



Make your own biodiesel

Anybody can make biodiesel. It's easy, you can make it in your kitchen -- and it's BETTER than the petro-diesel fuel the big 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 oil it's not only cheap but you'll be recycling a troublesome waste product. Best of all is the GREAT feeling of freedom, independence and empowerment it will give you. Here's how to do it -- everything you need to know.

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Three choices

There are at least three ways to run a diesel engine on bio-power, using vegetable oils, animal fats or both. All three work with both fresh and used oils.

- Use the oil just as it is -- usually called SVO fuel (straight vegetable oil);
- Mix it with kerosene (paraffin) or with biodiesel;
- 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

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

Most people use a mix of up to 30% kerosene and 70% vegetable oil, some use 50/50 mixes. Some people just use it that way, others say it needs at least pre-heating and probably a two-tank system too, like SVO (see below), and we agree with that. The same goes for mixes with vegetable oil and biodiesel -- usually 50/50. In both cases, you might get away with just using it with an older Mercedes 5-cylinder IDI diesel, which is a very tough and tolerant motor. Otherwise, not wise.

So, to be safe, you're going to need what amounts to an SVO two-tank system with heating anyway, so you don't need the

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kerosene. If you're mixing SVO with biodiesel, you'll use very much less of it by using it in the second tank for start-ups and stops rather than mixing it 50/50. (See next.) Or just use 100% biodiesel and don't bother with two tanks and heating. (See after next.)

Mixes are a poor compromise. But they do have advantages in cold weather. Some kerosene or #1 diesel mixed with biodiesel lowers the temperature at which it starts to gel, and a 50/50 mix with biodiesel will do the same for an SVO system.

2. Straight vegetable oil

With SVO you have to start the engine on ordinary petrodiesel or biodiesel to warm it up, then switch to the straight vegetable oil, and switch back to petro- or biodiesel before you stop the engine. If you don't do that you'll coke up the engine and the injectors. This means having two fuel tanks -- no simple matter with diesels, which have airtight fuel systems. Using SVO also means pre-heating the oil or it'll be too viscous (thick).

But there's a lot to be said for straight vegetable oil systems -- running on straight vegetable oil while starting up and shutting down on biodiesel can be a clean, effective and economical option.

More information on straight vegetable oil systems [here](#).

3. Biodiesel

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). And, 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 SVO systems are still experimental and need further development.

On the other hand, biodiesel can be more expensive, depending what you make it from and whether you're comparing it with

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Rubber

Pure biodiesel will eventually devour any natural or butyl rubber parts in the fuel system (hoses and seals). Check with the vehicle manufacturer and replace the parts with resistant synthetic parts (such as Viton B). See [Durability of plastics](#) table. Newer motors don't use rubber. See also [Biodiesel and your vehicle](#).

new or used oil (and where you live). And, unlike SVO, it has to be processed -- you have to make it. But the large and rapidly growing worldwide band of homebrewers don't seem to mind -- they make a supply every week or once a month and soon get used to it. Many have been doing it for years.

And anyway, you have to process SVO too, especially WVO (waste vegetable oil, used, cooked), which many people with SVO systems use because it's cheap or free for the taking. WVO has to be filtered and dewatered, and probably should be deacidified, and SVO should probably also be deacidified.

Biodieselers say, "Well, if I'm going to have to do all that I might just 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	Cheaper
Biodiesel	Yes	Yes	No	Sometimes
SVO/WVO	Less	No	Yes	Usually

Costs and prices: Biodieselers using waste oil feedstock say they can make biodiesel for 60 cents US per gallon or less. Most people use about 600 gallons of fuel a year (about 10 gallons a week) -- say US\$360 a year. An SVO system costs from \$300 to \$1,200 or more. So with an SVO system you'll be ahead in a year or two, which is not a long time in the life of a diesel motor. But will it last as long with SVO? Too soon to tell. Probably, if you use a good system. Recommendations, and much more, [here](#).

Biodiesel

Converting the oil to biodiesel is probably the best of the three options (or we think so anyway).

You could simply [buy](#) your biodiesel instead. Most major European vehicle manufacturers now provide vehicle warranties covering the use of pure biodiesel -- though that might not be just *any* biodiesel. Some insist on "RME", rapeseed methyl

Conversions

1 US gallon = 0.83

Imperial gallons = 3.78
litres

1 acre = 0.405 hectares

1 lb = 0.454 kilograms

1 US bushel = 35.24 litres

esters, and won't cover soy biodiesel in the US, but this seems to be more a trade-related issue than a quality-control one. Germany has more than 1,500 filling stations supplying biodiesel, and it's cheaper than ordinary diesel fuel. It's widely used in France, the world's largest producer. Virtually all fossil diesel fuel sold in France contains between 2% and 5% biodiesel. New EU laws will soon require this Europe-wide. Some states in the US are legislating similar requirements. There's a growing number of US suppliers. Biodiesel is more expensive than ordinary diesel in the US but sales are rising very fast and prices will drop in time. In the UK biodiesel is to be taxed less than petrodiesel and it's already available commercially.

But there's a lot to be said for the GREAT feeling of independence you'll get from making your own fuel (and it's more than just a feeling -- it's real!).

If you want to make it yourself, there are [several good recipes](#) available for making high-quality biodiesel, and they all say what we also say: some of these chemicals are dangerous, take full safety precautions, and if you burn/maim/blind/kill yourself or anyone else, that will make us very sad, but not liable -- we don't recommend anything, it's nobody's responsibility but your own.

On the other hand, a lot of people are doing it -- it's safe enough if you're careful and sensible. Learn as much as you can first -- [lots of information](#) is available. Make small [test batches](#) before you try large batches. Make it with [fresh oil](#) before you try waste oil.

CAUTION:

Wear proper protective gloves, apron, and eye protection and do not inhale any vapors. Methanol can cause blindness and death, and you don't even have to drink it, it's absorbed through the skin. Sodium hydroxide can cause severe burns and death. Together these two chemicals form sodium methoxide. This is an extremely caustic chemical. Wear a mask and full body covering for safety, that means chemical-proof gloves with cuffs that can be pulled up over long sleeves -- no shorts or sandals. These are dangerous chemicals -- treat them as such! Always have a hose running when working with them. The workspace

must be thoroughly ventilated. No children or pets allowed.

Where do I start?

Start here: make a test batch of biodiesel using 1 litre of fresh new oil in a blender. If you don't have a spare blender, either get one (you can pick them up quite cheap second-hand), or try [this](#).

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

[Here's](#) the recipe, just use 1 litre of oil instead of 10 litres, and 200 ml of methanol instead of 2 litres, with 3.5 grams of lye.

[Here's](#) how to use a blender, and [here's](#) how to mix the sodium methoxide -- "Methoxide the easy way".

What's next?

Learn. You have some decisions to make. It's all quite simple really, thousands of people are doing it, very few of them are chemists or technicians, and there's nothing a layman can't understand, and do, and do it well. But there is quite a lot to learn. You should find everything you need to know right here. We've tried to make it easy for you.

First, here's how we started.

The process

Vegetable oils and animal fats are triglycerides, containing 7-13% glycerine. The biodiesel process turns the oils into esters, separating out the glycerine. The glycerine sinks to the bottom and the biodiesel floats on top and can be syphoned off.



"Cooking" biodiesel on the kitchen stove.

The process is called transesterification, which substitutes

alcohol for the glycerine in a chemical reaction, using lye as a catalyst.

We use methanol to make methyl esters. We'd rather use ethanol because most methanol comes from fossil fuels (though it can also be made from biomass, such as wood), while ethanol is plant-based and [you can distill it yourself](#), but the biodiesel process is more complicated with ethanol. (See [Ethyl esters](#).)

Ethanol also goes by various other names, such as whisky, vodka, gin, and so on, but methanol is a deadly poison: first it blinds you, then it kills you, and it doesn't take much of it. It takes a couple of hours, and if you can get treatment fast enough you might survive.

The catalyst can be either sodium hydroxide (caustic soda, NaOH) or potassium hydroxide (KOH), which can provide a potash fertilizer as a by-product, but sodium hydroxide is easier to get and it's cheaper. If you use potassium hydroxide, the process is the same, but you need to use 1.4 times as much. (See [More about lye](#).)

CAUTION:

Lye is dangerous -- 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 aluminum, tin and zinc. Use glass, enamel, stainless steel or HDPE (High-Density Polyethylene) containers. (See [Identifying plastics](#).)

See also [Making lye from wood ash](#).

Our first biodiesel

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

We got about 60 litres of used 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) and filtered it through a fine mesh filter, and then again through coffee filter papers, but it was quite clean -- very little food residue was left in the filters.

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 used this for our first experiment.



Used cooking oil from McDonald's.

Biodiesel from new oil

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 (198 proof) or better. (See [How much methanol?](#))

We used 2 litres of methanol to 10 litres of vegetable oil, and 3.5 grams of pure, granular lye (sodium hydroxide) per litre of oil. (See [More about lye.](#))

You can get lye at most hardware stores. Shake the container to check it hasn't absorbed moisture and coagulated into a useless mass, and make sure to keep it airtight.

We had to be quick measuring out the 35 grams of lye required -- 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.

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. See [Methoxide the easy way.](#)

This mixture is sodium methoxide, an extremely powerful base which enjoys eating stuff like human flesh -- take full safety precautions when working with sodium methoxide, have a source of running water handy.

Meanwhile we'd warmed the 10 litres of new oil in a steel bucket on the stove to about 40 deg C (104 deg F) to thin it so it mixed better. In fact, 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.)



Midori checks the temperature of the oil.

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 bucket. This did a good job without splashing.

Stirring well, we carefully added the sodium methoxide to the oil. The reaction started immediately, the mixture rapidly separating into a clear, golden liquid on top with the light brown glycerine settling out at the bottom. 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 in the bottom of the bucket.

Biodiesel from waste oil

This is more appealing than using new oil, but it's also more difficult.

First, get rid of the water content. Used oil usually has some water in it, and water in the oil will interfere with the lye, especially if you use too much lye, and you'll end up with a bucket of jelly. See [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. Make sure you never empty the settling vessel more than 90%.

Waste oil needs more catalyst than new oil to neutralize the Free Fatty Acids (FFAs) formed in cooking the oil, which interfere with the transesterification process.

You have to titrate the oil to determine the FFA content and how much lye will be required to neutralize it. This means determining the pH -- the acid-alkaline level (pH7 is neutral, lower values are increasingly acidic, higher than 7 is alkaline). An electronic pH meter is best, but you can also use pH test strips (or litmus paper), or phenolphthalein solution (from a chemicals supplier).

We also thought of using red cabbage juice, which changes from red in a strong acid, to pink, purple, blue, and finally green in a strong alkali (see [Natural test papers](#)). We didn't have a pH meter then so we used phenolphthalein solution. Phenolphthalein is colorless up to pH 8.3, then it turns pink (or rather magenta), and red at pH 10.4.

Dissolve 1 gm of lye in 1 litre of distilled water (0.1% lye solution). In a smaller beaker, dissolve 1 ml of the cooled oil in 10 ml of pure isopropyl alcohol. Warm the beaker gently by standing it in some hot water, stir until all the oil dissolves in the alcohol and turns clear. Add 2 drops of phenolphthalein solution.



Keith checks the pH of the waste oil.

Using a graduated syringe, add 0.1% lye solution drop by drop to the oil-alcohol-phenolphthalein solution, stirring all the time, until the solution stays pink for 10 seconds. Take the number of millilitres of 0.1% lye solution you used and add 3.5. This is the number of grams of lye you'll need per litre of oil. (See [Better](#)

titration.)

Our first titration took 6 ml, so we used $6 + 3.5 = 9.5$ grams of lye per litre of oil: 95 grams for 10 litres.

Then proceed as with new oil: measure out the lye and mix it with the methanol to make sodium methoxide -- it will get even hotter and take longer to mix, as there's more lye this time. Make sure the lye is completely dissolved in the methanol.

Carefully add the sodium methoxide to the warmed oil while stirring, and mix for an hour. Settle overnight, then syphon off the biodiesel.

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 twice, just to be sure.

The production rate was less than with new oil, ending with 8-9 litres of biodiesel instead of 10.

Washing

Biodiesel should be washed to remove soap, catalyst and other impurities. Some people insist on it, others don't and argue that the small amounts of impurities cause no engine damage.

We recommend washing it. Add water and stir, let the water settle to the bottom (which takes time), drain it off and measure the pH. Repeat until the pH measures 7. If this leaves the biodiesel looking a bit cloudy, that means there's still water in it. Heat it slowly to evaporate the water.

More on washing, including the Idaho bubble washing method: see [Washing -- Mike Pelly's method](#).

See also [Bubble washing](#)

Using biodiesel

You don't have to convert the engine to run it on biodiesel, but

you do need to make some adjustments and check a few things.

Retard the injection timing by 2-3 degrees -- this overcomes the effect of biodiesel's higher [cetane](#) number. It also causes the fuel to burn cooler, thus reducing [NOx emissions](#).

Petro-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.

Check there are no natural rubber parts in the fuel system. If there are, replace them. Viton is best. See "[Durability of Various Plastics](#)".

See [Biodiesel and your vehicle](#)

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How much methanol should you use?

The *stoichiometric* quantity of methanol is the amount needed to convert triclycerides (fats and oils) into esters (biodiesel) -- the "methyl" portion of methyl esters.

You also need an *excess* of methanol to push the conversion process towards completion -- without the excess the process runs out (reaches equilibrium) before all the triglycerides are converted to esters, resulting in poor fuel that doesn't combust well and can be corrosive.

The excess methanol acts more like a catalyst: it encourages the process but does not become a part of the final product and can be recovered afterwards.

Stoichiometric quantity

The stoichiometric quantity is usually said to be 12.5% methanol by volume -- that is, 125 millilitres of methanol per litre of oil. Some people put it at 13%, or 13.5%, or even as low as 8%.

In fact it depends on the amounts of the various fatty acids in the oil, and varies from one oil to another. Biofuel mailing list member Christian Lenoir figured it out, and here are the results. Christian provided the average proportions of the different fatty acids in each of the more common fats and oils, calculated their total molecular weights, and from this was able to calculate the stoichiometric amount of methanol required to convert them. The amount varies from 11.3% for rapeseed oil (canola) to 16.3% for coconut oil.

These figures are averages -- fatty acid quantities vary somewhat when oil crops are grown in different conditions in different parts of the world. But they're close enough for our purposes, and a lot more accurate than the general figure of 12.5%.

If you have an analysis of the fatty acid content of your oil, you can calculate the correct stoichiometric ratio from the figures provided in these tables.

Fats and oils	Fatty acids %							
	C4:0 Butyric	C6:0 Caproic	C8:0 Caprylic	C10:0 Capric	C12:0 Lauric	C14:0 Myristic	C16:0 Palmitic	C16:1 Palmitoleic
<i>Molecular wt.</i>	88	116	144	172	200	228	256	254
Tallow	-	-	-	-	0.2	3	27	2
Lard	-	-	-	-	-	1	26	2

Butter	3.5	1.5	-	2.5	3	11	30	3.5
Coconut	-	-	8	8	48	16	8.5	-
Palm kernel	-	-	3	5	48.5	17	7.5	0.5
Palm	-	-	-	-	-	3.5	39.5	-
Safflower	-	-	-	-	-	-	5.2	-
Peanut	-	-	-	-	-	0.5	7	1.5
Cottonseed	-	-	-	-	-	1.5	19	-
Maize	-	-	-	-	-	1	9	1.5
Olive	-	-	-	-	0.5	1	13	2
Sunflower	-	-	-	-	-	-	6	-
Soy	-	-	-	-	-	0.3	7.8	0.4
Rapeseed/Canola	-	-	-	-	-	-	3.5	0.2
Mustard	-	-	-	-	-	-	3	-
Cod liver oil	-	-	-	-	-	4	10	14.5
Linseed	-	-	-	-	-	0.2	6	-
Tung	-	-	-	-	-	-	-	-

Fats and oils (continued)	Fatty acids %						
	C18:0 Stearic	C18:1 Oleic	C18:2 Linoleic	C18:3 Linolenic	C20:0 C22:0 Arachydic - Behenic & others	Mono- unsaturated acids <C16:1	C20:1 C22:1 Arachidonic - Erucic & others
<i>Molecular wt.</i>	284	282	280	278	326	226	324
Tallow	24.1	40.7	2	-	0.7	-	0.3
Lard	13	45.2	10.3	-	-	-	2.5
Butter	12	26	3	-	1.65	1.5	0.85
Coconut	2.5	6.5	2	-	-	-	0.5
Palm kernel	2	14	1	-	1.5	-	-
Palm	3.5	46	7.5	-	-	-	-
Safflower	2.2	76.4	16.2	-	-	-	-
Peanut	4.5	52	27	-	7.5	-	-
Cottonseed	2	31	44	-	-	-	2.5
Maize	2.5	40	45	-	-	-	1
Olive	2	68	12	-	0.5	-	1

Sunflower	4.2	18.7	69.4	0.3	1.4	-	-
Soy	2.5	26	51	5	7	-	-
Rapeseed/Canola	2	13.5	17	7.5	0.9	-	56.3
Mustard	1.5	39.5	12	8	-	-	36
Cod liver oil	0.5	28	-	-	-	1	42
Linseed	5	17.3	16	55	0.5	-	-
Tung	-	8	12	80	-	-	-

Oils and fats	Total molecular weight	Density	Density @ 50°C	Volume oil (ml)	Volume methanol (ml)	Stoich. ratio methanol : oil %
Tallow	858.54	0.895	0.88	981.18	121.52	12.4
Lard	863.73	0.92*	0.9*	959.7*	121.52	12.7
Butter	797.64	0.91	0.89	896.73	121.52	13.6
Coconut	674.51	0.926	0.91	744.57	121.52	16.3
Palm kernel	704	0.912	0.89	789.33	121.52	15.4
Palm	847.28	0.923	0.9	938.29	121.52	13
Safflower	879.1	0.927	0.91	966.44	121.52	12.6
Peanut	885.02	0.919	0.9	984.45	121.52	12.3
Cottonseed	867.38	0.918	0.9	963.76	121.52	12.6
Maize	872.81	0.923	0.9	966.57	121.52	12.6
Olive	870.65	0.923	0.9	964.17	121.52	12.6
Sunflower	877.22	0.925	0.91	969.3	121.52	12.5
Soy	882.82	0.925	0.91	975.5	121.52	12.5
Rapeseed/Canola	959.04	0.914	0.89	1072.75	121.52	11.3
Mustard	925.43	0.916	0.9	1032.85	121.52	11.8
Cod liver oil	908.81	0.929	0.91	1000.34	121.52	12.1
Linseed	872.4	0.934	0.91	954.48	121.52	12.7
Tung	873.68	0.944	0.92	945.54	121.52	12.9
* Approximate						

Excess

Further arguments rage over how much excess is needed, with figures quoted claiming that *this* much will achieve 98% conversion but *that* much only 95% or less.

It depends on several different factors: the type of oil, its condition, the type, size and shape of the processor, the type and duration of agitation, the temperature of the process -- and it doesn't make much sense anyway if the stoichiometric ratio is wrong in the first place.

However, excess is usually between 60% and 100% of the stoichiometric amount. So if the stoichiometric ratio of the oil you're using is 12.5%, that is 125 ml of methanol per litre of oil, the excess would range between 75 ml and 125 ml, for a total amount of methanol of 200-250 ml per litre of oil.

Oils with higher stoichiometric ratios seem to need higher excesses. So, for fresh (virgin, uncooked) soy or canola, you can try 60%, though 67% or more would be better. For palm kernel or coconut, closer to 100% excess would be better. For tallow and lard, use higher excesses.

For used oil, WVO -- waste vegetable oil, as it's called, though it often contains animal fats from the cooking, use 67% minimum excess. For heavily used oils with high titration levels, use higher excesses, up to 100%.

If you don't know what kind of oil your WVO is, try using 25% methanol -- 250 ml methanol to 1 litre of oil. If you've taken care with the titration, used accurate measurements and followed the instructions carefully, you should get a good, clean "split", with esters on top and the glycerine and free fatty acids cleanly separated at the bottom. If you have trouble washing it, with a lot of frothing, that could be because the process didn't go far enough and unconverted material is forming emulsions -- try using more methanol next time. If everything works well, try using less methanol. You'll soon figure out what's best for you.

With the "[Foolproof](#)" acid-base two-stage method, don't worry about it, just follow the instructions.

Ethyl esters

The same principles apply for making ethyl esters instead of methyl esters, using ethanol rather than methanol -- with some differences. Use 1.4 times more ethanol than methanol. It won't work if there's any water in the ethanol or the oil. It works much better with some methanol added, up to 3:1 ethanol:methanol. Virgin oil is better -- with waste oil (WVO) it won't work with FFA content much more than 1ml by titration. Experiment -- there's more information here: [Ethyl-esters biodiesel](#). Please let us know your results.

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More about lye

The catalyst used in transesterification of vegetable or animal fats and oils is lye -- either sodium hydroxide (NaOH, caustic soda), or potassium hydroxide (KOH).

Lye is hygroscopic -- it absorbs water from the atmosphere. So make sure you get fresh lye, and keep the container tightly sealed.

When weighing it out, don't leave it exposed to the air too long.

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In humid weather we weigh it out into plastic bags, one on either side of the scale to equalise the extra weight of the bag. As soon as it's weighed out, close the container, close the bag, and add the lye to the methanol as quickly as possible.

Lye also absorbs carbon dioxide from the atmosphere and becomes carbonated if not stored properly. Carbonated lye is white, fresh lye is almost translucent. You can still use carbonated lye, but you'll have to use a bit more (add about 25%).

Sodium hydroxide (NaOH) is more readily available than potassium hydroxide (KOH) and much cheaper. It usually comes in three grades: flakes and 5mm pearls or half-pearls are 96-97%, small pearls (1-2 mm) are 99%+, but much more expensive. Either will do.

KOH is not as strong as NaOH -- use 1.4 times as much KOH. Titration is the same, just use a 0.1% KOH solution instead of NaOH solution, and use 1 gm of KOH for every millilitre of 0.1% solution used in the titration. But instead of the basic 3.5 grams of NaOH lye per litre of oil, use $3.5 \times 1.4 = 4.9$ grams of KOH. So, if your titration was 5 ml, use $5 + 4.9 = 9.9$ gm KOH per litre of oil.

How much lye to use?

It requires 3.5 gm of NaOH lye as catalyst to transesterify new oil (virgin, uncooked).

Used oil (WVO) needs more lye than new oil, to neutralize the Free Fatty Acids (FFAs) formed in cooking the oil, which can slow or stop the transesterification process.

You have to titrate the oil to determine the FFA content and how much lye will be required. Titration measures the pH of the oil, ie the acid-alkaline level (pH7 is neutral, lower values are increasingly acidic, higher than 7 is alkaline, or "base"). From this you can calculate how much extra alkali (lye) will be needed to neutralize the FFAs.

The extra lye converts the FFAs to soap, which drops out with the glycerine layer.

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Too much lye will make extra soap, very alkaline biodiesel that's difficult to wash, with loss of production, or it can ruin the reaction; too little lye will mean some of the oil is left unreacted. See below: [How the process works](#).

Basic titration

An electronic pH meter is best, but you can also use pH test strips (or litmus paper), or phenolphthalein solution (from a chemicals supplier).

Dissolve 1 gm of lye in 1 litre of distilled or de-ionized water (0.1% lye solution).

In a smaller beaker, dissolve 1 ml of dewatered WVO oil in 10 ml of pure isopropyl alcohol. Warm the beaker gently by standing it in some hot water, stir until all the oil dissolves in the alcohol and the mixture turns clear. Add 2 drops of phenolphthalein solution.

Using a graduated syringe, add 0.1% lye solution drop by drop to the oil-alcohol-phenolphthalein solution, stirring all the time, until the solution stays pink for 10 seconds.

Take the number of millilitres of 0.1% lye solution you used and add 3.5. This is the number of grams of lye you'll need per litre of oil.

With a pH meter or test strips, use the same procedure without adding the phenolphthalein. Add the 0.1% lye solution drop by drop as before until the pH reaches 8.5.

Better titration

Unless you have a very accurate scale, it's not easy to measure exactly 1 gram of sodium hydroxide. It's much easier to measure 5 gm than 1 gm, so mix 5 gm of sodium hydroxide with 500 millilitres of distilled or de-ionized water.

Before titration measure out 5 ml of the stock solution, add 45 ml of distilled or de-ionized water. This makes a 0.1% lye

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Rubber

Pure biodiesel will eventually devour any natural or butyl rubber parts in the fuel system (hoses and seals). Check with the vehicle manufacturer and replace the parts with resistant synthetic parts (such as Viton B). See [Durability of plastics](#) table. Newer motors don't use rubber. See also [Biodiesel and your vehicle](#).

solution.

It's also not easy to measure exactly 1 millilitre of oil. Instead of the usual 1 ml of oil and 10 ml of isopropyl alcohol, mix 4 ml of oil in 40 ml of isopropyl alcohol in a glass beaker.

Warm the mixture gently by standing the beaker in hot water, stir until all the oil disperses and it becomes a clear mixture.

Then titrate as usual, measuring millilitres of stock solution used. When it reaches pH8.5 count up the number of millilitres used as normal and divide by 4. This will give a much more precise measurement.

To save on isopropyl alcohol, use 2 ml of oil in 20 ml of isopropyl and divide the results by two -- still twice as accurate.

Accurate measurements

Truly accurate scales are expensive, unless you can pick up a second-hand set in good condition. Even then, it pays to check your scales for accuracy.

A good way of doing this is with new coins. Find out from your bank, or the Central Bank, what the weight is (in grams) of the coins in your country. If you get a full set of new coins you can use them to check accuracy of a wide range of weights.

With a balance-type scale (two sides with a fulcrum between them), get two full sets of coins, and figure out different combinations to put on each side; you should also be able to use this to achieve smaller gradations than your scale allows: it's useful to be able to measure a tenth of a gram.

If you have a standard millilitre measure that you know is accurate, use it to check all your various measuring flasks, syringes, pipettes, etc. Otherwise, check them against each other. With syringes or pipettes, whatever you use to add the 0.1% lye solution to the oil-alcohol mixture for titration, you should be able to measure 0.1 ml accurately.

pH meters

Conversions

1 US gallon = 0.83

Imperial gallons = 3.78
litres

1 acre = 0.405 hectares

1 lb = 0.454 kilograms

1 US bushel = 35.24 litres

It's said you can't reliably use an electronic pH meter for titration, nor to check the pH of biodiesel, because biodiesel is not an aqueous solution. Not quite true -- biodiesel is hygroscopic and will always have about 1,200 ppm water content absorbed from the atmosphere, if from nowhere else. And laboratory-standard titration equipment uses electronic pH meters.

We have two pH meters, one of them rather expensive, and we did some comparisons, with phenolphthalein, fresh from a major laboratory supplies company in Tokyo, and with various test strips. We used WVO from several sources, and virgin oil as a check. The results were checked with test batches. In each case, the two pH meters agreed with each other and produced the best test-batch results. Phenolphthalein and test-strip results were consistently higher, but the results were still acceptable.

Good-quality oil that hasn't been cooked too much or overheated is quite forgiving, but with poor-quality WVO with a high FFA content, accurate titration is more important. The higher the FFA level, the more sensitive the reaction, the more precise you have to be with titration and everything else, the more reactive agents you'll need -- and the lower will be the production rate.

Phenolphthalein

Phenolphthalein is often confused with "phenol red", obtained at pool supply stores and used for checking water. It's not the same thing, and phenol red won't really do for titrating WVO, its pH range isn't broad enough. It ranges from pH 6.8, at which point it's yellow, through orange, to a maximum of pH 8.2, red. For accurate titration you need to be able to measure pH 8.5.

Phenolphthalein is colorless up to pH 8.3, then it turns pink (magenta), and red at its maximum of pH 10.4. When it stays pink for more than 10 seconds, it's measuring pH 8.5.

With good-quality oil with low FFA levels you might just get away with using phenol red for titration, but for higher FFA levels it isn't accurate enough.

High FFA levels

Most people find their used cooking oil generally gives a titration of 2-3 ml, but some used oils can have much higher FFA levels than this -- we've seen horrific titration levels of 9.6 ml. "Horrific" because FFAs are not good for you -- it's a very bad idea to eat food from a restaurant that does that to their cooking oil. Another biodieseler reported titration levels of 16 ml -- black stuff with the consistency of sump oil.

We did succeed in making biodiesel with our 9.6 ml oil. It required 30% methanol, and had a production rate of only 60%, hardly worth the effort, even if we'd recovered the excess methanol.

The oil had to be very thoroughly dried first -- again, traces of water make a bigger difference with high FFA levels, because there's more lye for the water to react with. And the reaction itself releases traces of water, especially with high levels of lye. So unless high-FFA oil is thoroughly dried, you'll end up with a tub of soap and jelly.

Having been used that much longer, high-FFA oil also seems to have more water in it, which takes more time to boil off, thus using more energy. At a certain point you have to ask yourself if you're investing more energy in the process than the biodiesel you're producing can deliver. With this 9.6 ml oil, the answer was almost certainly negative -- not worth it.

The answer then is to use the [Foolproof](#) two-stage acid-base method, which effectively handles high FFA levels and still produces high production rates with low levels of reactants and easy washing.

You can also deacidify the oil.

Deacidifying WVO

In professional oil processing, this is done with lye:

"Caustic soda is used in this procedure to remove free fatty acids. It is vigorously mixed (a small excess, as determined in the lab) with the heated fat at relatively high temperature (say 60-80°C) and left to stand for the aqueous phase to settle.

"The aqueous solution that remains is known as foots or soapstock and, after separation, may be used for producing soap. Residual foots are eliminated from the neutral oil by washing it with hot water, along with settling or centrifugation."

-- From "**Chemical Reactions of Oil, Fat and Fat Based Products**":

<http://alfa.ist.utl.pt/~fidel/creac/reac.html>

Use the titration amount of NaOH -- eg, 9.6 grams for our 9.6 ml WVO -- and mix it with as little water as possible. It takes 2 ml of distilled or de-ionized water to dissolve 1 gm of NaOH, 2.5 ml is easier. It takes a bit of time, and it gets hot. Use a stainless steel container, mix it outside (by stirring), and take care! This is very corrosive stuff, take full safety precautions, have running water handy.

Warm the oil to about 55 deg C (131 deg F). When the lye is completely dissolved, gently mix the solution with the oil. Then let it settle for a day or longer. The FFAs will settle out at the bottom. Drain off the oil, wash in the same volume of water, again gently. Settle, drain water, wash a second time. Then dewater the oil by heating to 100 deg C (212 deg F), stirring to prevent steam pockets.

We deacidified 5.6 ml titration oil to 0.2 ml this way, yield was 72%.

This is also useful if you're making ethyl esters biodiesel, using ethanol rather than methanol: the ethyl esters process doesn't work well with oils with more than about 2 ml titration.

No titration?

There are three ways of avoiding titration:

1. Use the [two-stage base-base method](#);
2. Use the [two-stage acid-base "Foolproof" method](#);
3. Do a series of [test batches](#) using graded quantities of lye and compare the results. Start off with maybe 6 gm of lye per litre (3.5 gm for the transesterification and 2.5 gm for

the FFAs). If that works really well, then go ahead. Otherwise try more tests, at 5 gm, then at 7 gm; if, say, 7gm is better, try 6.5 gm and 7.5 gm, and so on until you get satisfactory results.

Satisfactory results mean that you get a good, clean "split" (ie separation), that it settles well, leaving a clear product with not too much soap formation, a good production rate, and, most important, that it washes easily without frothing.

There is a school of thought that holds that titration isn't necessary, just use 6.25 gm per litre and you'll be fine. Don't listen to them! They might have always done it that way and they've driven 20,000 miles already in their diesel without any problems, but 20,000 miles is nothing in the life of a diesel motor. Oils vary considerably from place to place -- even the fabled "stable source of supply" can't be all that stable, unless it's a food processing factory with a standardized operation. If it's the usual restaurant or canteen, that would mean they cooked exactly the same number of identical meals in exactly the same way, every day. It just ain't so.

Sometimes the "no titration" folks point to Aleks Kac's two-stage methods, neither of which use titration, though they're both based on an "average" lye requirement of 6.25 gm/litre. But two-stage processes work in a different way, and this cannot be applied to a single-stage process. In fact even with two-stage processes we'd want to do a titration, just to know what sort of oil we were working with.

They also point to [Mike Pelly's](#) statement that he usually needs between 6 and 7 gm of lye -- but Mike also says titration is the "most critical" step in the process: "Make your titration as accurate as possible." And: "It's a good idea to do this entire process more than once to ensure that your number is correct." In fact Mike has a stable source of supply for his WVO, but he checks it regularly just the same, by titration or with test batches.

The basic lye quantity -- 3.5 grams?

This is the amount of lye (NaOH, sodium hydroxide) required as

catalyst to transesterify 1 litre of virgin, uncooked oil. For used oils, titration determines the amount of lye needed to neutralize the Free Fatty Acid (FFA) content, and this quantity is added to the basic figure of 3.5 grams per litre.

In fact 3.5 grams is an empirical measure -- an average. Different oils have slightly different requirements, and even the same type of oil varies according to how and where it's grown. Other estimates are 3.1 gm, 3.4 gm, and some people have set it as high as 5 gm.

Here is what we've found. For most virgin oils and low-FFA used oils (with titration levels less than 2-3 ml), 3.5 grams works just fine. For high-FFA used oils, use more lye -- up to about 4.5 gm instead of 3.5 gm. Do small test batches to see what works best.

Different oils also require different amounts of methanol -- see [How much methanol?](#) For oils and fats requiring more methanol -- coconut, palm kernel, as well as tallow, lard, butter -- again, use more lye, up to 4.5 gm, even with new oils, and especially when it's used. Once again, do small test batches first.

Mixing the methoxide

See [Methoxide the easy way](#).

For larger quantities, most 5-gallon buckets are made of HDPE plastic, which is resistant to methoxide. If you're using a 55-gallon drum as a processor, use two or three buckets for the methoxide -- half-empty buckets are much safer than having them too full. Don't use "the easy way" with buckets -- it takes too long and you'll lose methanol to evaporation, even if you put lids on the buckets and weigh them down. Use a wooden stick for mixing, keep on stirring until all the lye is dissolved, and remember to wash the stick thoroughly afterwards, as well as the buckets.

Instead of buckets, you can use the easy method with 4-gallon HDPE carboys or similar containers with screw-on caps (preferably with bungs as well), which you can shake instead of stirring. Swirl it about rather than shaking it up and down.

For HDPE, see below, [Identifying plastics](#)

PET bottle mixers

This isn't a very good method of making test batches, though it does work if you're careful. It is useful if you're doing a demonstration. Do a test-run first in private before you stick your neck out in front of a crowd.

PET bottles are transparent plastic soft-drinks bottles, generally 1.9 litres. "PET" stands for Polyethylene Terephthalate -- see below, [Identifying plastics](#)

Here's how they do it: warm up the oil (or maybe not), funnel it into the PET bottle, add the (pre-mixed) sodium methoxide, screw on the cap, shake the bottle vigorously up and down 40 times, leave it for an hour, and it's done.

Well, maybe. Or maybe not -- it's a good recipe for an inadequate reaction.

Here's a better way: warm the oil to 55 deg C (131 deg F). Pour it into the PET bottle, add the methoxide, screw on the cap, shake vigorously up and down 40 times or more. Then stand the bottle in a bath of hot water to maintain the temperature -- keep the water in the bath at a minimum of 55 deg C. Shake again every 15 minutes or more often, for a total of at least two hours, maintaining the heat all the time. This will have a much better chance of not leaving unreacted and partly reacted material in the mix. See below: [How the process works](#).

Viscosity testing

Viscosity is a useful comparative indicator of biodiesel quality. Unfortunately, and despite claims to the contrary, that's all it is -- a comparative indicator: this batch is better than that batch. Even at the laboratory or industrial level, viscosity testing alone cannot tell you if the process has gone far enough before reaching equilibrium -- in other words that there are not unacceptably high levels of harmful unreacted and partly reacted materials in your fuel. Unconverted monoglycerides and

diglycerides are very similar in viscosity to biodiesel and stay in solution with it after an incomplete reaction. The allowed maximums are low -- less than 1% for DGs and less than half that for MGs. Viscosity tests might get you within 5% accuracy, maybe even a bit better than that, but still not close enough. The same goes for density -- specific gravity measures (SG). Even both viscosity and density together can't assure you of a completed reaction. The only way to know that is with a Gas Chromatography test, which very few biodieselers have available. Short of a GC, the best indicator of a completed reaction is the wash -- easy washing and a crystal-clear product. See below: [How the process works](#).

Nonetheless, viscosity is a useful indicator, especially with test batches. You can check viscosity with a 100 ml pipette and a stopwatch -- time exactly how long it takes 100 ml of your fuel to empty from the pipette. Or use a proper [viscosity meter](#). Excess methanol in the fuel will render the results meaningless, so you must wash the biodiesel first. Measure some petro-diesel for a comparison. Remember that viscosity is sensitive to temperature -- try it at two or three different temperatures. See the various quality-specification tables [here](#) for some guidance.

Measure specific gravity (SG) by weighing a specific volume of the fuel. Remember that volume is also sensitive to temperature. A litre should weigh about 880 gm at 15.5 deg C.

See [Quality testing](#)

How the process works

What is meant by "completion" and "equilibrium"?

The transesterification process converts triglycerides (in other words vegetable or animal fats and oils) into alkyl esters (biodiesel) by means of an alcohol reagent (usually methanol) and a catalyst (lye).

It happens in three stages (this has nothing to do with the single-stage or two-stage processes): first the triglycerides (TGs) are converted to diglycerides (DGs), then the diglycerides are converted to monoglycerides (MGs), and finally the monoglycerides are converted to esters, with glycerin as the by-

product -- completion.

The problem is that it can run out of reagent or catalyst before it gets that far, or agitation, temperature or processing time may be inadequate.

The result: unconverted or partly converted material. Well, so what if the process isn't completed? SVO (straight vegetable oil) is a good fuel anyway, so what's it matter if some of it is unreacted? But it's not just unreacted material that's the problem so much as the partly-reacted stuff. Diglycerides and monoglycerides are bad things to put in your diesel. Diglycerides don't burn well and lead to coking problems, monoglycerides can lead to corrosion and other problems -- bad fuel. So, either don't process it at all and use SVO (which can have its own problems), or process it PROPERLY.

In fact the process never reaches 100% completion, it always reaches equilibrium first, so there will always be some unreacted glycerides left. The various [national biodiesel standards](#) stipulate just how much is allowable, and it's not very much at all: diglycerides range from less than 0.4% to less than 0.1% by mass, monoglycerides less than 0.8% by mass.

The first part of the process happens rapidly, which is why some people think it only needs a few shakes and that's it. Not so. If it takes X minutes to convert half the TGs to DGs, it takes almost as long, another X minutes, to convert half the remaining TGs, then a further X minutes for the remaining half, and so on. So the process goes more and more slowly, and never quite arrives -- there's always half left. Finally comes a point when the remaining half is insignificant, and, indeed, within the limitations set by the various quality standards. But it's very easy to fall short of that point and end up with nasties in your beautiful clean eco-friendly nice-smelling home-brewed fuel, and in your motor.

It really isn't necessary though -- you can make high-quality biodiesel, all it takes is a little care. On analysis, biodiesel made by home-brewers with no qualifications and no special equipment using the methods detailed here has proved the equal of professionally made commercial fuel. Professional mechanics checking their motors have been amazed by the lack of wear and corrosion. You can do it too. See [Quality](#)

For beginners, start off with good practices: follow the instructions carefully, be meticulous with your titration, make sure your measurements are as accurate as you can make them. Learn as much as you can. You'll soon get a feel for it, and then, once you're familiar with the process in all its aspects, you'll be able to decide what's best for you in your situation, with your source of oil, on your budget, and just where you can relax a little and take calculated shortcuts, based on your own experience.

Which method to use?

Three main choices, all of them here:

[Single-stage base -- Mike Pelly;](#)

[Two-stage base-base -- Aleks Kac;](#)

[Two-stage acid-base "Foolproof" method -- Aleks Kac.](#)

What's the difference?

The single-stage base method is the original method, most widely used, tried and trusted. In many ways it's the simplest method, especially for new oils which don't need titration.

A lot of beginners want to use WVO but they're put off by the titration, thinking it's too complex. Actually it's simple enough. Many more experienced users think the single-stage is the simplest method, titration and all. However, the single-stage process produces more and more uncertain results the higher the FFA content gets in WVO, with lower production levels even when it works well.

The two-stage base-base method avoids the need for titration and produces good results even with higher FFA levels. It's the method-of-choice for animal fats.

Growing numbers of biodieselers are now turning to the "Foolproof" method, especially with high-FFA oils. Here are some of the reasons:

- Less base catalyst needed.
- Less neutralizing acid needed for the wash.

- Less acid needed to neutralize base during glycerin recovery.
- Less soap production.
- Less emulsion formation in the wash.
- Less loss of fuel in the wash as a result of emulsion formation.
- Less wash water as a result of less soap formation.
- Higher conversion rates as a result of less soap formation.

The negatives:

- A little extra processing time.

Even with high-FFA oils the production rate should be 100% or more by volume (biodiesel has a lower density than the original oil).

In fact the same advantages apply to new oil, although to a lesser extent. Many biodieselers who turn to the "Foolproof" method for high-FFA oils soon make it their method-of-choice for all oils.

Here's some advice from Aleks Kac on using the Foolproof method: "Stick to the recipe, to the letter. There's two years of trial and error research in this. Do not change, simplify or speed up anything. It will take care of all sorts veg fats, even heavily used. The 'solid' portion must be reduced to less than 50% because of the much lower acid-stage temperature. Animal fats content is best at less than 25% for pork or chicken and less than 10% for bovine. These fats at greater concentration should be processed with the two-stage base-base method."

Still, if your oil is quite good and usually titrates at 3 ml or less, you might well be satisfied with the single-stage process.

Other uses

Biodiesel is very useful stuff. "We must be crazy to burn it!" Mike Pelly once said, only half-jokingly. He's a carpenter and had just finished refitting his house with wooden interiors. He and his wife treated all the wood with biodiesel, floors included. The smell was soon gone (and it's a pleasant enough smell

anyway), and the results were fine. We've also used it for wood treatment, nice!

It's an excellent lubricant, very slippery stuff indeed. It's better than household lubricating oils, and it's non-obnoxious and non-toxic -- it doesn't matter much if the kids swallow some by mistake. Great for gardeners, especially organic gardeners, nothing better for lubricating your tools and keeping them clean and rust-free, and non-toxic. And great in the workshop.

You can also use biodiesel as a lubricating additive for low-sulphur fuels. With diesels, engine parts are lubricated by the fuel itself. There are already indications that diesel motors are not lasting as long as they did because of the lack of lubrication with low-sulphur fuel (500ppm), let alone the new ULS ultra-low-sulphur fuel (15 ppm), and biodiesel can fix that. Adding just 1% biodiesel improves the lubricity up to 65%. Research suggests that just 0.4% to 0.5% is enough.

[Biofuels mailing list](#) member Martin R. of Australia uses biodiesel as two-stroke oil in his chain saw, at a mix of 20 to 1 with gasoline. "It works fine," he says. "After using the saw for 2.5 hours in one go on dead Australian hardwood with no hiccups I was very impressed to say the least."

Sad to say, biodiesel will not travel up a wick, like kerosene or heating oil will, so it can't be used for lamps or stoves using wicks. It also won't work in heating furnaces or stoves that aren't purpose-built, though some can be adjusted.

The **BriteLyt** Petromax multi-fuel lantern works just fine on biodiesel. "We are happy to report that the burn-time was over 8 hours, at the highest setting, and you did not have to re-pressurize the lantern as often as you would using other fuel-types. The performance was great, and the lantern was just as bright, and there was NO SMELL. Using the product inside, we noticed no smell at all." The lanterns also work with ethanol.

<http://www.britelyt.com/>

<http://store.britelyt.com/>

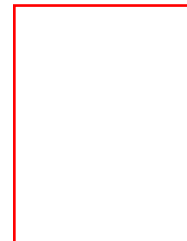
-- Purifying vegetable oils for use in lamps: [Fixed oils: To Purify Rape Oil.](#)

Identifying plastics

What is this "HDPE" plastic that people use for mixing chemicals, and how do you identify it? What sorts of plastics can withstand what sorts of chemicals?

Identifying different kinds of plastic and their properties, American Plastics Council:

http://www.americanplasticscouncil.org/benefits/about_plastics/resin_codes/resin.html



This helps even more: **Plastics Identification** -- Society of Plastics Engineers, Mid-Michigan Section
<http://www.midmichiganspe.org/education/identification.pdf>

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There's a choice to make for running diesels on biofuels:

- make biodiesel and just use it, no need to modify the engine, or
- buy a ready-made conversion system for your vehicle or build your own so you can run it on straight vegetable oil (SVO) -- no need to process the fuel, just put it in and go.



[Elsbett, Germany](#)

Does the SVO option work? Yes -- IF you go about it the right way. It's not quite that simple a choice. For one thing, if you want to use waste vegetable oil, which is often free, you're going to have to process it anyway, though less so than to make biodiesel. And it still might not be a very good fuel.

But read on -- you CAN run your diesel motor safely on straight vegetable oil, just put it in and go. There are pitfalls and provisos, but we'll help you to steer your way through them.

One of the great advantages of biodiesel is that it will work in any diesel motor -- see [Biodiesel and your vehicle](#). ([More](#) on the choice between biodiesel and SVO.)

The same claim is often made for straight vegetable oil fuel systems, such as this: "Ready-to-install kit that will allow you to run any diesel on waste vegetable oil."

Is it true? Yes, BUT... and it's an important "but".

Diesel motors last a long time, half a million miles or more is not unusual, and there are very few thorough, long-term studies of the effects of using straight vegetable oil in diesel motors. What is clear, however, is that "any diesel" is an exaggeration.



- Some vegetable oils are better than others.
- Some diesels are more suitable than others.
- Some injection pumps work better than others.
- Some computerized fuel systems don't like vegetable oil at all.
- There are doubts about using vegetable oil in DI (Direct Injection) diesels.
- There are also doubts about using waste vegetable oil.

The main problem is that vegetable oil is much more viscous (thicker) than conventional

[Spanish-language sister-site for DIY biodieselers](#)

[EN ESPAÑOL, sitio hermano para biodieseleros DIY](#)

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diesel fuel (DERV, petro-diesel). It must be heated (thinned) so that it can be properly atomised by the fuel injectors. If it's not properly atomised, it won't burn properly, forming deposits on the injectors and in the cylinder head, leading to poor performance, higher emissions, and reduced engine life.

This can also happen with unsuitable oils, for instance those with a high iodine value, such as linseed oil (see [Iodine Values](#)), which can form tough epoxy deposits, not good for engines. It's argued that a good SVO system will prevent this, but solid proof is lacking.

"In the high temperatures commonly found in internal combustion engines, the process is accelerated and the engine can quickly become gummed-up with the polymerised oil." -- From "Waste Vegetable Oil As A Diesel Replacement Fuel":

<http://www.shortcircuit.com.au/warfa/paper/paper.htm>

Waxes can clog up the fuel system, especially in [cold weather](#). Waste oils can contain acids that cause corrosion in the injector pump, and impurities that can cause coking and further corrosion.

"In autumn 2001 an injection pump was damaged for the first time ... so that an exchange was necessary. The vehicle had previously been driven without problems for two years. An examination of the defective sections found substantial surface erosion of the hardened steel high pressure parts, which are not acid-proof." The problem was traced to a supply of soy oil which was not the usual food-grade oil and had a high acid-content. BioCar (German page):

<http://biocar.de/info/warnung1.htm>

Here's some more:

"Rapeseed oil ... can only be used as a diesel fuel extender, with inclusion rates of up to 25%." -- From "Results of engine and vehicle testing of semi-refined rapeseed oil":

<http://www.regional.org.au/au/gcirc/6/214.htm>

And yet more:

"Deacidified rapeseed oil can be used as fuel for a diesel engine. Degummed oil and crude rapeseed oil were found to be unsuitable for use as fuel due to the high level of incombustible materials in oil." -- From "Operation of a Diesel Engine Using Unrefined Rapeseed Oil as Fuel":

<http://ss.jircas.affrc.go.jp/engpage/jarq/33-2/Togashi/togashi.html>

Nonetheless, experience is showing that SVO systems are a practical proposition with a lot of advantages to offer, not least of all that using SVO is cheaper than turning it into biodiesel and uses less energy than making biodiesel does.

It's critical to pay close attention to the properties, quality and condition of the oil -- much more critical with an SVO system than if you're going to convert the oil into biodiesel. Study the resources below carefully, as well as the information on oil and fuel qualities and properties on our [Oil yields and characteristics](#) page.

That done, get a good system matched to the right kind of engine with the right kind of



Cutaway view of an injector pump -- complex, expensive

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injection pump, as well as to your climate, and you'll be just fine, like thousands of others.

The following chart is a guide to safe, long-term use of vegetable oil as diesel fuel.

Guide to using vegetable oil as diesel fuel

Key

+ favored

- less favored

SVO = straight vegetable oil (virgin oil, fresh, uncooked)

WVO = waste vegetable oil (used cooking oil, "grease", fryer oil, including tallow, fats)

-- With information provided by Ed Beggs of Neoteric Biofuels, Inc.

<http://www.biofuels.ca/>

Engine type

IDI (Indirect Injection) +

DI (Direct Injection) -

Newer engines are generally less tolerant of SVO.

Injection type

Mechanical injection +

Computerized injection -

Injection pump

Inline +

Rotary -

Lucas/CAV injection pumps have had high failure rates running on SVO.

Oil type

New SVO +

WVO -

Brassicas (mustard, rapeseed, canola -- all high-lubricity oils) seem to be among the best, or at least there are more results available on using them in SVO applications.

Pre-treatment

Raw SVO pressed on-site from seed should be degummed and deacidified.

Oil must be free of water (especially WVO).

Deacidification of WVO recommended.

WVO must be pre-filtered.

Filtering (engine fuel system)

To 10 microns, preferably 5 microns or even lower.

Oil should be filtered to the specifications for the injection pump. Additional coarser, upstream filters recommended, final filter should be the same rating as original equipment.

Injection temperature of SVO

For IDI engines, the oil should be pre-heated to 70-80 deg C (160-180 deg F).

Research indicates that DI engines require much higher injection temperatures for efficient fuel atomization, but higher temperatures cause other problems. DI engines are being run with SVO systems, but it's a less favored option than IDI engines.

Maintenance

Injector inspection and cleaning if indicated.

Head removal, combustion chamber cleaning if indicated.

Lube oil sampling.

Check/change fuel filters often, especially in cold weather -- vacuum gauges can warn when filters are plugging.

Start-stop fuel

Biodiesel or petro-diesel (high-quality). The solvent properties of biodiesel and of premium petro-diesel fuels help to remove any deposits that may form. See: Fuel Quality

<http://www.dieselpage.com/art0599fq.htm>

Lubricity benefits

http://www.biodiesel.org/pdf_files/Lubricity.PDF

Frequency of start-stop cycle

Fewer is probably better, especially in cold weather, eg.:

Genset +

Taxi -

Load

Full load operation +

Idling -

Method

Two-tank system, start-stop on petro-diesel or biodiesel, with pre-heating of SVO + +

Single tank with SVO heating +

(for IDI genset, this may be okay, since very low number of start-stop cycles and high loads)

Unheated SVO -

SVO systems

Apart from the Elsbett system (below), the best systems use **two tanks**, one for SVO and one for diesel or biodiesel. Start up the engine on biodiesel/diesel from one tank while the SVO in the other tank is heated to at least 70 deg C (160 deg F) using the engine coolant and/or electric heating. Once it's warm enough, switch the fuel supply to the SVO tank -- and then back to biodiesel/diesel several minutes before shutting down. This flushes out the fuel system and prevents cooling SVO from clogging the injectors and filters. Extra upstream filters should be included.

Elsbett, Germany -- Full conversion to running a diesel car on pure vegetable oil -- includes new injectors, glowplugs, heat exchangers, everything required. This is the truly professional system, but it's not cheap. Warranty limited to SVO, excludes WVO, but not limited to rapeseed oil.

<http://www.elsbett.de/>

Also exports do-it-yourself "tuning kits", on application:

submit a form online for feasibility, prices, etc.

<http://elsbett.com/emotanfr.htm>



BioCar -- "The mother of all D-I-Y kits for vegetable oil and fat in unmodified diesel

engines." Advanced dual-tank straight vegetable oil system from G. Lohmann in Munich, Germany. The patented "BioCar" computerized controller monitors and controls fuel flows and temperatures, allows use of veg-oil with the newest injection pumps, adding petro- or biodiesel before the injection pump to adjust the viscosity. Can be installed by any handiman who "can solder and read". See "List of the motor vehicle types already converted". German-language site with on-site BabelFish/Systrans translation to English and other languages. Not a cheap system.

<http://www.biocar.de/home.htm>



The BioCar computer



Neoteric Biofuels Inc. in British Columbia, Canada -- Neoteric's G3 SVO Systems are complete two-tank systems with a range of options, starting at US\$299, or \$199 without the plastic tank, which you can easily supply yourself. Also, inline G3 VEG-Therm vegoil heaters (12-volt, self-regulating), tank heaters, vegoil pumps, canola-based lubricants, KOMET oil presses, workshop filters and transfer pumps, and more.

<http://www.biofuels.ca/>

Greasel conversion kit --

"Ready-to-install kit that will allow you to run any diesel on waste vegetable oil. The key to running a diesel on vegetable oil is heat. This is done by a special tank and fuel line, heated with the hot coolant your engine is already producing." From \$365, popular system.

<http://www.greasel.com/>

Also from China Depot:

<http://www.chinadepot.com/>

greasel1.html



Diesel-Therm (German pages with English version) -- ATG, Innovative Products and Solutions for Diesel Vehicles and Motors, Vegetable Oil-Kit, Converting Diesel-Operating Vehicles to Vegetable Oil. (SVO heating only. Lines and tank are not heated.)

<http://www.diesel-therm.com/veggie-kit.htm>

From **TäbyPressen** in Sweden: "Drive your diesel-engine with warm raw straight vegetable rape-oil" -- Skeppsta Maskin AB veg-conversion, veg-tuning -- dual-tank system with thermostat-controlled electric valve to switch to veg-oil after start-up and back to diesel on shut-down. Electric SVO heating, extra fuel

filters, etc. Also small-scale oil-presses, information on using SVO, online forum and links to other forums and resources (some in English).

http://www.oilpress.com/drive_your_diesel.htm

The book "**From the Fryer to the Fuel Tank**" by Joshua Tickell has how-to details on a basic SVO system. No need for a custom-made stainless steel tank though. Coolant-heating only.

<http://www.veggievan.org/book/>

Grease Car -- Dual-tank system with coolant heating, no electric heating, claims suitable for WVO use in any climate.

<http://www.greasecar.com/>

<http://www.greasecar.com/products.cfm>

[Fuel heaters, filters](#)

Vegoil-diesel mailing list discussion group:

Subscribe: vegoil-diesel-subscribe@yahoo.com

Unsubscribe: vegoil-diesel-unsubscribe@yahoo.com

Post message: vegoil-diesel@yahoo.com

List URL: <http://groups.yahoo.com/group/vegoil-diesel>

Veg-Oil-Car.com web forum for discussion of the advantages and disadvantages of running your car on vegetable oil.

<http://pub41.bravenet.com/forum/show.php?>

[usernum=3470269378&cpv=1](http://pub41.bravenet.com/forum/show.php?usernum=3470269378&cpv=1)

References

Report of the **European Advanced Combustion Research for Energy from Vegetable Oils** (ACREVO) study of the use of straight vegetable oil as diesel fuel.

Investigates the burning characteristics of vegetable oil droplets from experiments conducted under high pressure and high temperature conditions. Very interesting study, worth a thorough read (4,400 words).

<http://www.nf-2000.org/secure/Fair/F484.htm>

"Renewable Oil Fuels and Diesel Engines As Components of Sustainable System Design" by Ed Beggs of Neoteric Biofuels -- "Are renewable oils, as fuels in unmodified compression ignition engines, a technically and economically feasible component of sustainable system design, in both developing and developed countries?" -- 196-page Master's degree thesis, 1Mb Acrobat file:

<http://members.shaw.ca/biofuels/ebeggsthesis.pdf>

"Technical Overview of Vegetable Oil as a Transportation Fuel", 1991, Charles L. Peterson and Dick L. Auld, Department of Agricultural Engineering, University of Idaho -- see section concerning Fuels, South Africa, indirect injection engines: Fuels, J., Hawkins, C.S. and Hugo, F.J.C., 1984, "Tractor Engine Performance on Sunflower Oil Fuel," Journal of Agricultural Engineering Research 30:29-35. Download (Acrobat file, 2152kb):

<http://www.biodiesel.org/resources/>

[reportsdatabase/reports/gen/gen-292.pdf](http://www.biodiesel.org/resources/reportsdatabase/reports/gen/gen-292.pdf)

"Waste Vegetable Oil as a Diesel Replacement Fuel" -- Informative 6,500 article by Phillip Calais, Environmental Science, Murdoch University, Perth, Australia,

pcalais@ieee.org, and AR (Tony) Clark, Western Australian Renewable Fuels Association

Inc, ar.clark@bigpond.com:

<http://www.shortcircuit.com.au/warfa/paper/paper.htm>

"Waste Vegetable Oil Conversion of Mazda 1990 2.0L diesel station wagon", by Tony Clark:

<http://www.shortcircuit.com.au/warfa/WVOMazdaDiesel.htm>

Pictures of the Mazda conversion:

<http://www.shortcircuit.com.au/warfa/warfaPictures.htm>

"Biodiesel: The Use of Vegetable Oils and Their Derivatives as Alternative Diesel Fuels", G. Knothe, R.O. Dunn, and M.O. Bagby, in *Fuels and Chemicals from Biomass*. Washington, D.C.: American Chemical Society.

<http://www.oup-usa.org/j778/isbn/0841235082.html>

Download full-text article (Acrobat file, 901kb):

<http://www.biodiesel.org/resources/reportsdatabase/reports/gen/gen-162.pdf>

"Operation of a Diesel Engine Using Unrefined Rapeseed Oil as Fuel", Chiyuki Togashi, Department of Agricultural Engineering, Miyagi Agricultural College, and Jun-ichi Kamide, Faculty of Agriculture, Yamagata University, Japan. Report of tests with unrefined rapeseed oil in a small diesel engine on short-term performance, long-term operation and no-load continuous operation using deacidified oil, degummed oil and crude oil.

<http://ss.jircas.affrc.go.jp/engpage/jarq/33-2/Togashi/togashi.html>

"Results of engine and vehicle testing of semi-refined rapeseed oil", Kevin P. McDonnell, Shane M. Ward & Paul B. McNulty, University College Dublin, Dept of Agricultural & Food Engineering, Dublin, Ireland.

<http://www.regional.org.au/au/gcirc/6/214.htm>

General information: **"Vegetable oil instead of diesel -- an alternative fuel?"**

<http://people.freenet.de/sthl/poel/vegoil.htm>

Using vegetable oil as a substitute for diesel fuel -- extensive **FAQ**

<http://people.freenet.de/sthl/poel/VegFAQ.htm>

There's a helpful **FAQ** at the **Neoteric Biofuels Inc** website:

<http://members.shaw.ca/biofuels/faq.html>

John Nicholson's **Bio-power UK** in North Wales -- good information on SVO use, informative, cautious but encouraging. "The fact is that this is an unknown territory. We need to test the use of SVO in all kinds of vehicles, but to do so cautiously, and not fool-hardily... We need to know which diesel engines work well on straight fat." Can I burn straight vegetable fat in my diesel engine? How can I know if my engine will run on Straight Vegetable Oil? If my engine runs on SVO, then can I burn WVO? How to make your own heat exchanger.

<http://www.northwales.org.uk/bio-power/svo.htm>

Using jatropha oil as fuel -- a selection of interesting papers at the **Jatropha Website**, along with lots of other material on the uses and benefits of the wonderful *Jatropha curcas* tree. See "Literature":

<http://www.jatropha.org/>

Honge Oil as diesel fuel in India

<http://www.goodnewsindia.com/Pages/content/discovery/honge.html>

SVO vs biodiesel in Europe

Much of the work with SVO as a fuel has been done in Northern Europe, and there's much valuable information to be found there. But (again!) -- in a word, beware. A lot of Northern

Europeans simply chuck it in and go -- no dual-tank systems, no modifications at all, and they claim high mileages with no trouble.

Maybe so, but note the provisos listed above. And also be aware that they generally don't use waste vegetable oil, it's usually new, virgin oil, most often rapeseed oil, one of the best oils for fuel use.

Also, there's quite a lot of mis- or disinformation, especially about SVO vs biodiesel.

A Northern European gent sent a message to the [Biofuels mailing list](#) which caused widespread derision and amusement, and some anger. He was pushing the use of "pure plant oils", but ignored all the caveats on using SVO, and added some serious nonsense about biodiesel to strengthen his case for pure plant oils:

"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."

He was referred to the comprehensive, much corroborated tests in the US that found that biodiesel is "less toxic than table salt, more biodegradable than sugar", to the U.S. Department of Energy study at the University of California at Davis, which found a 93.6% lower risk of cancer from biodiesel emissions than from petro-diesel, to life-cycle and economic studies of biodiesel production that found the opposite of his cost and energy claims, and to [this picture](#) at our website.

Asked to support his claims, he descended into accusation and denial, and then unsubscribed from the list.

Such stories of the alleged horrors of biodiesel are not uncommon in Northern Europe, especially on websites promoting SVO. It seems partly to stem from an apparent misclassification of water pollution standards in Germany, where the risk from rapeseed oil is not even classified, whereas biodiesel is a class 1 hazard, and fossil diesel is in class 2 (worse). It only refers to water pollution and no other aspects of toxicity or hazard.

Some would argue that a biodiesel spill would be less of a problem than a spill of vegetable oil, which coats everything, like fossil oil does. In fact biodiesel is used to clean up marine oil spills. In North America it is not classed as hazardous goods.

You'll encounter a few such yarns being spun at the European sites listed below. Here's another one:

"Biodiesel is chemically produced and substantially more expensive than vegetable oil. Except for a few new vehicles, most are not suited for using biodiesel. The majority of diesel vehicles must first be converted, in order to guarantee they will operate on biodiesel. The problem is the durability of the plastic and rubber components, which come into contact with the fuel. If biodiesel is used in a system that has not been adapted, the fuel can leak from places where it frequently backs up, which weakens and dissolves the fuel system's components. When using pure, untreated vegetable oil, these problems will not occur." -- From Diesel-Therm.

<http://www.diesel-therm.com/>

The introduction of low-sulphur diesel fuel in Europe about 10 years ago caused severe problems for fuel systems and all manufacturers hastened to correct it, which also made the

vehicles safe for biodiesel. In effect, no European cars made in the last 10 years have fuel-system parts that are susceptible to rot from biodiesel use. Also, all French diesel fuel now contains 2-5% biodiesel (partly to make up for the lack of lubricity in low-sulphur diesel fuel), and European diesel cars can and do use it safely, as with Japanese diesels. See: **Stanadyne White Paper on diesel fuel** -- "Low-Sulfur Diesel Fuel Requires Additives to Preserve Fuel Lubricity":

<http://fiss.com/rm/firm0015.htm>

If you're in any doubt, check the resources linked from our [Biodiesel resources on the Web](#) page, and make up your own mind.

European SVO resources

Some of these sites are also listed above under "SVO systems" or "References". Many European sites have English versions. Or use these translation sites:

AltaVista -- World / Translate

<http://babel.altavista.com/>

Google Language Tools

http://www.google.com/language_tools



Report of the **European Advanced Combustion Research for Energy from Vegetable Oils** (ACREVO) study of the use of straight vegetable oil as diesel fuel.

Investigates the burning characteristics of vegetable oil droplets from experiments conducted under high pressure and high temperature conditions. Excellent study, worth a thorough read (4,400 words).

<http://www.nf-2000.org/secure/Fair/F484.htm>

Elsbett, Germany -- Full conversion to running a diesel car on pure vegetable oil, dedicated system -- includes new injectors, glowplugs, heat exchangers, everything required. Not at all cheap. Warranty limited to SVO, excludes WVO, but not limited to rapeseed oil.

<http://www.elsbett.de/>

Also exports do-it-yourself "tuning kits", on application: submit a form online for feasibility, prices, etc.

<http://elsbett.com/emotanfr.htm>

BioCar -- "The mother of all D-I-Y kits for vegetable oil and fat in unmodified diesel engines." Advanced dual-tank straight vegetable oil system from G. Lohmann in Munich, Germany. The patented "BioCar" computerized controller monitors and controls fuel flows and temperatures, allows use of veg-oil with the newest injection pumps, adding petro- or biodiesel before the injection pump to adjust the viscosity. Can be installed by any handiman who "can solder and read". See "List of the motor vehicle types already converted". German-language site with on-site Babelfish/Systrans translation to English and other languages. Not a cheap system.

<http://www.biocar.de/home.htm>

TäbyPressen, a Swedish company making small-scale oil-presses, has much information on SVO, online forum and links to other forums and resources (some in English). Also supplies Skeppsta Maskin AB veg-conversion kits.

<http://www.oilpress.com/index.html>

General information: "**Vegetable oil instead of diesel -- an alternative fuel?**"

<http://people.freenet.de/sthl/poel/vegoil.htm>

Using vegetable oil as a substitute for diesel fuel -- extensive **FAQ**

<http://people.freenet.de/sthl/poel/VegFAQ.htm>

Finland: 1,800 hours and seven years on mustard oil in a farm tractor:

<http://personal.inet.fi/yritys/ekolaiho/mustarddiesel.html>

Diesel-Therm (German pages with English version) -- ATG -- Innovative Products and Solutions for Diesel Vehicles and Motors -- also supplies Vegetable Oil-Kit SVO system:

<http://www.diesel-therm.com/>

Datenbank des Forums '**Fahren mit Salatöl**' (Database of the forum 'driving with salad oil') -- This German database has information on more than 300 cars using veg-oil.

<http://www.poeltech.de/database/>

Folkecenter for Renewable Energy, Denmark -- Plant oil technology -- modification of standard diesel engines: Running cars on pure plant oil

http://www.folkecenter.dk/plant-oil/plant-oil_en.htm

Ökologisch ohne Ökosteuer (German page with English version) -- "I drove with pure salad oil for the next 12,000km... I didn't make any changes on my car at all. I'm driving, driving and driving... for already 146,000km."

<http://www.rerorust.de/>

<http://valenergol.free.fr/>

<http://www.pro-ev.de/>

<http://www.fnr.de/>

<http://www.pflanzenoelinitiative.de/>

<http://www.bioenergie.inaro.de/>

Diesel information

How Diesel Engines Work

<http://www.howstuffworks.com/diesel.htm>

Diesel Engines (Chevron)

http://www.chevron.com/prodserv/fuels/bulletin/diesel/L2_6_fs.htm

Diesel Fuels -- Technical Review (Chevron)

http://www.chevron.com/prodserv/fuels/bulletin/diesel/L1_toc_fs.htm

All About Diesel Fuels -- Lubrizol Corporation

<http://www.lubrizol.com/ReadyReference/GasolineDieselFuels/default.htm>

So, This is Your First Diesel

<http://www.dieselpage.com/art1110fd.htm>

Breaking in a Diesel Engine

<http://www.ford-diesel.com/contents/getititems.php3?Breaking>

[%20in%20a%20Diesel%20Engine](#)

Diesel Injection Systems

<http://www.dieselpage.com/art1110ds.htm>

Bosch -- Past, Present and the Future

<http://www.dieselpage.com/art0898pf.htm>

20 Questions with Racor

<http://www.dieselpage.com/art1021ra.htm>

20 Questions with Stanadyne

<http://www.dieselpage.com/art0898sg.htm>

Robert Bosch type VE Diesel injection pump -- how it works, illustrations

<http://www.cs.rochester.edu/u/jag/vw/engine/fi/injpump.html>

Fats and oils

[The Fats and Oils: a General View](#), by Carl L. Alsberg and Alonzo E. Taylor, 1928, Food Research Institute, Stanford University, California

First in a series of five Fats and Oils Studies published in the 1920s by the Food Research Institute. Good overview of the subject written in layman's terms, covers nature and sources of fats and oils, properties, technology, production, international trade and more. Not very much has changed since then, it's just grown more complex. A clear and informative guide -- useful information for anyone making biodiesel or working with SVO. Full text online at the Biofuels Library.

Oils -- King's American Dispensatory, by Harvey Wickes Felton, M.D., and John Uri Lloyd, Phr. M., Ph. D., 1898

<http://www.ibiblio.org/herbmed/eclectic/kings/olea.html>

Chemical Reactions of Oil, Fat and Fat Based Products

<http://alfa.ist.utl.pt/~fidel/creac/reac.html>

Food Fats and Oils (1994) -- online book (Acrobat file):

<http://www.iseo.org/foodfatsoils.pdf>

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Separating glycerine/FFAs

Most of the lye and most of the excess methanol used in the biodiesel process collect in the glycerine layer that settles out at the bottom, along with the soap formed when Free Fatty Acids (FFAs) are neutralized by the excess lye.

The proportions of each depend on the oil you used and your process -- the two-stage acid-base process will give different results to a single-stage base process.

Adding phosphoric acid (H_3PO_4) converts the soap back to FFAs and separates it all into three distinct layers, with catalyst-phosphorus on the bottom, glycerine-methanol in the middle, and FFAs-methanol on the top.

The methanol can then be recovered separately from each of the top two layers by heating to above 65 deg C (150 deg F) in a closed container fitted with an outlet into a simple condenser.

Some home brewers recover the excess methanol at the end of the processing step while the brew is still warm, before settling and separating the biodiesel from the glycerine layer. But treating the glycerine layer to separate the catalyst and FFAs is more difficult if the methanol has already been recovered.

Add the phosphoric acid and mix it thoroughly. The mixture gets a bit hot from the reaction. A translucent glycerine layer will form under a dark FFA layer, and not long afterwards the catalyst precipitates out at the bottom -- sodium phosphates if you used NaOH as the catalyst, or potassium phosphates with KOH (in which case separation takes a bit longer).

The catalyst layer is yellowish, the glycerine layer is translucent and the color of sherry, the FFA layer much darker. There's a clear separation between each.

Then the methanol can be removed separately from the glycerine and from the FFAs.

How much phosphoric acid to use? You have to neutralize all the catalyst -- ie, the basic 3.5 gm per liter of oil for

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transesterification plus whatever titration indicated was needed to neutralize the FFAs. Traces of catalyst will remain in the biodiesel rather than collecting in the glycerine at the bottom, but it's better to allow for the full amount of lye used.

Concentrated phosphoric acid is usually 85% strength, the other 15% is mostly water. We found that it takes about 1.5 to 1.7 ml of 85% phosphoric acid for each gram of sodium lye used in the process.

So, if the WVO you used titrated at 3 ml, you'd have used $3 + 3.5 = 6.5$ grams of lye per liter of oil in the process. To treat the glycerine layer, add $6.5 \times 1.5 = 9.75$ ml of 85% phosphoric acid per liter of oil used.

You can try it, but feedstocks, methods and techniques vary so widely that it might not work for everybody. Also it's worth trying to use less phosphoric acid, it's expensive stuff. Experiment a bit, or do it this way, as recommended by Todd Swearingen of Appal Energy. Email [mailto:"Appal%20Energy"%20apenergy@frognet.net](mailto:Appal%20Energy)

"As the glycerine/FFAs from all batches accumulate, it's easier for us to conduct a titration with phosphoric acid rather than trying to assess an ideal quantity to use.

"We start at 10 ml of 85% phosphoric acid per 250 ml of glycerine/FFAs. Put 250 ml of the glycerine layer in a jar, add 10 ml of phosphoric acid, shake vigorously. The first hint of glycerine separation should be visible within 5 minutes. If not, then add another 5 ml; work your way up in 5 ml increments until it starts to separate.

"This is too much acid, so we then go into reverse with further titrations. Start with 2 ml less phosphoric acid than the sample that started to separate, and another 2 ml less in each titration after that.

"Come back 24 hours later, observe the 'break point' where samples do and don't separate out. We then use that level of phosphoric acid on 45-gallon batches of glycerine/FFAs."

The crude glycerine layer in the middle is acidified in the process and should be neutralized, with a dilute lye solution, or baking

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soda. This leaves you with industrial-grade glycerine of about 95% purity. It's a much more attractive product for glycerine refiners than prior to FFA recovery, and you should be able to sell it to a refiner, if not for much, or at least give it away rather than having to dispose of it. Getting it purer than this takes a great deal of energy and isn't worth it for anything less than a large-scale operation.

Glycerine does burn, but unless it's properly combusted at high temperatures it will release acrolein, which is highly toxic. The [Mother Earth Waste Oil Heater](#) or other waste oil burners should be suitable, or the [Babington burner](#).

The FFAs can be composted (hot compost is best). It also makes an effective weedkiller, and should biodegrade quickly once it hits the soil. It burns well, but like biodiesel it won't climb a wick. It should work just fine in the [Mother Earth Waste Oil Heater](#). It should also work well as diesel fuel with an [SVO two-tank system](#), but we have no reports of this yet.

The catalyst, whether sodium or potassium, can safely be added to the compost pile. Industrial-scale biodiesel operations often use potassium hydroxide, KOH, as the catalyst, because the potassium phosphates left after separation can be sold as a fertilizer. It's said that the sodium phosphate you're left with if you use sodium hydroxide is nothing but a "useless salt".

Not quite true. We have good reason not to be interested in fertilizers, and also for applying any plant nutrients to the compost pile rather than directly to the soil. In fact sodium is also a plant nutrient, and almost as much of it is required as potassium. The common idea that more fertilizer is better is dangerous -- too much of either sodium or potassium, or of any nutrient, can cause soil imbalances that can ruin the soil structure and leave other nutrients unavailable to plants. As a minor constituent in a compost pile, this won't happen, any excesses are buffered.

However, farmers who use chemical fertilizers don't know much about this, as their advice mostly stems from the chemical fertilizer companies. And they will pay for potassium fertilizer, but not for sodium.

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The jar on the left shows what was the glycerine layer separated out of single-stage base reactions. The jar on the right shows the glycerine layer from two acid/base reactions ([the Foolproof method](#)) and two single-stage base reactions.



Photograph by Todd Swearingen

Both were treated with 85% phosphoric acid, cracking the soaps back to FFAs.

The precipitate on the bottom is potassium phosphate -- the catalyst neutralized by the phosphoric acid. We use potassium hydroxide as the base catalyst. If you use sodium hydroxide it will be sodium phosphate.

The center layer is a blend of crude glycerin, water and excess phosphoric acid. The top layer is the recovered FFAs.

The jar on the left is 16 fluid ounces and the one on the right 24 fluid ounces, but the important point here is the ratios of recovered co-products. The left jar (single-stage) has a much higher proportion of FFAs and catalyst than the right jar (half acid/base and half single-stage).

This is one of the benefits of the acid/base process -- FFAs are converted to biodiesel in the acid stage rather than saponified. The acid stage also reduces the amount of base catalyst required, so less phosphoric acid is needed for FFA recovery -- more biodiesel, lower volumes of co-products. A third jar on the right using the glycerine layer from strictly acid/base reactions would show even smaller ratios of FFAs and catalyst.

-- Todd Swearingen, Appal Energy

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