Making Crude Biodiesel from Vegetable and Coconut Oil

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ABSTRACT

The use of diesel in modern transportation poses a serious threat to the health of the population while simultaneously creating a negative footprint on ecological systems and urban environments. The focus of this experiment was to explore 1) how biodiesel and biodiesel variants can be created in the lab environment, and 2) how biodiesel and coconut biodiesel equate to diesel within the field of energy and emissions. In order to make biodiesel and coconut biodiesel, students combined potassium hydroxide, methanol, and oil variants in two separate ball jars, which were then separated into crude biodiesel and crude glycerin through use of a filter. The observations made during the lab in regards to diesel vs. biodiesel showed that the diesel was a darker color and gave off a darker smoke than biodiesel. In additional tests, it was observed that the coconut biodiesel was light and burned with less smoke than the pure biodiesel. These results imply that, if usable in diesel engines, coconut oil biodiesel would provide a cleaner source of energy in modern transportation than both traditional diesel as well as biodiesel.

Figure 1: Diesel emissions often contain nitrogen dioxide (NO_2), which, in combination with air particles, can be seen as a reddish-brown layer over many urban areas. (Image Courtesy of MSN)

INTRODUCTION

Diesel Engines & Petroleum Fuel

In the 1890's, engineer Rudolf Diesel patented a compression ignition, internal combustion engine named the "diesel engine" after its creator. Treated as waste for decades, the true potential of petroleum byproducts was not fully understood until the days of Diesel and his associates. Diesel engines using petroleum fuel were largely popular upon their introduction because they provided an alternative method of transportation that was much more powerful and cost efficient than the traditional coal powered engines of the time.

Over the years, diesel technology has grown into a popular source of energy for large vehicles, as well as many public transportation alternatives. Unfortunately, this source of energy is not entirely without consequence. The widespread use of petroleum fuel has had many unprecedented effects on the social and ecological structures of the world. These downsides include (but are not limited to) high carbon dioxide emissions, as well as a high amount of NOx emissions in comparison to other modern power sources. These negative effects have left scientists searching for a more safe and effective alternative to meet the needs of this field and the health of the earth.

Biodiesel Fuel

Many in the field of early diesel development (including Diesel himself) envisioned vegetable oil and byproducts being substituted for petroleum in diesel engines used for agriculture in rural areas of the world that did not have access to the latter. Interested in vegetable oil as a domestic fuel for their African colonies, the French led much of the early research in alternative fuels and biodiesel. With the rise in popularity of petroleum in the 19th century, vegetable oil was almost completely forgotten in the search for more powerful and economic engines. As of recently, however, concerns about the environment and energy security have caused biodiesel to return to the forefront of the energy debate.

Providing a cleaner emission process, biodiesel would seem like the perfect solution to the environmental impacts that diesel can have on the environment. The reduced emissions benefits of biodiesel are especially significant, since the majority of carbon dioxide released from engines during combustion is offset by the CO2 captured by plants which biodiesel is produced from. Varied blends of biodiesel can have large impacts on carbon emissions, reducing emissions from petroleum engines by 15% for lower concentrations, and up to 75% for high/pure concentration biodiesel blends (AFDC, 2015).

By doing this experiment, we will learn the process by which biodiesel and biodiesel variants can be created in the lab environment, and observe how the burning of biodiesel vs. coconut biodiesel compares in relation to smoke emissions, heat, etc. We anticipate that the outcomes of these tests will support current evidence in regards to these fields.

❑ METHODS

In preparation for the lab, the amount of reagents and catalysts were calculated. For every 1L of vegetable oil used, 0.2 L of methanol and 8.0 g of KOH were added. The first step in the lab process was to make the reagent potassium methoxide. To make potassium methoxide, ~2 g potassium hydroxide was combined with 40 mL methanol in a ball jar. After combining these two compounds in the ball jar, the lid of the jar was securely fastened and the contents of the jar were shaken until all pieces of KOH had dissolved. After creating the homogeneous mixture of potassium methoxide, the lid of the ball jar was removed and 200 mL of vegetable oil was added to the mixture. After returning the lid, the mixture of vegetable oil and potassium methoxide was shaken for ~10 minutes, until the reaction turned a bright yellow color. During the reaction the fatty acids from the triglyceride molecules, which is the vegetable oil, are split and attach to the molecules from the methanol, which then reacts to create biodiesel, this is shown in Figure 2 The base, KOH, is used as a catalyst during this reaction to increase the rate of the reaction. Once the reaction turned bright yellow, the mixture was placed in a filter in order to let the crude biodiesel and crude glycerin separate. After the crude biodiesel and crude glycerin had separated, the crude glycerin was drained and disposed of in a waste container. The remaining liquid was sprayed with distilled water to remove any extra glycerin/KOH particles from the vegetable oil biodiesel.

To make biodiesel with coconut oil, to steps above were repeated, but 200 mL coconut oil was used in place of 200 mL vegetable oil. Coconut oil comes in the form of a solid, therefore it must be melted completely before being added to the potassium methoxide.

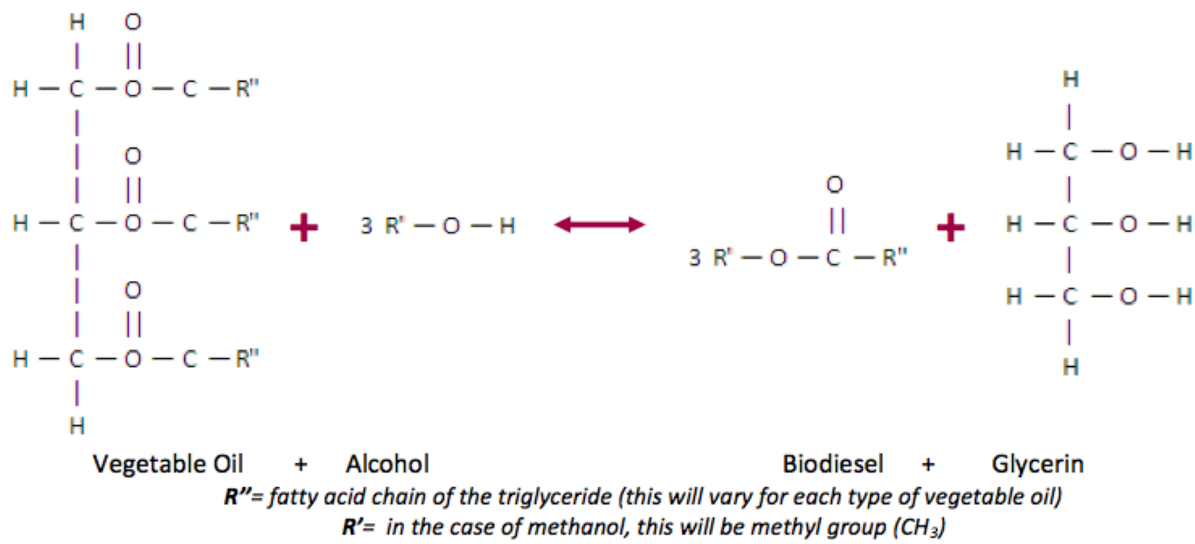

Figure 2: Particulate representation of chemical reaction of vegetable oil, methanol, and KOH becoming biodiesel and glycerin. (Image Courtesy of Loyola University Chicago)

❑ HAZARDS

Students worked with a set of compounds throughout this lab that required special attention in regards to safety and disposal. The first compound requiring safety precautions was potassium hydroxide (KOH). Potassium hydroxide can be hazardous in cases of skin contact, eye contact, ingestion, or inhalation. The amount of tissue damage caused by this substance depends on length of exposure. To prevent the chance of acute or chronic health effects associated with potassium hydroxide, students wore lab goggles and protective gloves as prescribed in lab safety manuals. In addition to these safety measures, students took special care to avoid inhalation of this substance.

The next solution used was methanol (CH_3OH). Methanol is a highly flammable substance, so students worked in a lab environment completely free of open flame. Methanol is irritating to the eyes, and can be toxic if inhaled, absorbed by the skin, or swallowed. To avoid these risks, students worked in a fume hood and ensured that no bottles of methanol were open while not in use. To prevent the chance of acute or chronic health effects associated with methanol, students wore lab goggles and protective gloves as prescribed in lab safety manuals To dispose of the crude biodiesel and byproducts, students followed guidelines provided by provincial and federal disposal requirements. All materials were disposed of in a waste container to be transported at a later time.

❑ RESULTS

$\frac{200ml\ oil}{1000ml\ oil}$ $\frac{40ml\ methanol}{200ml\ methanol}$ $\frac{1.6g\ base\ KOH}{8g\ base\ KOH}$

Table 1: Observations of Biodiesel

Type of Biodiesel	Observations
Coconut Oil Biodiesel	• Burns cleaner • Light yellow/white in color
Vegetable Oil Biodiesel	• Burns not as clean as the coconut biodiesel • Yellow, egg like, in color

Table 2: Observations of Reactions During Lab

Reactions	Observations
Methanol + Base (KOH)	= potassium methoxide • Mixture bubbles • Container gives off heat

- While making the coconut oil biodiesel we had to heat the coconut oil up because at room temperature coconut oil is a solid. We heated it up until we had 200 ml of coconut oil in liquid form. We then completed the experiment as detailed in the methods section. Oven mitts were used in order to shake the biodiesel because it was extremely hot.
- When the two different biodiesels were burned, we noticed that the coconut oil biodiesel burned hotter and cleaner than the vegetable oil biodiesel. The flame on the coconut biodiesel was larger and did not produce smoke. The vegetable oil when burned, burned as a smaller flame, as well as produced some smoke towards the end of when it was being burned.

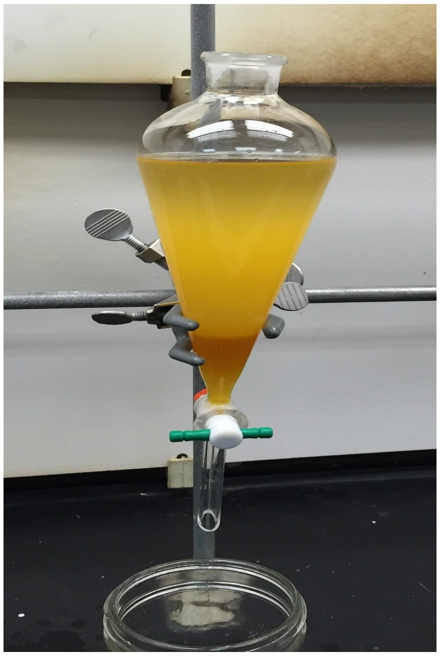

Figure 3: Vegetable Oil Biodiesel

Figure 4: Coconut Oil Biodiesel

❑ DISCUSSION

We chose to make coconut oil biodiesel in addition to vegetable oil biodiesel because of the recent popularity of coconut oil in skin care, hair care, and health food. We were curious to see if a healthier oil, like coconut oil, would work better than the vegetable oil in regards to biodiesel. It can be inferred from the tests performed on the biodiesel vs. coconut biodiesel that if usable in modern diesel engines, coconut oil would be more effective at achieving high temperature burning while simultaneously providing a cleaner source of energy. If pure coconut oil is used in a diesel engine, smoke emissions are reduced by ~75%, NOx emissions reduced by ~40%, and CO2 emissions reduced by ~15% (Engineers Without Borders Australia, 2010). However, since diesel engines are designed to operate based on specific viscosity thresholds and combustion rates, raw coconut oil will cause damage to diesel engines over time. This is why, if coconut oil were to be mixed with potassium methoxide, as done in this experiment, the fuel may be perfectly suited to power diesel engines. By combining coconut oil and biodiesel, the burning rate of the oil will be lowered, and the engine can run more smoothly and effectively at a cheaper rate than other fuel variations. Overall we found that burning coconut oil biodiesel is a cleaner and more efficient diesel than the vegetable biodiesel and perhaps is a better solution for the world's energy needs.

The uncertainty in this experiment arises from the “cleansing” of the crude biodiesel blends. Although these tests did not include steps to test purity of the crude biodiesel, this could have been one of the next steps in our exploration of this topic. When we completed this lab, we had cleansed our biodiesel blends fairly well, but it may have been worth it to spray the biodiesel with distilled water a couple more times just in case we wanted to do any further exploration. Additionally, it would be a valuable learning experience to test our biodiesel and coconut biodiesel blends in a standard diesel engine and test efficiency, measure carbon dioxide emissions, and measure NOx emissions. The data from these tests could then be collected and compared to current data from varying sources.