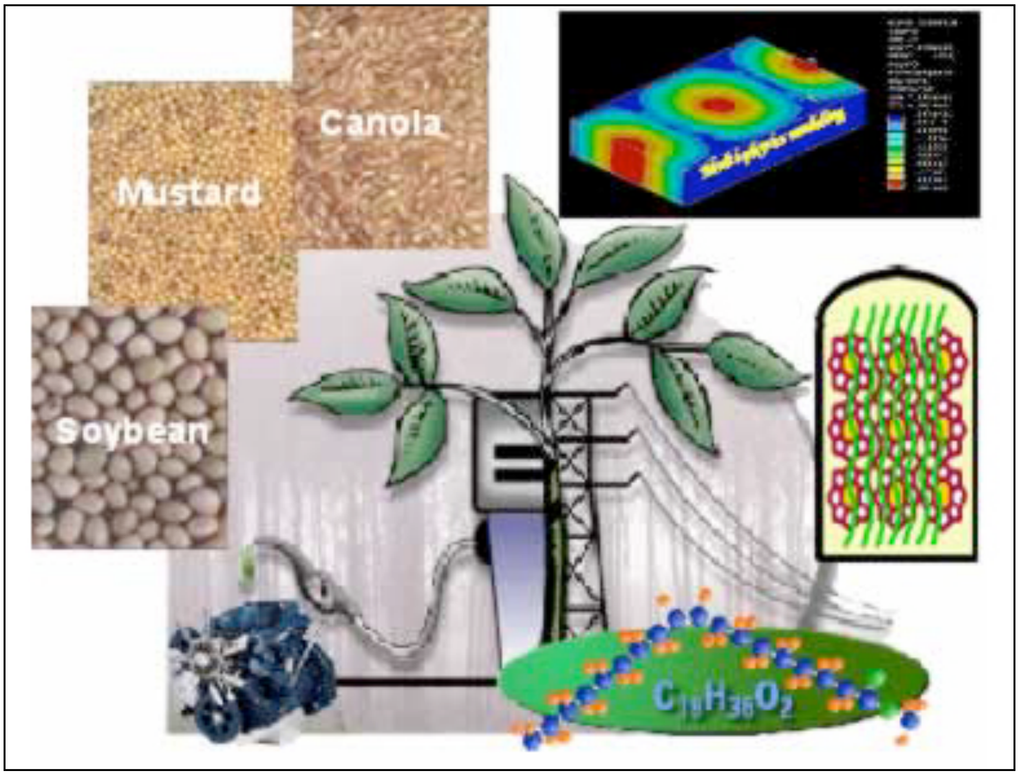
Food or Fuel? (Student Handout)

(The Chemistry and Efficiency of Producing Biodiesel)

Name:______________________________________



Source: http://www.cmu.edu/cmnews/extra/050527_biodiesel.html

Our lab research goal is simple:
To *learn how to make biodiesel from household ingredients and materials.*

In order to build a more balanced energy portfolio for our transportation wants and needs, it is important for you to understand the pros and cons of an alternative fuel like biodiesel. Since the Department of Energy's Office of Biomass Program has discontinued its biodiesel research due to other priorities, we are recruiting you! In the enclosed investigation, your team will synthesize a batch of fuel (that could be used in a diesel engine of a VW Jetta TDI) from oil that can be purchased in the local grocery store. The procedure is relatively simple, but there are some important safety issues to keep in mind. If you are prepared to take responsibility for minding the precautions involved and operate in a SAFETY FIRST fashion, sign below and welcome the potential for a piece of a whole new world of energy security and independence from foreign Oil.

Signed:______________________________________

Dated:______________________________________

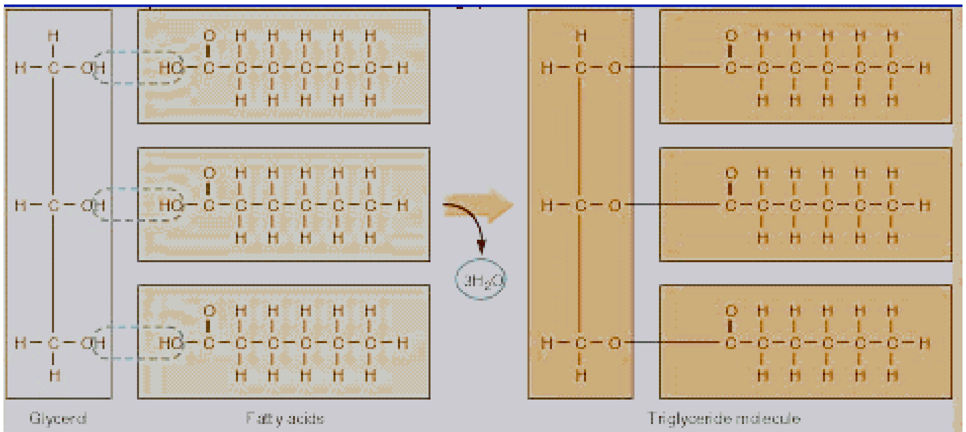
Background (Adapted from the *Biodiesel Handout for the 2005 New Hampshire Science Teacher's Association Workshop*[1] and Kitchen Biodiesel's step-by-step guide[2] to brewing small batches of biodiesel.)

What is Biodiesel Made From?

Biodiesel consists of three principal feed stocks.

1. Oil:

Glycerides are commonly known as oils or fats, chemically speaking these are long chain fatty acids joined by a glycerin backbone. They appear most often with three fatty acid chains connected to the glycerin (named glycerol in the diagram below), making them *trigylcerides*.



Source: www.unh.edu/p2/biodiesel/media/NHSTA05.ppt

In the US, the primary triglycerides used currently for biodiesel production are soybean oil and waste vegetable oil (which is often used soybean oil). Other vegetable oils like corn oil, canola (and edible version of rapeseed) oil, cottonseed oil, mustard and palm oil, etc[3]. To get more information on the chemical structure of different oils you can purchase in the grocery store, visit: http://www3.me.iastate.edu/biodiesel/Pages/biodiesel1.html

During the process of being used in fryolators, some of the triglycerides are broken apart into mono or diglycerides, leaving free fatty acids (FFAs) in the oil. To counter this, additional catalyst must be added according to the acidity of the specific oil, since the FFAs will bond with and neutralize some of the alkali catalyst.

2. Alcohol:

Although a variety of alcohols can be used to produce Biodiesel, such as, ethanol or butanol, this experiment will focus on methanol as it is most readily available, and most frequently used. Therefore, the Biodiesel produced is referred to as *methyl esters*. Methanol is one of the most common industrial alcohols; because of its abundant supply it's most often the least expensive alcohol as well. Most methanol comes from fossil fuels (though it can also be made from biomass, such as wood), while most ethanol is plant-based (though it's also made from petroleum).

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1 UNH Biodiesel Group. *Biodiesel Handout for the 2005 New Hampshire Science Teacher's Association Workshop.* http://www.unh.edu/p2/biodiesel, accessed 15July 2005.

2 Kitchen Biodiesel. "Step by step guide to making one liter batch of Biodiesel in a two liter soda bottle." http://www.kitchen-biodiesel.com, accessed 22 December 2005.

3 Biodiesel Education. "What is biodiesel?" http://www3.me.iastate.edu/biodiesel/Pages/biodiesel1.html, accessed 4 January 2006.

METHANOL

http://www.kitchen-biodiesel.com/Methanol_MSDS.htm**POISON!** Causes eye and skin irritation. May be absorbed through intact skin. This substance has caused adverse reproductive and fetal effects in animals. **Danger! Flammable liquid and vapor.** Harmful if inhaled. May be **FATAL** or cause **BLINDNESS** if swallowed. May cause central nervous system depression. May cause digestive tract irritation with nausea, vomiting, and diarrhea. MSDS

3. Catalyst:

The third reactant needed is a catalyst that initiates the reaction and allows the esters to detach. The strong base solutions typically used are commonly found in stores as lye or chemically know as sodium hydroxide (NaOH) and potassium hydroxide (KOH). The **lye** catalyst can be either sodium hydroxide (caustic soda, NaOH) or potassium hydroxide (KOH); however, NaOH is often easier to get and it's cheaper to use. With KOH, the process is the same, but you need to use 1.4 times as much (1.4025). KOH can also provide potash fertilizer as a by-product of the biodiesel process.

Once again since this classroom experiment will be using NaOH…**CAUTION**:
Lye (both NaOH and KOH) 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. Lye reacts with aluminum, tin and zinc. Use HDPE (High-Density Polyethylene), glass, enamel or stainless steel containers for methoxide (The result of mixing NaOH and methanol).

Sodium Hydroxide

http://www.kitchen-biodiesel.com/naoh.htm**POISON! DANGER! CORROSIVE.** MAY BE **FATAL** IF SWALLOWED. HARMFUL IF INHALED. CAUSES BURNS TO ANY AREA OF CONTACT. REACTS WITH WATER, ACIDS AND OTHER MATERIALS. MSDS

How is Biodiesel Made?

(Here I would put the step by step equations showing the reactants that you just described above, and the mechanism of the reactions. I will help you with this if you need me!)
Vegetable oils and animal fats are triglycerides, containing glycerin. The biodiesel process turns the oils into esters, separating out the glycerin. The glycerin sinks to the bottom and the biodiesel floats on top and can be siphoned off.

The process is called **transesterification**, which substitutes alcohol for the glycerin in a chemical reaction, using lye as a catalyst.

You will be working with DANGEROUS/POISONOUS chemicals. Common sense MUST be used. **You are responsible for your actions and the safety of yourself and everyone/everything around you!**

Recommended Safety Gear:

The minimum is chemical proof gloves, apron, eye protection and dust mask.

Do NOT inhale any vapors.

Always have running water available to wash off any splashes.

Making your Own Biodiesel

Materials for each lab group **All equipment should be clean and dry**

- Safety goggles (for all lab inhabitants!)
- Nitrile gloves-2 pairs
- Long pants and sleeves and lab aprons
- Ventilating masks
- 200 mL of new vegetable oil: We are using ______________________ oil
- 4 mL of methanol
- Lye catalyst, _____ mg NaOH !!! Get your teacher's initials & approval ______
- Scales accurate to 0.01 grams
- 400 mL beaker (for oil)
- glass graduated cylinder or comparable glass measuring device (for methanol)
- 1 canning jar with secure lid and sealing ring
- 2 funnels
- 1 plastic bottle with cap (water or soft-drink bottle clean and dry) for settling

Pre-Lab Preparation:

1. Read over the lab handout.
2. Calculate the amount of NaOH you must use in your transesterification reaction if 3.5 g are needed to process 1 L of new vegetable oil.
3. Read "Biodiesel and Energy Security" (a separate handout) and make note of any questions you may develop about the lab. Take care to look at the procedure carefully…you may have a quiz before beginning the lab activity…

PROCEDURE:

Step 1: **MAKING THE METHOXIDE:**

WARNING: METHOXIDE is a **POISON!** MSDS

DO NOT BREATH VAPORS. WASH OFF ANY SPLASHES.

!!DO NOT MIX THE METHOXIDE IN A PLASTIC SOFT DRINK BOTTLE AS THE NaOH ATTACKS THE PLASTIC AND YOU WILL QUICKLY BE SHAKING A BOTTLE FULL OF HOLES WITH METHOXIDE GOING EVERYWHERE!!

1. In a well ventilated area, measure 4 mL of room temperature methanol using a glass graduated cylinder and pour it into a glass mason jar.

2. Measure out the quantity of NaOH (lye) you calculated earlier and add to the methanol in the jar replacing the lid tightly to prevent any leaks.

3. Shake/swirl until all the lye is dissolved. **As you mix the temperature will increase substantially. This is normal and may take 10 minutes or more to dissolve all of the lye—be patient and swirl until ALL lye is dissolved**

Step 2: **MAKING THE BIODIESEL With NEW OIL**

1. Using a funnel, pour the oil into a **DRY** 16 oz soda/water bottle.
2. In a well ventilated area, pour the mixture of methanol/NaOH (methoxide) on top of the oil using the same funnel.
3. Remove funnel.
4. Screw the top down TIGHT onto the bottle.
5. Shake vigorously for about ten seconds/ 40 good shakes.
   *NO appreciable pressure is generated during this mixing.

6. Now place the bottle on a table and begin work on the *Questions to Consider* section of the lab handout.
7. After 10 minutes, take a look at your product and shake vigorously for about ten seconds again.
8. After another 10 minutes, catalog (diagram with labels) what has happened in the box below or in your lab journal.

Diagram of biodiesel product after two shakings:

9. Follow your teacher's instructions for next steps with your biodiesel product and complete the Questions to Consider for homework.

Questions to Consider

1. Which substance in this reaction is the catalyst?______________________
2. What kind of reaction is this? _____________________________________ [Hint: it generates heat…]
3. What might the "glop" that is settling out be? __________________________
4. Why is this reaction called *transesterification*?

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5. What does biodiesel look like? (at the molecular level, using chemistry notation)

6. How might our processing technique be improved to make a better biodiesel product?

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7. How can biodiesel contribute (if you feel it can at all) to our future?

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Analyzing Your Product:

Possible errors:

1. Soap formation. You can get this if using waste vegetable oil that is heavily used, or using too much catalyst. Any Free Fatty Acids (FFAs) will combine with the alkaline catalyst (NaOH or KOH) to make soap (which is why you need to use extra NaOH when dealing with used oils with FFAs). These soaps need to be removed from the biodiesel by "washing" it (discussed later). A large amount of FFAs can result in enough soap forming to turn the entire reaction into a bunch of "glop" (non-scientific term). If using waste vegetable oil (WVO) with high levels of FFAs (determined via titration), a slightly different process can be used, known as an "acid-base" process (whereas this process discussed is strictly a base catalyzed process). In the acid-base process, you first add some acid (hydrochloric typically) and a small amount of methanol to esterify the FFAs into biodiesel, and then do the normal base catalyzed process to convert the triglycerides into biodiesel. With high FFA oils, the normal base process doesn't yield as much biodiesel, since the FFAs are being turned into soap (and removed through washing). The acid-base process allows you to turn those FFAs into biodiesel.
2. Not enough lye, resulting in unreacted oil.
3. Not enough alcohol (reaction does not proceed to completion), can also get more soap formation.
4. Water in oil (results in catalyst being broken apart, and more soap formation)
5. Not enough reaction time (a common problem with demonstration batches like this. Ideally you want to mix for an hour or so, at a slightly elevated temperature (120-130º F). The reaction does not proceed instantly from triglycerides (oils) to 3 biodiesel molecules (per triglyceride). Instead, the methoxide first cleaves off one fatty acid (making one biodiesel molecule from it, by combining with the methanol), leaving a diglyceride (DG). If there is further agitation, the DG is broken apart by the methoxide to make another biodiesel molecule and leaving a monoglyceride (MG). Further agitation breaks that MG apart, making the third biodiesel molecule and leaving free glycerin. If the agitation does not continue long enough (or is not repeated multiple times), you will likely not see full conversion of triglycerides to biodiesel, instead being left with some MGs and DGs, which will often show up as white "chunks" when the fuel cools down to room temperature.

Additional analysis notes