How to Make Homemade Biodiesel

Biodiesel is a diesel fuel made from animal fats, vegetable oils, or recycled restaurant greases. It is not only biodegradable but also safer and produces fewer air pollutants compared to petroleum-based diesel. Biodiesel is typically made by reacting lipids with alcohols to produce fatty acid esters. This instruction set outlines the steps to make homemade biodiesel. Making biodiesel can help save money and the environment. The length of time needed for making biodiesel depends on the quantity being made and the materials used to make it. In this instruction set, assume making less than a liter of biodiesel should take about 3 hours. Specialized machinery allows creating gallons of biodiesel, which can take from 10 hours to 3 days.

Choosing a Catalyst
The two common catalysts used in making biodiesel are sodium hydroxide (NaOH) and potassium hydroxide (KOH). Both catalysts have their advantages and disadvantages.

Safety

Both NaOH and KOH are hazardous chemicals. Do not get them in your eyes or on your skin. They can blind you and severely burn your skin. However, if contacted, flush them with lots of water for up to 30 minutes. Always remember to wear safety goggles when dealing with NaOH and KOH. Keep them away from children.

Comparing Potassium Hydroxide and Sodium Hydroxide
KOH dissolves better in methanol compared to NaOH. It is more tolerant of free fatty acid (FFA) in the oil. Although the process is the same, we need to use KOH in 1.4 times the amount as NaOH. KOH is not only required in greater quantity, but it is also more expensive than NaOH. KOH is only available in 90% purity while NaOH is relatively pure. As a side reaction of making biodiesel, the free fatty acid will be converted into soap. While soap made from KOH is liquid, soap made from NaOH is solid. A huge difference between using KOH and NaOH can be seen in the glycerin layer. Glycerin
from NaOH is much thicker than KOH. In general, KOH is easier to use and it is recommended for beginners.

**Storing catalyst**
Both KOH and NaOH are hygroscopic. This means that they absorb moisture from the atmosphere. Water will make the catalyst become less effective as it will be difficult for the catalyst to dissolve in methanol. Hence, always keep lye containers (NaOH and KOH) sealed and airtight.

**Obtaining catalyst**
NaOH can be obtained in the hardware store as drain cleaner. However, some drain cleaners may not work as they contain aluminum that disrupts the chemistry. So, make sure that it is 100% sodium hydroxide when purchasing it. Shake the container to check that it hasn’t absorbed moisture and coagulated into a useless mass. Make sure to keep it airtight. Both NaOH and KOH are also available online. You can buy them either from Amazon or any companies that supply soap makers. You can also find local sources for NaOH and KOH if you look in the yellow pages under the chemical suppliers.

**Choosing Oil for Biodiesel**
Although biodiesel can be made from any plant or animal derived oils, there are certain things that need to be considered when choosing the oils.

*Table 1: Nutritional Makeup of Various Oils* retrieved from [1]

<table>
<thead>
<tr>
<th>Oil</th>
<th>Saturated</th>
<th>Monounsaturated</th>
<th>Polyunsaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola oil</td>
<td>7%</td>
<td>62%</td>
<td>31%</td>
</tr>
<tr>
<td>Safflower Oil</td>
<td>7%</td>
<td>14%</td>
<td>79%</td>
</tr>
<tr>
<td>Camelina Oil</td>
<td>10%</td>
<td>33%</td>
<td>54%</td>
</tr>
<tr>
<td>Sunflower oil</td>
<td>10%</td>
<td>20%</td>
<td>66%</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>13%</td>
<td>24%</td>
<td>59%</td>
</tr>
<tr>
<td>Olive oil</td>
<td>14%</td>
<td>73%</td>
<td>11%</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>16%</td>
<td>23%</td>
<td>58%</td>
</tr>
<tr>
<td>Peanut oil</td>
<td>17%</td>
<td>46%</td>
<td>32%</td>
</tr>
<tr>
<td>Chufa oil</td>
<td>20%</td>
<td>67%</td>
<td>12%</td>
</tr>
<tr>
<td>Cottonseed Oil</td>
<td>26%</td>
<td>18%</td>
<td>52%</td>
</tr>
<tr>
<td>Chicken Fat</td>
<td>30%</td>
<td>45%</td>
<td>21%</td>
</tr>
<tr>
<td>Lard</td>
<td>39%</td>
<td>45%</td>
<td>11%</td>
</tr>
</tbody>
</table>
Saturated fats are fatty acids without a double bond. The lower the saturated fat content, the lower the gel point of the biodiesel made from it. Unsaturated fats are fatty acids containing double bonds. Unsaturated fats tend to spoil faster than saturated fats. Keep in mind that oil can become a "drying oil", which is not good to make biodiesel if oil contains too many double bonded sites.

Cooking oils are typically unsaturated oils with a single double bond per fatty acid and they are usually recommended in making biodiesel (refined oil, not raw oil straight from the press). Canola, for example, is the best oil since it ages slowly, has a high energy content and remains as a liquid at low temperature.

Hydrogenated oils are oils that are chemically altered to remove the double bond. This can cause the oils to last longer. Even though hydrogenated oils can be used as cooking oils, they are unhealthy oils for our bodies.

Cooking practices affect the waste vegetable oil (WVO) quality. Free fatty acids (FFA) are formed when long carbon chain breaks away from the glycerin molecules. Since these fatty acids are acidic, they will be converted into soap under the normal base catalyst processing method. Soap made from oils that are high in FFA content can be difficult to process. High heat leads to the formation of FFA. Hence, when cooking, the oil temperature needs to be below 300F for healthy food and good biodiesel.

High FFA oils can have up to 50% water content since FFA are hygroscopic. If the oils are filtered often, the oil will last longer. This is because crumbs that are not filtered can absorb water from the atmosphere. The water will react with oil to produce more FFA when the oil is cooled down. Hence, filtering helps in keeping the FFA level low.

**Titrating Waste Vegetable Oil (WVO)**

Titrating WVO precedes the step of actually making biodiesel. This step is important to understand the quality of your oil to know how much extra lye (KOH or NaOH) needed to add to your biodiesel recipe. There are even biodiesel titration kits that can be bought online that would provide necessary equipment and further instructions to help with this process. Note that WVO does not actually have to be vegetable oil, but actually testing your chosen oil.

<table>
<thead>
<tr>
<th></th>
<th>Palm Oil</th>
<th>Butter</th>
<th>Palm Kernal Oil</th>
<th>coconut oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated</td>
<td>49%</td>
<td>63%</td>
<td>81%</td>
<td>90%</td>
</tr>
<tr>
<td>Unsaturated</td>
<td>37%</td>
<td>26%</td>
<td>11%</td>
<td>6%</td>
</tr>
<tr>
<td>other</td>
<td>9%</td>
<td>4%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

* note- approximated values - actual values vary depending on the individual plant and extraction methods.
Step 1: Making the Alkali Solution

In this step, we are making a liter of alkali solution, though only a few milliliters are going to be used for titrating.

Materials

● 1 g of lye
● 1 L of water

Method

1. Add a gram of lye to a liter of water.
2. Mix and stir.

Note: For these steps, make sure that you don’t use intermediate glassware that will cause loss of water or lye.

Step 2: Blanking the Titration

This would “zero” out the compound. Isopropyl alcohol gets acidic with age; this step accommodates this variability.

Materials

● Alkali solution from step 1
● Isopropyl Alcohol
● 10 mL syringe
● 5 mL syringe
● 4 baby jars or 100 mL beakers
● Dropper
● Indicator solution (phenolphthalein)

Method

1. Pour 50 mL of alkali solution into a beaker. Label beaker “alkali.”
2. Pour 50 mL of isopropyl alcohol into another beaker. Label beaker “alcohol.”
3. Using 10 mL syringe measure out 10 mL of alcohol from alcohol beaker then place solution into a third beaker. Label beaker “titration.”
4. Add three drops of indicator solution into titration beaker.
5. Using 5 mL syringe measure out 5 mL of alkali from alkali beaker.
6. Slowly pour alkali into the titration beaker until a color change occurs. (Should change from clear to pink)

Note: Do not throw away the product; it will be used in the next step.

Step 3: The Titration

It is good to repeat these titration steps 3-5 times to have an average of results that will provide an accurate assessment of the quality of the oil.

Materials

- Everything used from step 2
- Sample of oil to test
- 3 mL pipette

Method

1. Pour 50 mL of oil into fourth beaker. Label beaker “oil.”
2. Using 3 mL pipette, add 1 mL of oil from oil beaker to the titration beaker. (It is crucial that is exactly 1 mL)
3. Mix the solution in the titration beaker. You may need to heat the solution if the oil does not mix well.
4. Using the same 5 mL syringe, add alkali solution from the alkali beaker to the titration beaker, while mixing or swirling beaker. Keep track of the amount of alkali solution being added!
5. Continue adding alkali solution until color goes away for more than 15 seconds. Note that the pink color can reappear after a short amount of time; that is why you must wait until it remains gone. Try to continually stir mixture to make sure color does not reappear.
6. Record the amount of alkali solution added, excluding the amount used to blank the titration. This value is the “titration value.”
Building the Recipe

When building a recipe for biodiesel, two essential parts are the following: the amount of lye used as a catalyst and the amount of lye to add to neutralize acids. This value is the titration value. There is no single recipe for making biodiesel. You will need to take into consideration quality, cost, oil type, time required, and etc.

For making biodiesel, there are many recipes that can be found ranging in complexity, cost, and quality of biodiesel. This guide will just explain a standard single stage recipe. In this recipe the amount of each material will vary according to the type of catalyst used, amount of oil (batch size of WVO), titration value, and base catalyst amount.

Safety

Methanol is a highly flammable poison. If it contacts your eyes or skin, flush them with water for at least 15 minutes. Since methanol is dangerous, extreme safety measure should be taken when dealing with it.

Storing methanol

Store in a segregated and approved area. Keep container in a cool, well-ventilated area. Keep container tightly closed and sealed until ready for use. Avoid all possible sources of ignition (spark or flame).

Obtaining methanol

Methanol is usually available from distributors of racing fuels. It is also available online.

For test batches, methanol can be obtained from chemical supply houses or even drug stores. Sometimes, it is sold in supermarkets and chain stores as “stove fuel” for barbecues. However, make sure to check the content as it could also be “white gas”,

Figure 2: From left to right. The first image is mixing the oil with titration solution from step 2. The second image shows adding alkali solution with the last image when the color disappears. Images retrieved from [1].
which is basically gasoline. The methanol needs to be pure to make the biodiesel.

**Step 1: Standard Single Stage Recipe**

This is a standard procedure that is very common in the production of biodiesel.

**Materials**

- WVO/oil
- Methanol = 22% of WVO used
- KOH = (8 grams + titration value) x liters of oil or NaOH = (5 grams + titration value) x liters of oil
- Thermometer
- Large pot

Note: This link has a calculator that provides the exact amount of materials needed in metric and US system: [http://www.make-biodiesel.org/zcalc/index.php?id=8&catype=5](http://www.make-biodiesel.org/zcalc/index.php?id=8&catype=5)

**Method**

1. Heat the oil until it reaches 130 °F-150 °F
2. Mix methanol and catalyst.
3. When the correct temperature has been reached, add methanol solution to the oil.
4. Make sure to continually mix the mixture. *Could try to mix it in a mixer or can be done by hand.*
5. Every 20 minutes, perform a 3/27 test (see step 2 below) until you have achieved a good biodiesel.
6. Store final product in a glass jar or strong sealable container.

Note: If it takes more than and 3 hours for the batch to pass the test consider the next time adding more catalyst.

**Step 2: Performing a 3/27 test**

3/27 tests the quality of biodiesel that has been created.

**Materials**

- Clear vial or test tube with lid
- Methanol
- Sample of water-free biodiesel from step 1

**Method**

1. Measure 27 mL of methanol to the vial.
2. Add exactly 3 mL of room temperature biodiesel into the vial.
3. Then shake vial and allow it to settle.

Note: If it takes more than 30 minutes for the oil to settle, then the fuel contains trace amounts of triglyceride. If nothing settles out, then you have created highly converted fuel.
Congratulations you have made a simple biodiesel in your own home.

Making biodiesel is one of the major improvements in the development of more sustainable fuel system. Standard gas and oil that fuels homes and cars is depleting, but the willingness to leap into a better future is the start of an advancing society. If you want to improve the quality of your biodiesel, then the first and third link in the references will show different recipes and procedures to make high quality biodiesel. It would be helpful also to look through the references with the corresponding pictures so that you could obtain more information about the product or method. Also, if you wish to create large amounts of biodiesel for personal use, then it is suggested you invest in a biodiesel processor. If you are interested in making your own or buying one, information is available here: http://www.make-biodiesel.org/The-Appleseed-Biodiesel-Processor/the-appleseed.html

References