-alkyl esters, or Fatty Acid Methyl Esters (FAME) -- biodiesel. The glycerine sinks to the bottom and is removed.

The process is called transesterification. See **How the process works**

Chemicals needed

Some basic information on the chemicals you'll be using. The quantities required and full instructions for use follow.

For beginners starting out with small, 1-litre test batches it's best to buy top-quality chemicals from a chemicals supplies company

buy top-quality chemicals from a chemicals supplies company!

The unit costs might seem quite high, but since you'll only be needing small amounts at first it's worth the price to eliminate the risk and confusion of poor-quality chemicals spoiling your results.

Once you've mastered the process and you're ready to move up to full-scale batches, then it's time to find cheaper sources of chemicals in bulk.

The **alcohol** used can be either methanol, which makes methyl esters, or ethanol (ethyl esters). Methanol can be made from biomass, such as wood, but nearly all methanol is made from natural gas, which is a fossil fuel. There is as yet no "backyard" method of producing methanol, it's an industrial process.

Most ethanol is plant-based (though some is also made from petroleum), and **you can make it yourself**. But making biodiesel with ethanol is much more difficult than making it with methanol -- ethanol biodiesel is not for beginners. (See **Ethyl esters**.)

Ethanol (or ethyl alcohol, grain alcohol -- EtOH, C2H5OH) also goes by various other well-known names, such as whisky, vodka, gin, and so on, while methanol is a poison. Actually they're both poisons, it's just a matter of degree, methanol is more poisonous.

Don't be put off -- methanol is not dangerous if you're careful, it's easy to do this safely. Safety is built-in to everything you'll read here. See **Safety**. See **More about methanol**.

Methanol is also called methyl alcohol, wood alcohol, wood naphtha, wood spirits, methyl hydrate (or "stove fuel"), carbinol, colonial spirits, Columbian spirits, Manhattan spirits, methylol, methyl hydroxide, hydroxymethane, monohydroxymethane, pyroxylic spirit, or MeOH (CH3OH or CH4O) -- all the same thing. (But, confusingly, "methylcarbinol" or "methyl carbinol" is used for both methanol and ethanol.)

Methanol must be 99+% pure.

You can usually get methanol from bulk liquid fuels distributors; in the US try getting it at race tracks. It's also sold as a solvent by paint companies. With a bit of patience, most people in most countries manage to track down a source of methanol for about US$2-3 per US gallon.

For test batches, some suppliers sell small quantities as well as bulk

For test batches, some suppliers sell small quantities as well as bulk, try chemicals suppliers. **Duda's Alternative Energy Store** supplies pure methanol in small quantities "for getting started", and in 55-gal drums, buy online: http://dudadiesel.com/

"DriGas" fuel antifreeze can also be used for test batches, one type is pure methanol (eg "HEET" in the yellow container), another type is isopropyl alcohol (isopropanol, rubbing alcohol), make sure to get the methanol one.

Methanol is also sold in some supermarkets and chain stores as "stove fuel" for barbecues and fondues, but check the contents -- not all "stove fuel" is methanol, it could also be "white gas", which is basically gasoline. It must be pure methanol or it won't work for making biodiesel. See **Methanol suppliers**

Methylated spirits (denatured ethanol) doesn't work; isopropanol also doesn't work.

The **lye** catalyst can be either potassium hydroxide (KOH) or sodium hydroxide (caustic soda, NaOH).

Both KOH and NaOH are *hygroscopic*, which means they rapidly absorb moisture from the atmosphere. Water makes them less effective catalysts: always keep lye containers sealed and airtight.

Either KOH or NaOH can be used in all of the various biodiesel methods, whether it's the basic single-stage base method, the two-stage base-base method, or the two-stage acid-base method.

NaOH is cheaper to use.

KOH is easier to use, and it does a better job -- KOH is a better catalyst all-round than NaOH. Experienced biodieselers making top-quality fuel use KOH, and so do the commercial producers. (KOH can also provide potash fertiliser as a by-product of the biodiesel process.)

We recommend KOH, especially for beginners.

With KOH, the process is the same as with NaOH, but you need to use 1.4 times as much (1.4025), and it comes in various concentrations -- see **More about lye** and **Using KOH**.

You can get high-quality KOH and NaOH from **Duda's Alternative Energy Store**, buy online: http://dudadiesel.com/. Also from soapmakers' suppliers and from chemicals suppliers.

NaOH is used as a drain-cleaner and you can also get it from hardware stores. It has to be pure NaOH. Shake the container to check it hasn't absorbed moisture and coagulated into a useless mass, and make sure to keep it airtight.

The Red Devil-brand NaOH lye drain-cleaner previously sold in the US is no longer made. Don't use Drano or ZEP drain-cleaners or equivalents with blue or purple granules or any-coloured granules, it's only about half NaOH and it contains aluminium -- it won't work for biodiesel.

With used oil, titration with NaOH to check the acid content has become the de-facto comparative measure of different oils -- whether they use NaOH or KOH in their processing, when describing oils most biodiesel brewers refer to however many millilitres of NaOH solution it needed to titrate the oil.

CAUTION:
Lye (both NaOH and KOH) is extremely caustic -- don't get it on your skin or in your eyes, don't breathe any fumes, keep the whole process away from food, and right away from children. Lye reacts with aluminium, tin and zinc. Use HDPE (High-Density Polyethylene), glass, enamel or stainless steel containers for methoxide. (See **Identifying plastics**.) See **Safety**

See also **Making lye from wood ash**.

Which oil is best?

For beginners making their first test batches with **new, unused oil**, the best oils to use are rapeseed oil or canola oil (canola is a variety of rapeseed developed in Canada), corn oil, soy oil, sunflower oil.

Avoid peanut oil -- biodiesel made from peanut oil is summer fuel, it can start to crystallise and gel at 60 deg F (15.5 deg C), and it can give strange results in the quality-control checks, which are a crucial part of learning how to make biodiesel.

Palm oil, coconut oil, tallow and lard are also summer fuels, with high melting points: they start to gel and set at quite high temperatures. Biodiesel usually has a lower melting point (or "cloud point") than the oil it's made from, but if your weather is cool, avoid these oils and fats, at least for your first test batches.

Olive oil, peanut oil, palm oil, tallow, lard, can all contain more acids than the standard amount for refined edible oils (less than 0.1%), and

extra acid interferes with the biodiesel process. For your first test batches you need oil with the standard acid content, so avoid these oils too.

Most commercial cooking oils contain additives, usually preservatives such as TBHQ (Tertiary Butyl Hydroquinone) or citric acid, and silicone (dimethylpolysiloxane), an anti-foaming agent. These additives are not a concern, they have no effect on the biodiesel process or the quality of the fuel.

If you can't find any of the recommended oils, try the most commonly used cooking oil in your area (refined oil, not raw oil straight from the press). Most likely it'll be fine.

Once you've mastered small test batches with new oil that pass the quality control checks provided, you'll learn how to make test batches of **used oil** (WVO) that also pass the quality checks.

Once you've made successful test-batches with a variety of used oils, you'll be ready to move up to production of full-sized batches of top-quality fuel, and you'll know how to deal with the peculiarities of different kinds of oil.

Make your first test batch

Here's what you need:

- 
- AMW-100 Digital Scale, 100 grams, 0.01-gram accuracy -- Buy from Amazon.com
- 1 litre of new vegetable oil, fresh, uncooked (see **Which oil is best?**, above)
- 200 ml of methanol, 99+% pure
- lye catalyst, either potassium hydroxide (KOH) or sodium hydroxide (NaOH) can be used, but we recommend KOH,

especially for beginners -- KOH is easier to use and it gives better results
- blender or preferably a mini-processor
- scales accurate to 0.1 grams, preferably less -- 0.01 grams is best
- measuring beakers for methanol and oil
- half-litre translucent white HDPE (#2 plastic) container with bung and screw-on cap
- 2 funnels to fit the HDPE container, one for methanol, the other for lye
- 2-litre PET bottle (water or soft-drinks bottle) for settling
- two 2-litre PET bottles for washing
- duct tape
- thermometer

See **Accurate measurements**

All equipment should be clean and dry.

Buy top-quality methanol and lye from a chemicals supplies company or laboratory supplies company; high-quality lye can also be bought from soapmakers' suppliers. Unit costs from these sources might be quite high, but since you'll only be needing small amounts at first it's worth the price to eliminate the risk and confusion of poor-quality chemicals spoiling your results. **Duda's Alternative Energy Store** supplies top-quality chemicals at low prices, buy online: http://dudadiesel.com/

1. Safety

Read and observe the **Safety** instructions below.

2. Lye

You need to be quick when measuring out the lye because it rapidly absorbs water from the atmosphere and water interferes with the biodiesel reaction.

Measure the lye out into a handy-sized lightweight plastic bag on the scales (or even do the whole thing entirely inside a big clear plastic bag), then close the lid of the container firmly and close the plastic bag, winding it up so there's not much air in it with the lye and no more air can get in. Have exactly the same kind of bag on the other side of the scale to balance the weight, or adjust the scale for the weight of the bag.

How much to use. NaOH must be at least 97% pure, use exactly

3.5 grams.

With KOH it depends on the strength. If it's 99% pure (rare) use exactly 4.9 grams (4.90875). If it's 92% pure (more common) use 5.3 grams (5.33), with 90% pure use 5.5 grams (5.454), with 85% pure use 5.8 grams (5.775). Any strength of KOH from 85% or stronger will work.

3. Mixing the methoxide

Use the "**Methoxide the easy way**" method -- it's also the safe way. Here's how to do it.

Measure out 200 ml of methanol and pour it into the half-litre HDPE container via the funnel. Methanol also absorbs water from the atmosphere so do it quickly and replace the lid of the methanol container tightly. Don't be too frightened of methanol, if you're working at ordinary room temperature you won't be exposed to dangerous fumes. See **More about methanol**.

Carefully add the lye to the HDPE container via the second funnel. Replace the bung and screw on the cap tightly.

Shake the container a few times -- swirl it round rather than shaking it up and down. The mixture gets hot from the reaction. If you swirl it thoroughly for a minute or so five or six times over a period of time the lye will completely dissolve in the methanol, forming sodium methoxide or potassium methoxide. As soon as the liquid is clear with no undissolved particles you can begin the process.

The more you swirl the container the faster the lye will dissolve. With NaOH it can take from overnight to a few hours to as little as half-an-hour with lots of swirling (but don't be impatient, wait for ALL the lye to dissolve). Mixing KOH is much faster, it dissolves in the methanol more easily than NaOH and can be ready for use in 10 minutes, with five or six shakes it takes about half an hour.

4. The process

Using a blender. Use a spare blender you don't need or get a cheap second-hand one -- cheap because it might not last very long, but it will get you going until you build something better.

Check that the blender seals are in good order. Make sure all parts of the blender are clean and dry and that the blender components are tightly fitted.

Pre-heat the oil to 55 deg C (130 deg F) and pour it into the blender.

With the blender still switched off, carefully pour the prepared methoxide from the HDPE container into the oil.

Secure the blender lid tightly and switch on. Lower speeds should be enough. Mix for 20-30 minutes, or longer.

Using a mini-processor. Follow the instructions here and improvise where necessary -- there are many ways of building a processor like this.

Proceed with processing as above, maintain temperature at 55 deg C (130 deg F), process for one hour or longer.

5. Transfer

As soon as the process is completed, pour the mixture from the blender or the mini-processor into the 2-litre PET bottle for settling and screw on the lid tightly. (As the mixture cools it will contract and you might have to let some more air into the bottle later.)

6. Settling

Freshly made biodiesel, 20 minutes after processing

Allow to settle for 12-24 hours (longer is better).

Darker-coloured glycerine by-product will collect in a distinct layer at the bottom of the bottle, with a clear line of separation from the paler liquid above, which is the biodiesel. The biodiesel varies somewhat in colour according to the oil used (and so does the by-product layer at the bottom) but usually it's pale and yellowish (used-oil biodiesel can be darker and more amber). The biodiesel might be quite clear or it might still be cloudy, which is not a problem. It will clear eventually but there's no need to wait.

After settling, carefully decant the top layer of biodiesel into a clean jar or PET bottle, taking care not to get any of the glycerine layer mixed up with the biodiesel. If you do, re-settle and try again.

7. Quality

Proceed to the wash-test and the methanol test to check the quality of your biodiesel.

If the biodiesel doesn't pass the tests, first, don't be despondent! If your test sample "split" and the glycerine formed at the bottom, you have already succeeded in making biodiesel.

It often takes several attempts to pass the quality tests. For instance, different blenders and mini-processors have different shapes and different rates of agitation, and the processing time required for good process completion can vary accordingly. You might have to adjust it.

More likely you just need a little more practice, especially with

accurate measurements. Make sure the chemicals you're using are top-quality. Make sure you followed the instructions exactly.

Here's what to do if your test batch fails the tests.

8. Washing

If the test sample passes the quality tests then wash the rest of the biodiesel. See **Washing**. For washing use the two 2-litre PET bottles in succession, with half a litre of tap water added for each of the three or four washes required. Pierce a small 2mm hole in the bottom corner of each of the two bottles and cover the hole securely with duct tape.

Pour the biodiesel into one of the wash bottles. Add the half-litre of fresh water.

Stir-washing. See instructions here. If you have a small enough paint stirrer and a variable-speed drill, cut the threaded lids off the wash bottles to accommodate the stirrer. Stir until oil and water are well mixed and appear homogenous. Settle for three hours or more. Then drain off the water from the bottom of the bottle by removing the duct tape from the hole. Block it again with your finger when it reaches the biodiesel. Transfer the biodiesel to the second wash bottle, add fresh water and wash again. Clean the first bottle and replace the duct tape. Repeat until finished.

If you don't have a stirrer, don't cut the lids off the wash bottles. Add the biodiesel and the water as above. Screw the cap on tightly. Turn the bottle on its side and roll it about with your hands until oil and water are well mixed and homogenous. Settle, drain as above, repeat until finished.

9. Drying

When it's clear (not colourless but translucent) it's dry and ready to use. It might clear quickly, or it might take a few days. If you're in a hurry, heat it gently to 48 deg C (120 deg F) and allow to cool -- this evaporates the remaining water, so let it ventilate.

10. Congratulations! You have just made high-quality diesel fuel. Say goodbye to ExxonMobil & Co., you don't need them anymore.

Read on!

Next step

Our first biodiesel

This was just an investigative project for us when we made our first biodiesel more than seven years ago in Hong Kong. Most of the equipment was rough and improvised. Apart from chemicals and some beakers, syringes and so on, the only thing we bought was a set of scales.

We got some sodium lye draincleaner from a hardware store and about 60 litres of used cooking oil from Lantau Island's local McDonald's. There were four 16-litre cans of it, a mix of used cooking oil and residual beef and chicken fats. Two of the tins were solidified, the other two held a gloppy semi-liquid. We warmed it up a bit on the stove (to about 50 deg C, 122 deg F) and filtered it through a fine mesh filter, and then again through coffee filter papers, but it was fairly clean -- very little food residue was left in the filters.

Used cooking oil from McDonald's.

We'd also bought 10 litres of the cheapest new cooking oil we could find -- we don't know what kind of oil it was, the tins only said "Cooking Oil" -- and we used this for our first experiment.

It worked, though two of our first six batches failed. We've learnt a lot

since then. Now it's easy to make high-quality biodiesel every time without fail. And we don't use open containers for processing now, and neither should you (see **Safety**, see **Processors**) -- and mix the methanol in closed containers too.

Simple, safe, efficient biodiesel processors you can build cheaply and easily

Practices, knowledge, technology, equipment and safety measures have all improved tremendously in the years since we brewed our first batch, thanks mainly to the collaborative work of thousands of biofuellers worldwide at the Biofuel mailing list discussion group and other Internet forums, using the growing body of information at our website and others.

As a Biofuel list member said in 2002: "I just want to say how important what you all are doing here is. Closed-system fuel production, on a local or small regional scale, tied to local resources, using accessible technologies, and dependent on entrepreneurial innovation combined with open-source information exchange -- it's AWESOME. Keep up the good work everyone, before the planet fries."

Biodiesel from new oil

Make your first test-batch using one litre of new oil (fresh, uncooked). Follow the instructions above. Check the quality of your biodiesel with these **quality tests**.

We had difficulty finding pure methanol in Hong Kong, and eventually paid the very high price of US$10 per litre for 5 litres from a wholesale chemical supply company. It has to be 99% pure or better. (See **Methanol suppliers**)

We used sodium lye drain-cleaner (NaOH, sodium hydroxide) bought in small plastic containers at a local hardware store, not always very fresh. (We recommend using potassium hydroxide, KOH, instead of NaOH. See **More about lye**.)

We used 2 litres of methanol to 10 litres of vegetable oil, and 3.5 grams of NaOH per litre of oil -- 35 grams for 10 litres. (It's better to start with smaller one-litre test batches.)

We had to be quick measuring out the 35 grams of lye required. Lye is very hygroscopic, it absorbs moisture from the air; summer humidity in Hong Kong is usually about 80% at 30 deg C or more, and the lye rapidly got wet, making it less effective. (See **More about lye**.)

We mixed the lye with the 2 litres of methanol in a strong, heatproof glass bottle with a narrow neck to prevent splashing. It fumed and got hot, and took about 15 minutes to mix. (*Use **closed** containers for mixing methoxide!* See above, **Mixing the methoxide**.)

This mixture is sodium methoxide, a powerful corrosive base -- take full safety precautions when working with sodium methoxide, have a source of running water handy, along with a bottle of vinegar -- quench any splashes on the skin with vinegar, thern rinse thoroughly with running water.

Midori checks the temperature of the oil

Midori checks the temperature of the oil.

Meanwhile we'd warmed the 10 litres of new oil in a 20-litre steel oil drum to about 40 deg C (104 deg F) to thin it so it mixed better (55 deg C, 131 deg F, is a better processing temperature). Don't let it get too hot or the methanol will evaporate. (Methanol boils at 64.7 deg C, 148.5 deg F.)

We'd made a wooden jig with a portable vice clamped to it holding a power drill fitted with a paint mixer to stir the contents of the oil drum. This did a good job without splashing. (Not advised, it's dangerous to use sparking electric motors such as those in drills for processing with open containers. See "**Simple 5-gallon processor**" for a much better way.)

Stirring well, we carefully added the sodium methoxide to the oil. The reaction started immediately, the mixture rapidly transforming into a clear, golden liquid. We kept stirring for an hour, keeping the temperature constant. Then we let it settle overnight.

The next day we syphoned off 10 litres of biodiesel, leaving two litres of glycerine by-product in the bottom of the drum.

Biodiesel from waste oil

Chemicals for processing waste oil

Isopropanol (isopropyl alcohol, rubbing alcohol) used for titration (see below) is available from chemicals suppliers. Some people have used the other kind of DriGas, which is isopropanol, but they found that it's unreliable. 70% pure isopropanol is also said to work, but we found it didn't give satisfactory results. Best get 99% pure isopropanol from a chemicals supplier. **Duda's Alternative Energy Store** provides 99%+ pure isopropanol by the litre, buy online: http://dudadiesel.com/

Contrary to rumour, "phenol red", sold by pool supply stores, won't work for titrating WVO, its pH range isn't broad enough. Use **phenolphthalein** indicator, specifically 1% phenolphthalein solution (1.0 w/v %) with 95% ethanol. Phenolphthalein lasts about a year. It's sensitive to light, store it in a cool, dark place. You can get it from chemicals suppliers. Better, **Duda's Alternative Energy Store** sells phenolphthalein in convenient 18 ml dropper bottles, enough for about 180 titrations, buy online: http://dudadiesel.com/

See: **Phenolphthalein**

The process

Waste oil is more appealing than using new oil, but it's also more complicated.

First, check for water content. Used oil often has some water in it, and it has to be removed before processing. See **Removing the water**, below.

Then, check the acid content, by titration.

Refined fats and oils have a Free Fatty Acid (FFA) content of less than 0.1%. Used oil has more FFA, sometimes much more. FFAs are formed in cooking the oil, the longer and hotter the oil has been cooked the more FFAs it will contain. FFAs interfere with the transesterification process for making biodiesel. With waste oil you have to use more lye to neutralise the FFAs. The extra lye turns the FFAs into soap which drops out of the reaction along with the glycerine by-product.

Judging by appearances

By appearance, best to worst, left to right

Titration results, left to right: 2.2 ml, 29.5 ml, 1.7 ml, 0.9 ml, 13 ml

Best to worst by titration, left to right -- not what you'd expect just by looking. The longer oil is cooked and the higher the temperature, the poorer the quality will be, but the colour of used

poorer the quality will be, but the colour of used oil also depends on the food that's been cooked in it -- soy sauce and other sauces, sugar, food colourings can all make the oil darker, without affecting the quality and the FFA content.

It's essential to titrate the oil to find out how much FFA it contains so you can calculate exactly how much extra lye will be required to neutralise it.

This means determining the pH -- the acid-alkaline level (pH7 is neutral, lower than 7 is increasingly acidic, higher than 7 is increasingly alkaline). Use an electronic **pH meter** or **phenolphthalein** solution (from a chemicals supplier). pH test strips are less accurate than pH meters or phenolphthalein.

You can also use red cabbage juice, which changes from red in a strong acid, to pink, purple, blue, and finally green in a strong alkali, or one of the other plant-based pH indicators. See **Natural test papers** -- Cabbage, Turmeric, Brazil, Dahlia, Elderberry, Indigo, Litmus, Rose, Rhubarb.

Most people use a pH meter or phenolphthalein solution, and that's what we recommend.

We used phenolphthalein solution when we started making biodiesel in 1999. Phenolphthalein is colourless up to pH 8.3, then it turns pink (or rather magenta), and red at pH 10.4. When it just starts to turn pink and stays that way for 15 seconds it's reading pH 8.5, which is the measure you want.

Phenolphthalein lasts about a year. It's sensitive to light, store it in a cool, dark place.

Duda's Alternative Energy Store supplies phenolphthalein solution in convenient 18 ml dropper bottles, enough for about 180 titrations, buy online: http://dudadiesel.com/

Duda's also supplies a **WVO Titration Kit**, which includes a variety of syringes, beakers, all the titration chemicals and gloves: http://dudadiesel.com/

Don't be put off or frightened away by titration. It's not difficult, thousands of non-chemist biodiesel makers have learnt how to do it without difficulty and use it every time they make biodiesel. Just follow the directions, step by step. See also:

- **More about lye**
- **Basic titration**

- **Better titration**
- **Using KOH**
- **Joe Street's titrator**
- **Accurate measurements**

Titration

Keith checks the pH of the waste oil.

Dissolve 1 gm of lye (KOH or NaOH) in 1 litre of distilled water to make 0.1% w/v lye solution (weight-to-volume).

In a smaller beaker, dissolve 1 ml of the oil to be tested in 10 ml of pure isopropyl alcohol (isopropanol).

Warm the beaker gently by standing it in some hot water, stir until all the oil dissolves in the alcohol and turns clear. (Wooden chopsticks make good stirrers for titration.)

Add 2 drops of phenolphthalein solution.

Using a graduated syringe or a pipette, add 0.1% lye solution drop by drop to the oil-alcohol-phenolphthalein mixture, stirring all the time. It might turn a bit cloudy, keep stirring. Keep on carefully adding the lye solution until the mixture just starts to turn pink (magenta) and stays that way for 15 seconds.

Take the number of millilitres of 0.1% lye solution you used and add the basic amount of lye needed to process fresh oil -- 3.5 grams for NaOH or 4.9 grams for (pure) KOH. This is the number of grams of lye you'll need per litre of the oil you titrated. (Don't worry that you seem to be adding millilitres to grams, that's the way it works.)

Our first titration took 6 ml of 0.1% NaOH solution (not very good oil), so we used 6 + 3.5 = 9.5 grams of NaOH per litre of oil.

NOTE: Beginners should avoid poor-quality oil like this for their first test-batches with used oil.

Find a source of oil that titrates at about 2.5 ml of 0.1% NaOH solution or less, not more than 3.5 ml. Leave overcooked oils with higher titration levels for later when you have more experience.

Try to get a selection of used oils from different restaurants -- if you're friendly and polite and tell them what it's for they usually won't mind giving you a couple of litres. Find out what kind of oil they use. (This might not be the best time to suggest collecting large amounts of oil for full-scale production, leave that for later, unless they suggest it first.)

Start by titrating the samples. Use low-titration oil for your first used oil test batches, move on to higher titration levels and different kinds of oil as you gain experience.

If you have difficulties at first, it could be due to the kind of oil you're using -- see above, **Which oil is best?**

If not, then see **What should you do if your fuel doesn't pass the wash-test?** and **How to use the quality tests**, as with new oil.

Test batches with used oil

Make small, one-litre test batches. Use the same procedure as with new oil, see **above**.

Measure out the lye and mix it with the methanol to make sodium methoxide or potassium methoxide -- it will get slightly hotter and take a little longer to mix as there's more lye this time. Make sure the lye is completely dissolved in the methanol. (See above, **Mixing the methoxide**.)

Carefully add the methoxide to the warmed oil while stirring, and mix for an hour. Settle for 12-24 hours, then syphon off or decant the biodiesel.

Check the quality of your biodiesel with these **quality tests**.

The first five times we did this, using 10 litres of waste oil each time, we got biodiesel (a bit darker than the new oil product) and glycerine three times, and twice we got **jelly**.

The answer is to be more careful with the titration: do it two or three times at first, until you've had more practice and perfected your technique.

With poor-quality oils that have high titration levels do bracket tests as

well. Do everything you can to improve the accuracy of your measurements so you get consistent results.

Read on, and you'll learn how to make high-quality biodiesel every time, without fail. (It's a LONG time since we made jelly!)

The production rate with our first batches was less than with new oil, ending with 8-9 litres of biodiesel instead of 10. With care and experience the production rate improves.

Moving on to bigger things

When you're confident that you can get good results every time, even using oil from different sources, then it's time to scale up the process to provide your fuel needs. Now that you have a feel for the process and know what to expect, you'll have a much better idea of what sort of processor you want than if you'd started off building the processor (as many do) rather than learning the process first.

- "Understanding of the process is vital to operate the plant." -- Prof. P.V. Pannir Selvam, Technology Center, Department of Chemical Engineering, Universidade Federal do Rio Grande do Norte (UFRN), Brazil, Biofuel mailing list, 15 Apr 2007

See **Biodiesel processors**.

However, one-litre test batches are not just something for beginners. It's a basic technique you'll always use. Many experienced biodiesel makers do test batches with each batch of oil. Many not only titrate the oil every time to calculate the right amount of lye to use, they also do "bracket" tests in sequence, followed by wash tests. You learn a lot that way, your fuel gets better, life gets easier.

In fact life is already easier -- people who start off making 40-gallon batches often never learn the accuracy and discipline that comes from making one-litre test batches first. Their fuel quality suffers for it, and when they encounter that inevitable "problem batch", they suffer for it too.

But if you've followed the instructions here carefully, you'll be familiar with all the variables, you'll have good methodology, and you'll be in a much better position to trouble-shoot a problem batch successfully.

Keep a Biodiesel Journal -- make notes, keep records. Get some small glass jars and keep samples of all your batches, clearly labelled and cross-referenced to the notes in your journal. You won't regret it.

When scaling up from small test-batches to a full-sized processor, be aware that the process will probably need some adjusting. All the various processing methods use averages and approximations because processors and conditions vary so widely. Blenders especially agitate much faster than any full-scale processor, a real processor will probably take longer to achieve the same result. Use the fuel quality tests to fine-tune the process to your particular processor. See **Scaling up**.

Removing the water

Water in the oil interferes with the lye catalyst, especially if you use too much lye, and you can end up with a batch of jelly.

Test first for water content -- heat half a litre or so of the oil in a saucepan on the stove and monitor the temperature with a thermometer. If there's water in it it will start to "snap, crackle and pop" by 50 deg C (120 deg F) or so. If it's still not crackling by 60-65 deg C (140-149 deg F) there should be no need to dewater it.

See Mike Pelly's recommendations: **Removing the water**.

Here's another way, from **Aleks Kac** -- it uses less energy and doesn't risk forming more Free Fatty Acids (see below) by overheating. Heat the oil to 60 deg C (140 deg F), maintain the temperature for 15 minutes and then pour the oil into a settling tank. Let it settle for at least 24 hours (or for a week or two). Pump the oil out from the top, leave the bottom 90% for removal later and re-settling.

Here's what Biofuel mailing list member **Dale Scroggins** says about water removal:

- Water in vegetable oil can exist as free water, which will eventually settle to the bottom of a vessel; as suspended droplets, which may settle if the oil is heated, or the droplets are coalesced; and as water in solution with other impurities in the oil. Free water is the easiest to remove. The droplets are removed most efficiently by coalescing and draining. Suspended droplets that cannot be coalesced and water in solution are more problematic.

  Boiling off the water is more difficult than it appears on the surface. Colligative properties of solutions (and some mixtures) can make removal of the last traces of water almost impossible. Water mixed with oil will not boil at the same

temperature and pressure as pure water. As water is removed, more heat or lower pressure will be required to remove more water. If the oil contains salts or semi-soluble fatty acids, distillation is even more difficult.

As the percentage of water in the solution decreases (its molar fraction) its vapor pressure will continue to drop. Lowering pressure in the system alone may be insufficient to sustain vaporization when the solution becomes concentrated (the molar fraction of the solute greatly exceeds that of the solvent). Results will vary depending upon the nature of the water-soluble impurities in the oil. Few solutions are ideal, in terms of Raoult's law, and in used vegetable oil, there is no way to know what solutes are in the oil.

The important thing is how well-used, or overused, the oil is. Titration will tell you that. The higher the titration result and the more acidic the oil, the more water it's likely to contain, and the more difficult it will probably be to remove the water.

Biofuel list member **Joe Street** adds:

- Although Dale's points about unknown solutes in waste vegetable oil and their ability to lock up water are true I have found that practically speaking oil (even terrible oil) can be reliably dried to the point of being reacted without problems by the process of heat and vacuum.

  Heating the oil to reaction temperature (I use 58 deg C, 136 deg F) and pulling a vacuum to 27 inches of mercury immediately before the reaction has allowed me to remove water beyond what falls out by heating alone.

  I estimate that oil at 55-60 deg C can contain as much as 10,000 PPM (that's 1%) water. I have experimented with some extremely saturated oils (titrations up to 11 ml with 0.1% KOH) which require ridiculous amounts of catalyst when attempting base-only conversions. Although I cannot get complete conversions in these cases, drying the oil by heating and vacuum has allowed me to do this and still avoid problems with soap formation. (I am also very careful with my caustic and methanol.) Using a known temperature and a vacuum gauge is a very repeatable way of drying oil.

  (See: Joe Street's processor)

Short of vacuum, start with heating the oil to 60 deg C and settling it,

as Aleks Kac recommends, and if that doesn't give satisfactory results, try boiling the water off, as Mike Pelly recommends. Then try a small 1-litre test batch first.

If you still have difficulties, try to find a source of better-quality oil.

Or try using a glycerine pre-wash to lower the Free Fatty Acid level and dry the oil (see below, Glycerine pre-wash).

Or try this: Deacidifying WVO.

Filtering WVO

Many people filter their WVO before making biodiesel, but filtering takes time and energy, and there's really no need to filter it.

Settling the oil works just as well or better, and if it contains any water the water will settle out too.

If it's poor quality oil with a high titration level, heat it first, as in de-watering (above), and then let it settle.

If you don't have time to wait for the oil to settle, usually 1-2 weeks, it could be worth increasing the WVO supply and reserves to make the time.

- If in collection you keep ahead of your processing rate, oil has a chance to settle. I have found that oil that has been sitting for several weeks is very dry if carefully decanted. Settling also results usually in oil which is spectacularly clear when observed in a glass container (you can read fine print through it) which means it is quite clean, perhaps cleaner than filtering may give you.
  -- **Joe Street**, Biofuel mailing list, July 2006
  I recently helped someone get off the ground making biodiesel. He's a tinkerer, and came up with an elaborate filtering/ dewatering system. I repeatedly suggested that he trust gravity. He was away for about 10 days and when he came back he called to tell me that he couldn't distinguish the oil from the top half of an unfiltered cubie from his filtered oil. Getting rid of his filtering setup has made room for a settling tank.
  -- **Tom Kelly**, Biofuel mailing list, April 2006

This is how Tom does it:

- I allow the WVO to settle in cubies for a week. (A cubie is the

4.5 gal (17.7L) plastic container that veg oil is delivered to restaurants in.) I then pour the top 80% of each cubie into a 55 gal drum and consolidate the bottom 20% of 5 cubies into 1. Most of this will be ready for the barrel the next week. I have 4 WVO barrels. One is settled, two are settling, and one is being filled. I pump WVO out of the settled barrel from the top 3/4. This oil is very clear and requires very little drying.

We do it much the same way, settling the WVO first in the 18-litre metal cans it's supplied in here, then pouring it from the top. What's left at the bottom is re-settled.

We use a 55-gal (200-litre) steel drum for storage, but we don't pump the WVO out from the top. The drum has a bottom drain fitted with a 6"-high 3/4" standpipe (15cm-high x 1.9cm), which leaves any sediment on the bottom of the drum undisturbed.

Every now and then we drain the drum to the top of the standpipe, then remove the standpipe and drain the drum completely, sediment and all. The "bottoms" are resettled the same way, first in 18-litre metal cans.

The final sediment can be used as fire-starter, or added to the compost pile.

Simple gravity settling works well with oils titrating up to 3.5 ml NaOH solution and more.

The higher the titration level, the more water, impurities and suspensions the oil is likely to contain and the longer it will take to settle. For higher titration levels, heat the oil to 60 deg C (140 deg F), maintain the temperature for 15 minutes, then allow to cool, and let it settle.

Filtering biodiesel

There's no need to filter your biodiesel before using it either.

If you make the biodiesel properly, everything that a filter might remove will be in the by-product layer, not the biodiesel.

- The biodiesel should be ready for instant consumption if it's clear and bright and without sediments.
  -- **Jan Warnqvist**, Biofuel mailing list, Aug 2005

If the WVO has been filtered or settled to clear, any solid particles that

get as far as the processor are small and won't affect the processing. During processing and settling, all unfiltered solids drop out into the glycerine by-product layer.

Settle it properly, separate the by-product carefully, wash, dry, and use. No need to filter it.

Badly processed biodiesel with poor conversion and too much soap might contain sediments in suspension, but if it's properly made it will be without sediments. Keep your processing fine-tuned by making test batches and using the quality tests.

People often want to "speed up" the process in the hopes of making it more efficient, and that often means taking short-cuts with settling times.

Don't do it -- life is easier with longer settling times, for the WVO, for the by-product to separate after processing, and for the wash-water to separate, especially after the final wash.

Actually what people speeding up the process usually want isn't more efficiency, it's more production. Probably they need a bigger processor, or two processors in parallel, rather than trying to make gravity hurry. Extra washing and settling tanks also help.

Centrifuges

We don't have much time for centrifuges either, for similar reasons.

Again, people want to "speed up" the process by using a centrifuge instead of settling (or instead of washing, in some cases).

We've had a number of reports that centrifuges give poor results compared with normal settling, and especially compared with washing -- washing centrifuged fuel has yielded very soapy wash-water, so obviously the centrifuging didn't work very well.

We have laboratory test results of "finished" biodiesel made here in Japan in a $70,000 commercial processor. The finished fuel was washed and dried, and then it was centrifuged, and then samples were sent to the lab for testing. But the centrifuged fuel didn't come close to the standards requirements.

Our biodiesel surpasses the standards requirements though, made in a $100 homebuilt processor, with no need for a centrifuge.

You don't need a centrifuge. As with filtering, if you want more production get a bigger processor, or run two processors in parallel, add more settling and washing tanks.

Glycerine pre-wash

From Biofuel mailing list member **Chris Tan**: "Good use for your glycerine cocktail", 6 Oct 2007:

- Here's a good use for your glycerine cocktail before finally giving it away. My father came up with the idea that you can use the glycerine cocktail to dry your waste vegetable oil. And it works. Glycerine is hygroscopic enough to pull moisture out as it settles down so you don't have to heat or boil the oil to dry it. And as a bonus, most of the catalyst ends up in the glycerine cocktail so it neutralizes the Free Fatty Acids (FFAs) in the waste oil.

  What we do is use at least 10/90 weight ratio: 10kg of glycerine for 90kg of waste oil. It is possible to bring the FFA level to zero if you use large amounts of glycerine (if you happen to have accumulated large amounts).

  We use an ordinary 1/2 hp clear water pump with two inlet pipes to suck in glycerine and wvo. I adjust the inlet openings to regulate the mixing. We let it settle in a dedicated separate tank for about the same time as you would settle glycerine from biodiesel, though longer is better because of the viscosity of wvo.

  We pump both glycerine cocktail and oil at the same time into a separate container. The glycerine will flow at a lower rate and the the inlet opening should be adjusted so that it finishes at the same time as the oil.

  You can also mix it in the processor (just make sure to drain the water-rich glycerine and soap residue afterwards). Cycle the glycerine cocktail and oil mixture twice. The time it takes will depend on the gallons per minute rate of your pump, which is not the same for viscous oil, so measure and compute the time required for one or two cycles.

  If the weather is cold, warming the oil first helps for mixing as well as settling: pre-heat to about 30 deg C (86 deg F).

  -- Chris Tan

Washing

Biodiesel must be washed before use to remove soaps, excess methanol, residual lye, free glycerine and other contaminants. Some people (fewer and fewer of them) say washing isn't necessary, arguing that the small amounts of contaminants cause no engine damage.

Read what the **Fuel Injection Equipment (FIE) Manufacturers** (Delphi, Stanadyne, Denso, Bosch) have to say about these contaminants:
Summary -- html
Full document -- Acrobat file, 104kb

See also: **Determining the Influence of Contaminants on Biodiesel Properties**, Jon H. Van Gerpen et al., Iowa State University, July 31, 1996 -- 12,000-word report on contaminants and their effects. Acrobat file, 2.1Mb:
http://www.biodiesel.org/resources/reportsdatabase/reports/gen/gen014.pdf

Myth:

- > I did notice that a lot of the chemistry in the book was wrong.
  > His main argument seemed to be against losing the energy in
  > the methanol that was washed out.

  The "energy" does you no good if your particular thermodynamic cycle can't take advantage of it. What is the cetane rating of methanol?
  -- Ken Provost, Biofuel mailing list, "Re: washing?"

Quite so. The cetane rating of methanol is only 3, very low. Low cetane-number fuel in a diesel causes ignition delay and makes the engine knock. The high-speed diesel engines in cars and trucks are designed to use fuels with cetane numbers of about 50. The US biodiesel standard specifies a cetane number higher than 47, the EU standard specifies higher than 51. The methanol in unwashed biodiesel doesn't "make a great fuel anyway". It's also very corrosive. The EU biodiesel standard specifies less than 0.2% methanol content.

Quality biodiesel is well-washed biodiesel. Filtering it is no use, and letting it settle for a few weeks won't help much either. Anyway washing the fuel is easy.

See **Washing**

Using biodiesel

You don't have to convert the engine to run it on biodiesel, but you might need to make some adjustments and you should check a few things.

Petroleum diesel leaves a lot of dirt in the tank and the fuel system. Biodiesel is a good solvent -- it tends to free the dirt and clean it out. Be sure to check the fuel filters regularly at first. Start off with a new fuel filter.

If a car has been left standing for a long time with petroleum diesel fuel in the tank the inside of the tank may have rusted (water content is a common problem with petro-diesel fuel). Biodiesel will free up the rust, and it could clog the particle filter inside the tank. At worst the car simply stops, starved of fuel. It's not a very common problem, but it happens. See: **Biodiesel and your vehicle -- Compatability: Filters**.

A common warning is that biodiesel, especially 100% biodiesel, will rot any natural or butyl rubber parts in the fuel system, whether fuel lines or injector pump seals, and that they must first be replaced with resistant parts made of Viton. But rubber parts in diesel engine fuel systems have been rare or non-existent since the early 1980s -- it seldom happens, and when it does happen it's not catastrophic, you have plenty of warning and it's easily fixed. See: **Biodiesel and your vehicle -- Compatability: Rubber**.

See **Biodiesel and your vehicle**

Safety

Please read this whole section right to the end.

Wear proper protective gloves, apron, and eye protection and do not inhale any vapours. Methanol can cause blindness and death. Sodium hydroxide and potassium hydroxide can cause severe burns and death. Mixed with methanol they form methoxide. This is an extremely caustic chemical.

These are dangerous chemicals -- treat them with respect! Gloves should be chemical-proof with cuffs that can be pulled up over long sleeves -- no shorts or sandals. Always have running water handy. Have a bottle of vinegar handy to neutralise any lye or methoxide you may get on your skin -- rinse it off with vinegar, then rinse thoroughly

with water. (If you don't have any vinegar handy, just use lots of water.) The workspace must be thoroughly ventilated. No children or pets allowed.

Organic vapor cartridge respirators are more or less useless against methanol vapors. Professional advice is not to use organic vapor cartridges for longer than a few hours maximum, or not to use them at all. Only a supplied-air system will do (SCBA -- Self-Contained Breathing Apparatus).

The best advice is not to expose yourself to the fumes in the first place. The main danger is when the methanol is hot -- when it's cold or at "room temperature" it fumes very little if at all and it's easily avoided, just keep it at arm's length whenever you open the container. Don't use "open" reactors -- **biodiesel processors** should be closed to the atmosphere, with no fumes escaping. All methanol containers should be kept tightly closed anyway to prevent water absorption from the air.

We transfer methanol from its container to the methoxide mixing container by pumping it, with no exposure. This is easily arranged, and an ordinary small aquarium air-pump will do. The methoxide is mixed like this -- **Methoxide the easy way**, which also happens to be the safe way. The mixture gets quite hot at first, but the container is kept closed and no fumes escape. When mixed, the methoxide is again pumped into the (closed) biodiesel processor with the aquarium air-pump -- there's no exposure to fumes, and it's added slowly, which is optimal for the process and also for safety. See **Adding the methoxide**.

Once again, making biodiesel is safe if you're careful and sensible -- nothing about life is safe if you're not careful and sensible! "Sensible" also mean not over-reacting, as some people do: "I'd like to make biodiesel but I'm frightened of all those terrible poisons." In fact they're common enough household chemicals. Lye is sold in supermarkets and hardware stores as a drain-cleaner, there's probably a can of it under the sink in most households. Methanol is the main or only ingredient in barbecue fuel or fondue fuel, sold in supermarkets and chain stores as "stove fuel" and used at the dinner table. It's also the main ingredient in the fuel kids use in their model aero engines. So get it in perspective: be careful with these chemicals -- be careful with ALL chemicals -- but there's no need to be frightened of them.

For fire risks, see **Hazards**

More about methanol

Question: Just how dangerous is methanol?

Fact: Methanol is a poisonous chemical that can blind you or kill you, and as well as drinking it you can absorb it through the skin and breathe in the fumes.

Question: How much does it take to kill you?

Short answer: Anything from five teaspoons to more than half a pint, but nobody really knows.

Fact: Human susceptibility to the acute effects of methanol intoxication is extremely variable. The minimum dose of methanol causing permanent visual defects is unknown. The lethal dose of methanol for humans is not known for certain. The minimum lethal dose of methanol in the absence of medical treatment is put at between 0.3 and 1 g/kg.

That means it's thought to take at least 20 grams of methanol to kill an average-sized person, or 25 ml, five teaspoonsful. Or it might need more than three times as much, 66 grams, 17 teaspoonsful, or maybe more, and even then it'll only kill you if you can't reach a doctor within a day or two, and maybe it still won't kill you.

But it definitely can kill you. If you drink five teaspoonsful of pure methanol you'll need medical treatment even if it doesn't kill you. Yet people have survived doses of 10 times as much -- a quarter of a litre, half a pint -- without any permanent harm. But others haven't survived much lower doses. Getting rapid medical attention is crucial, though the poisoning effects can be slow to develop.

Authorities advise that swallowing up to 1.3 grams or 1.7 ml of methanol or inhaling methanol vapour concentrations below 200 ppm should be harmless for most people. No severe effects have been reported in humans of methanol vapour exposures well above 200 ppm.

Out of 1,601 methanol poisonings reported in the US in 1987 the death rate was 0.375%, or 1 in 267 cases. It might have been only 1 in more than a thousand cases because most cases weren't reported. Most cases were caused by drinking badly made moonshine, which is a worldwide problem.

Fiction: "Methanol is ... a very active chemical against which the human body has no means of defence. It is absorbed easily through the skin and there is no means of elimination from the body, so levels

of methanol dissolved in the blood accumulate."

That's from a British website trying to sell Straight Vegetable Oil (SVO) solvent additives by frightening people with the alleged perils of biodiesel. See **The SVO vs biodiesel argument**

Fact: 30 litres of fruit juice will probably contain up to 20 grams of methanol, near the official minimum lethal dose. Methanol is in the food we eat, in fresh fruit and vegetables, beer and wine, diet drinks, artificial sweeteners.

Not only that, methanol occurs naturally in humans. It's a natural component of blood, urine, saliva and the air you breathe *out*. It's there anyway even if you've never been exposed to chemical methanol or its fumes.

Methanol is eliminated from the body as a normal matter of course via the urine and exhaled air and by metabolism. Getting rid of it takes from a few hours for low doses to a day or two for higher doses. Some proportion of a dose of methanol just goes straight through, excreted by the lungs and kidneys unchanged. The normal background-level quantities of methanol in humans are eliminated and replenished all the time as a matter of course.

Fiction: It's largely biodiesel's methanol content that's being blamed when the same British SVO website charges that biodiesel is wasteful and environmentally irresponsible.

Fact: Methanol is readily biodegradable in the environment under both aerobic and anaerobic conditions (with and without oxygen) in a wide variety of conditions.

Generally 80% of methanol in sewage systems is biodegraded within 5 days.

Methanol is a normal growth substrate for many soil microorganisms, which completely degrade methanol to carbon dioxide and water.

Methanol is of low toxicity to aquatic and terrestrial organisms and it is not bioaccumulated. (It's toxic mainly to humans and monkeys.)

Environmental effects due to exposure to methanol are unlikely. Unless released in high concentrations, methanol would not be expected to persist or bioaccumulate in the environment. Low levels of release would not be expected to result in adverse environmental effects.

Fiction: A European SVO fuel website using similar anti-biodiesel tactics claims: "Biodiesel is a chemically altered plant oil. However the process to chemically change the structure of Pure Plant Oil is a very costly operation and requires a lot of energy, as it removes the glycerine substituting it by methanol as well as adding other chemicals, making the end-product poisonous and equally hazardous as fossil diesel fuel."

Fact: There is no free methanol in washed biodiesel. All the national standards require washing. According to US EPA studies methyl esters biodiesel is less toxic than table salt and more biodegradable than sugar. It has none of the toxic or environmental hazards of fossil diesel fuel.

To put it all in some perspective, methanol is the main or only ingredient in barbecue fuel or fondue fuel, sold in supermarkets and chain stores as "stove fuel" and used at the dinner table. It's also the main ingredient in the fuel kids use in their model aero engines.

Yes, methanol is a dangerous chemical, but quite how dangerous it may be is a little hard to say, and it causes surprisingly little harm. If you're careful and sensible and treat it with caution it won't harm you either. Many thousands of biodiesel homebrewers worldwide have been using it for years without serious mishap.

In our view, the difference between methanol and the really dangerous chemicals is that although methanol is poisonous, it's a natural chemical, you'd find it in the Garden of Eden too. It's not something nature's simply never heard of before and has no way of handling and neither do you, unlike too many of the 100,000-odd "new" chemicals now in use which aren't readily biodegradable and do accumulate, and spread, and keep being implicated in cancer clusters and bizarre sexual distortions of frogs and so on and on and on.

There are no reports of carcinogenic, genotoxic, reproductive or developmental effects in humans due to methanol exposure. Its environmental effects if any are minimal and short-lived.

Biodieselers can and do use methanol safely and the biodiesel fuel we make from it is safe and clean.

-- With information from: **United Nations Environment**

with information from: **United Nations Environment Programme / International Labour Organisation / World Health Organization: International Programme On Chemical Safety, Environmental Health Criteria 196 - Methanol**, from IPCS INCHEM, "Chemical Safety Information from Intergovernmental Organizations", in cooperation with the Canadian Centre for Occupational Health and Safety (CCOHS)
http://www.inchem.org/documents/ehc/ehc/ehc196.htm

See also:

Safety (MSDS) data for methyl alcohol
http://ptcl.chem.ox.ac.uk/MSDS/ME/methyl_alcohol.html

Methanol MSDS
http://www.jtbaker.com/msds/englishhtml/M2015.htm

Methanol as a plant nutrient

"Methanol is a fixed-carbon nutrient source for plants." -- From "Agriculture and Methanol", Chapter 7, *Methanol Production and Use*, ed. Wu-Hsun Cheng and Harold H. Kung, ISBN 0-8247-9223-8, 1994 (10th printing)

- "Methanol treatments of C3 plants [most food crops] have been found to result in growth improvement... As a plant source of carbon, methanol is a liquid concentrate: 1 cc of methanol provides the equivalent fixed-carbon substrate of over 2,000,000 cc of ambient air... Methanol treatments are a means of placing carbon directly into the foliage... The application of 10-100% methanol to some crops increased photosynthetic productivity... The uptake of methanol by plants in light leaves no significant residual methanol above baseline as detectable by chromotography within 15-30 minutes of penetration. Treatment with methanol is therefore an inexpensive, safe, and effective means of providing plants with a source of fixed carbon and carbon dioxide... An economical means of inhibition of photorespiration has been sought for decades, and methanol may well provide the solution... The control of photorespiration across the food crops of the world could double yields." -- Greg Harbican and Peter G., Biofuel mailing list, 8 Sep 2004. For discussion see:
  http://snipurl.com/j94f
  Methanol and Plants
  http://snipurl.com/j94e
  Use for wash water - methanol

Use for wash water - methanol

Note however that the authors of *Methanol Production and Use* caution that the application of methanol to crops still requires further study before we all "rush out to spray methanol".

Most of the excess methanol used in the biodiesel process ends up in the glycerine by-product layer, and should be reclaimed for re-use. The rest stays in the biodiesel and is washed out when you wash the fuel, mostly with the first wash. Reclaiming it costs more energy than it's worth -- the first wash-water probably won't contain more than 5-6% methanol (as well as a little sodium or potassium and some soap). You could try spraying it on half a small patch of weeds and don't spray the other half to see what happens. Choose a bright sunny day.

Next: **Make your own biodiesel -- Page 2**

Biofuels

Biodiesel

Make your own biodiesel

Ethanol