Designing Renewable Energy Experiments

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Introduction

Society is becoming more and more aware of the need for viable renewable energy resources, which is why it came as a shock to our group that there were no lab-based courses that focused on renewable energy at an undergraduate level. Most renewable energy labs were either designed for a high school level class or a graduate level class. This project is attempting to construct an experiment based course on renewable energy that is acceptable for undergraduate students in the junior and senior level.

The course was chosen to be experiment based because of the value experiments often provide students. Experiments can help a student see exactly what is happening when they are having trouble understanding a topic, as well as providing real world results based on what the student has learned. These experiments also help teach students a range of skills such as how to use certain pieces of equipment they may come across in their professional careers, like a calorimeter or a stirring plate. They also teach students skills such as how to properly take notes and readings, as well as observations, during experiments. Students then learn how to parse through the notes and observations they have gathered and turn them into a coherent report about their findings.

Several groups of students teamed up to work on this project together, with a selection of renewable energy topics to focus their efforts on. Some of the other students focused on different renewable energy topics such as photovoltaic cells, gas from anaerobic digestion, and thermocouples to harvest heat as different topics for experiments to be run in the course. One group of students was also tasked with the job of creating a curriculum and schedule for the experiments to all fit together into a complete undergraduate lab course. This paper will focus on making biodiesel from different feed stocks.

Background

Renewable Energy Background Information

Renewable energy is an important field as society continues to understand the impacts of our current fossil based energy sources. Renewable energies in general tend to be cleaner sources of fuel than their conventional counterparts. This helps lessen the environmental impact of our continually growing energy needs. These energies were starting to be developed during the late 1960's and 1970's, but there was little interest from the public. The technology required for renewable energy to really become a viable source was also very expensive and had a long way to go to reach efficiency levels required to compete with conventional resources.

In recent years, renewable energy has started to become more and more important to not only the public, but scientists and world leaders. Many new technologies as well as improvements to older technology have helped to make renewable energy competitive with conventional sources of energy, which is helping to increase interest in the topic. As the interest in renewable energy increases, more funding is made available from governments, which helps to rapidly increase the research efforts invested in this area. Some renewable energies are now being used on a very large scale such as solar energy or biofuels. Biofuels, for example, are now up to almost 1.4 billion gallons of production per year. (U.S. Energy Information Administration, 2013)

Biodiesel Background Information

Ideally, we would like to use a completely renewable energy source in order to fuel our cities and vehicles; however most renewable energy technology is not quite complete enough to take on tasks of that magnitude. This is where biodiesel can help alleviate the current strain on the environment and our resources. Biodiesel is a vegetable oil or animal fat based diesel fuel meant to be used in existing diesel engines. The traditional engines will need slight modifications as there are a few minor problems with using the biodiesel in them, but it serves as a very important resource for the current environment.

Since biodiesel is a transportable fuel, it can be used in environments that may not have access to the sources that some other renewable energy forms require. For example, photovoltaic cells are very efficient in deserts like Arizona, but they would become much less efficient in an environment that sees more precipitation like Seattle. This is where biofuels have an advantage over other fuels such as hydrogen. Biofuels have a very high energy density, comparable to conventional fossil fuels. The high energy density means that less storage space is required to transport the fuel. Most biofuel does have a slightly lower energy density then conventional fossil fuels, but those same biofuels can decrease some of the negative impacts such as greenhouse gas emissions by up to 50%.

Biodiesel can use different feedstocks, but the most common feedstocks are vegetable oils (such as rapeseed and soybean oil), various animal fats, and waste vegetable oil. Soybean oil alone makes up for over half of the biodiesel production in the U.S. Each feedstock has its own limitations, for example, soybean biodiesel has very high energy density and a high net energy balance, but the amount of biodiesel that is gathered per acre of feedstock grown is very low. The farmers must also consider which feedstocks will impact their land the least and balance that with the profits they may get from the various choices which can cause even more problems.

Animal fats do not suffer from the same problems as vegetable oils since they do not necessarily need to be grown for the express purpose of creating biodiesel. However simply using the leftover animal fats to create biodiesel cannot make the same quantities that vegetable oils can. Animal fats that are not used to make biofuels are typically used in pet food, soap, and various other products.

Once a feedstock for the given situation is chosen, methanol is mixed in as a catalyst for the reaction, which will generate biodiesel. The alcohol will strip the feedstock down and form glycerol and methyl esters, as shown in figure 1. The glycerol is then removed from the mixture leaving only biodiesel behind.

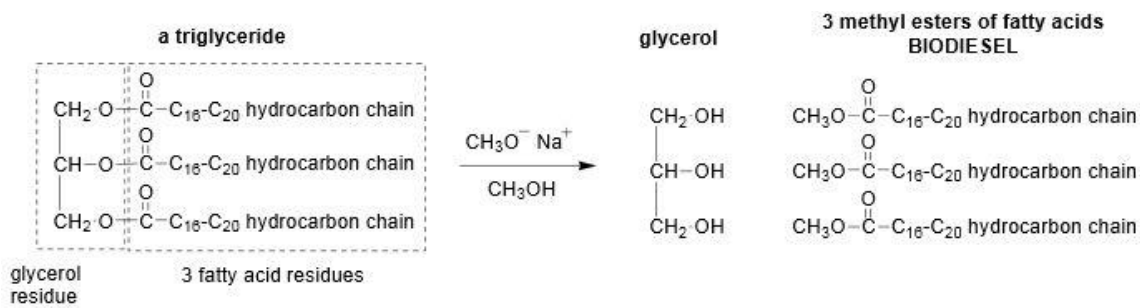

Figure 1: Chemical reaction to create biodiesel

Pure biodiesel is very viscous in nature, which can lead to problems if it is used in regular diesel engines. The high viscosity means that at low temperatures, biodiesel will have trouble igniting initially to start the engine. It will also plug the fuel filters and fuel lines much more often than normal diesel. Some diesel engines will also experience engine knocking if pure biodiesel is used with no modifications to the engine. Furthermore, the high viscosity of the biodiesel can result in excessive engine wear if nothing is done to the fuel.

However, these problems are not too difficult to overcome. In fact, the most common biodiesels used are blends of biodiesel and conventional diesel. A blend of 20% biodiesel and 80% conventional diesel is called B20 and is the highest biodiesel content that most engines and machinery can use without modification. Some of the most common blends are B100, B20, B5, and B2. The cold weather starting issues will be fixed if a blend of B20 or less is used instead of a more difficult B100 blend. (National Renewable Energy Laboratory, 2009) The biodiesel can also be filtered down to 4 microns, which should help combat the plugging of the fuel lines and filters.

As for the engine knocking, that problem will be helped by the blend of biodiesel and regular diesel, but it may also require adjusting the injection timing to completely eradicate the issue. The excessive engine wear will be helped by a blend rather than pure B100, but it can also be decreased by heating the fuel prior to injection as well as using motor oil additives to inhibit oxidation. If a B100 blend was desired, there would have to be much bigger modifications and different material selections in the engine.

Biodiesel and Bioethanol

One of the main alternatives to biodiesel is bioethanol, of which the most common form is corn ethanol. Bioethanol is an alcohol product that is produced from feedstocks such as corn, potatoes, wheat, and vegetable waste. When bioethanol is combined with conventional gasoline, it increases the octane level of the fuel and helps to burn more of the fuel. The more complete fuel combustion helps to reduce harmful emissions that conventional gasoline is more prone to produce. This corn ethanol has gained significant popularity due to the excess of corn that our country has.

Bioethanol may make a bigger impact because there are more gas-burning vehicles than there are diesel vehicles. But that does not necessarily mean that it is the more potent of the fuels. Bioethanol has an energy density of 25.7MJ/L which is only 70% of the energy density that biodiesel can achieve. (U.S. Department of Energy, 2013) Biodiesel also requires less energy to be spent for the fuel to be produced, giving a higher return on the energy spent. Corn ethanol will generate about 25% more energy than what would be spent generating the ethanol. Soybean biodiesel however will generate up to 90% more energy than what is spent processing it as one can see in Figure 2.

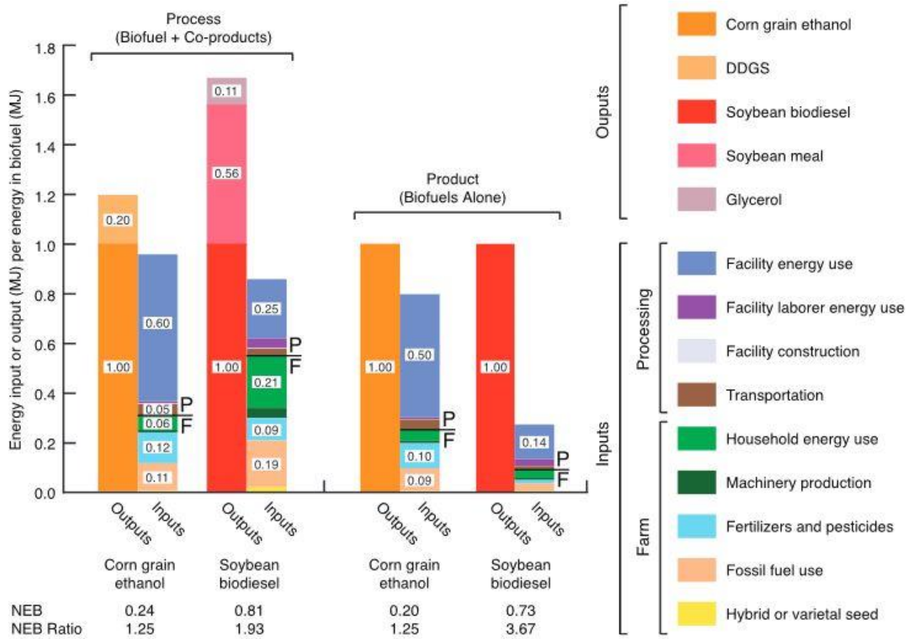

Figure 2: Net Energy Balance of Corn Grain Ethanol and Soybean Biodiesel (Jason Hill, 2006)

Experiment Background

The purpose of the biodiesel lab is to determine the energy density of biodiesel compared to bioethanol and to discuss it as a renewable energy source. Fuel, especially transportation fuel, must have an acceptable energy density or else the fuel would not be easily transported. For example, if a fuel had a very low energy density, a car would need an extremely large fuel tank to hold enough to get anywhere, whereas a very high density would allow the same car to fit much more fuel and travel much further.

Another important idea that this experiment hopes to convey is the idea of what can be used as feedstock. I personally would never have considered soybeans to be a viable fuel source for a car, but after this project I have realized that there are a great many fuel sources that can be used. Students should walk out of the class understanding that fuel doesn't come from just fossil fuels.

Students will be given a short reading before the experiment to help them learn about biodiesel before they go into the lab to make it themselves. This review will provide the students a good overview of biodiesel without going into too much detail that may confuse or overwhelm them. (Biodiesel: The New Energy Lifeline) The students will be asked several questions about the reading material to show that they have a basic understanding of biodiesel such as which compounds are left over after the chemical reaction, or if biodiesel is hygroscopic. Examples of questions and answers can be found in Table 1.

Questions	**Sample Answer**
What is biodiesel?	Biodiesel is a mono-alkyl ester of fatty acids that can be used as a renewable fuel.
What types of feedstocks can be used to create biodiesel?	Biodiesel can be made from vegetable oils, animal fats, and algae.
How much glycerol byproduct is produced by a 5 gallon batch of biodiesel?	Approximately 1.1 gallons of glycerol will be produced.
Does increasing the amount of biodiesel in your fuel blend have any drawbacks?	Yes. You will see a roughly 2% increase in nitrous as well as a drop in fuel efficiency of about 2% by the time you reach 100% biodiesel.
Is biodiesel hygroscopic?	Yes, to the point that it will potentially attract water molecules out of the atmosphere around itself.

What compounds are left after the chemical process has completed?	You will be left with mono-alkyl esters and glycerol.

Table 1: Pre-reading Questions and Answers

There are a few safety precautions for the execution of this lab, though they should be familiar to any students who completed freshman or sophomore year chemistry classes. Most of the safety is simply not touching any of the chemicals with bare skin and a danger of them catching fire, as displayed in Table 2. Students should wear safety goggles and gloves at all times to minimize this risk.

Methanol	Sodium Hydroxide	Sodium Methanol / Potassium Methanol	Potassium Hydroxide
Highly flammable		Highly flammable	
Corrosive: will burn bare skin	Corrosive: can burn bare skin and eyes	Can burn if inhaled or touches bare skin	Corrosive: can burn bare skin

Table 2: Safety Hazards

The equipment for this lab is listed in Table 3. The materials listed will allow for two experiments to be run with a variation in catalyst. Materials may need to be adjusted based on the variables that students are to be changing. For example, if a group is using soybean oil for one feedstock, and rapeseed oil for the second feedstock, they will only need 100ml of each one.

Equipment	**Materials**
Stirring Plate	200ml Vegetable Oil
Hot Plate	40ml Methanol (99% Purity)
Balance	0.35kg Finely ground NaOH
Thermometer	0.9kg Finely ground KOH

Stir Bar	100ml Water
2 x 250ml Erlenmeyer flask	
100ml graduated cylinder	
100ml beaker	

Table 3: Required Equipment and Materials

One of the main pieces of equipment for this lab will be a cone calorimeter. Very few, if any students will know how to work this device, therefore this lab will be useful for teaching them how to use it. A cone calorimeter works by igniting the sample via electricity from a conical heater which helps produce a uniform heat flux across the surface of the sample. As the sample burns, it will heat up the surrounding air, which will expand and escape through a copper tube that leads the air out of the container. The copper tube heats up water which is surrounding the tube. The temperature of the water is how the cone calorimeter calculates the caloric content of the fuel. Figure 3 shows a standard setup of a cone calorimeter.

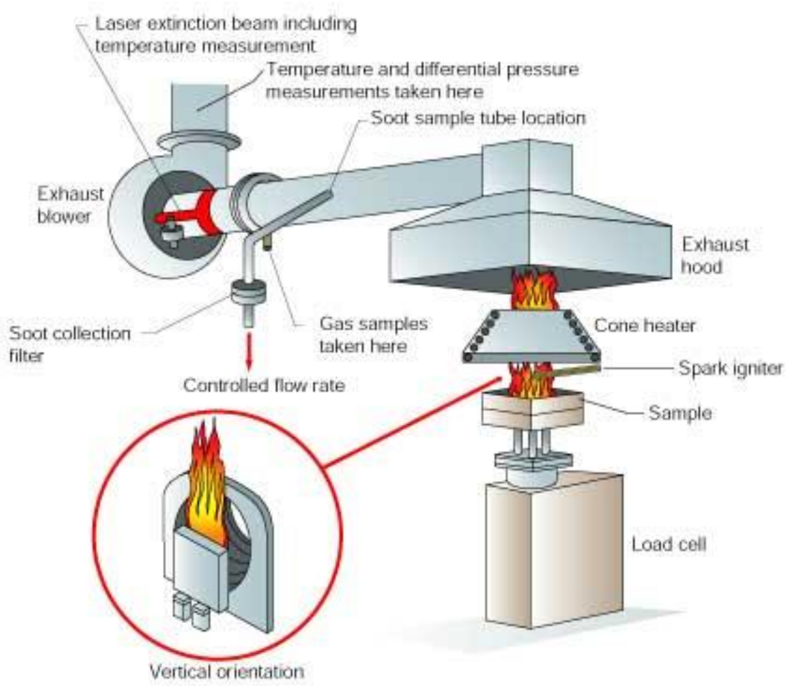

Figure 3: Diagram of a Cone Calorimeter (Cone Calorimeter)

Methods

Experiment Process

The first step of the experiment, outlined in figure 4, consists of filtering the vegetable oil that will be used as feedstock for the experiment. This can be done ahead of time. The students will need to measure out the proper amount of catalyst; either 0.35g of sodium hydroxide or 0.9g of potassium hydroxide. Then they should measure 20mL of methanol. The methanol will dissolve the catalyst and this new mixture will help turn the oil into a mixture of glycerol and methyl ester.

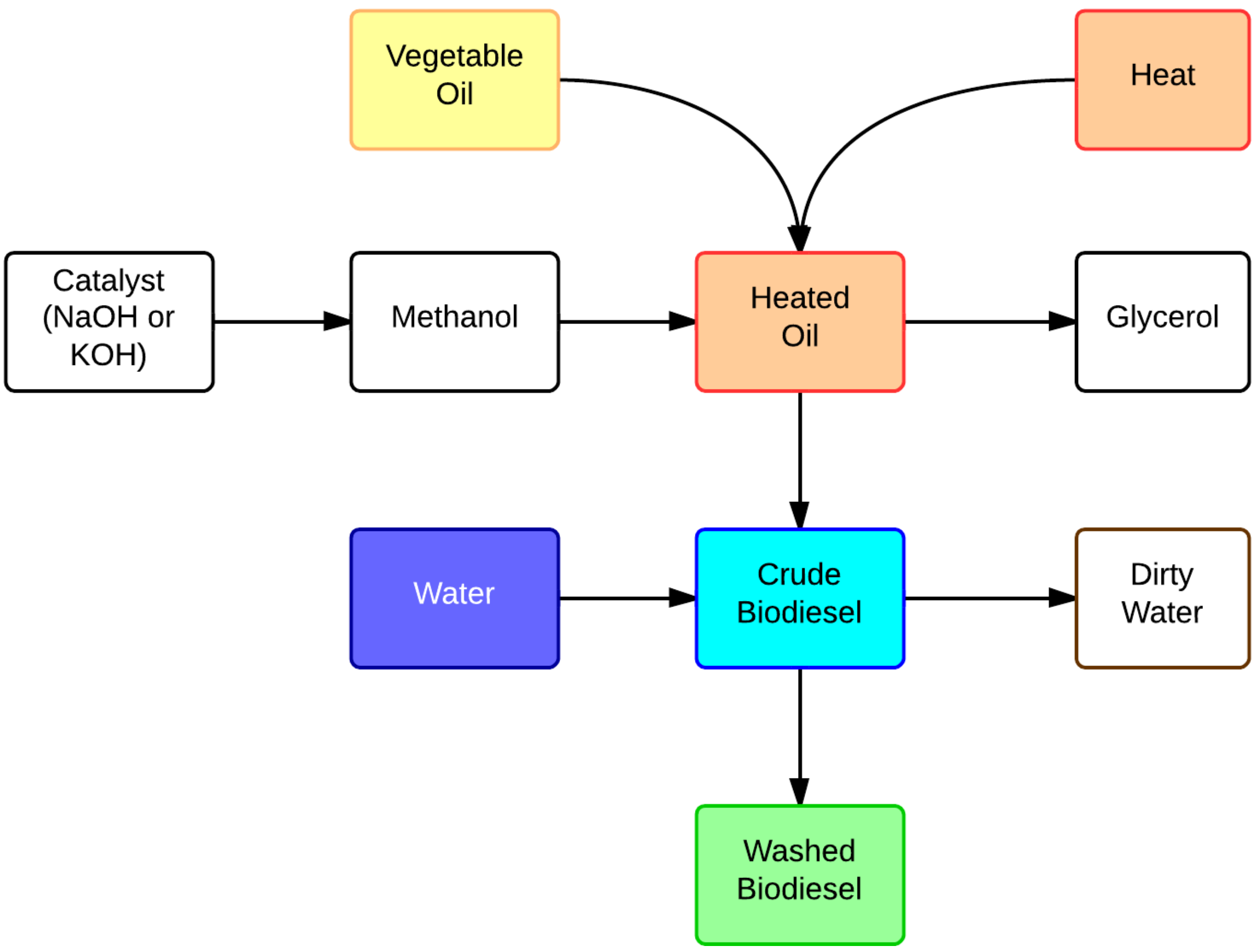

Figure 4: Flowchart of Processes

Place the stir bar in a 250mL Erlenmeyer flask along with the catalyst and methanol and place the flask on the stirring plate to help dissolve the catalyst. Measure out 100mL of oil and heat the oil to 40°C. Once the catalyst and methanol mixture is dissolved, add the heated oil to the catalyst and methanol mixture and let the stirring plate continue to stir the mixture for at least 15 minutes. Carefully remove it from the stirring plate and remove the stir bar and set the mixture aside. The mixture will now need to sit overnight in order to let the glycerol be separated from the biodiesel.

Now repeat the process again, but do one of the following differently: use a different feedstock, use a different catalyst, or run the experiment the exact same way again and alter the experiment later in the process. If possible, students should check their samples multiple times over the next few hours to see if they can notice how quickly their selected catalysts are working.

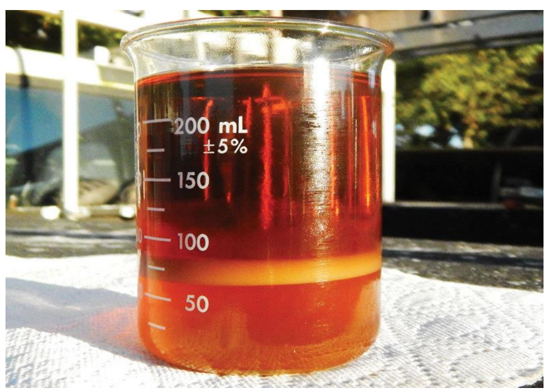

Figure 5: Separation of Biodiesel and Glycerol (Hobden, 2014)

After being set aside overnight, the mixture should be a very visible two layers once the mixture has properly separated, as seen in figure 5. Carefully drain the biodiesel layer into a beaker. Add approximately 50mL of water to the biodiesel and let it separate again. If your second experiment did not alter anything, then do not add the water to one of your biodiesel samples. Now the biodiesel can be drained off the top of the beaker and used in the cone calorimeter. Measure the resulting caloric content of the biodiesel from the cone calorimeter.

Lab Instructions:

1. Filter vegetable oil
2. Measure 0.35g of NaOH or 0.9g of KOH
3. Measure 20 mL of methanol (99% purity)
4. Place magnetic stir bar in a 250 mL Erlenmeyer flask
5. Place 0.35 g of NaOH (or 0.9g of KOH) and 20 mL methanol in flask
6. Place flask on stir plate
7. While the NaOH (KOH) is dissolving, prepare 100mL of oil
8. Heat oil to 40 degrees C
9. Once the NaOH (KOH) is dissolved, pour the oil into the mixture
10. Continue to stir for 15 minutes
11. Remove stir bar and place mixture aside to separate overnight
12. Repeat steps 2-11 only with your group's chosen variable altered
13. Drain biodiesel from the top (the bottom is glycerol)
14. Depending on your group's variable, 50ml of water are added to the biodiesel
15. Let settle again and drain the biodiesel off the top
16. Use cone calorimeter to determine the energy density of the different biodiesels

Experiment Discussion

Once the caloric content of the biodiesel has been determined, the students can begin to tackle the analysis questions. Some questions should be straightforward, such as whether or not washing the biodiesel will have any effect on the energy density of the final product. The washing should increase the energy density of the biodiesel since it would be removing any particles leftover from the chemical reaction from the mixture.

Students should also try to determine whether or not the different catalysts provided any change in the resultant energy density. There should not be a noticeable difference in energy density since the catalysts only help to speed up the reaction, not change the fundamental reaction. Something that the students and teacher may want to tackle is determining if filtering the biodiesel after washing instead of before washing has any effect on the energy density.

If the students have run the proposed lab on bioethanol, they should compare the results of the two labs. They should expect to see an increase in energy density from bioethanol to biodiesel, as biodiesel tends to have a higher caloric content. Something that the students should also try and figure out is the effect that different feedstocks have on the resultant energy density.

Question	Sample Answer
Did washing the biodiesel increase the energy density?	Yes, it was increased by 15.33%
Did the different catalysts change anything?	Yes, the KOH seemed to work faster than the NaOH, but they both had similar energy densities.
Which feedstock would be cheapest while still providing a good energy density?	Soybean vegetable oil is a cheap and powerful feedstock, as proven by our experiment.

Table 4: List of Sample Analysis Questions and Answers

This experiment will work well as an early part of the proposed course on renewable energy since it isn't too complicated, but should ease students into the course. The analysis questions can be modified depending on the level of students that are taking the course, asking for more in depth answers if the students are a higher level. This experiment is also designed to be run after a previous experiment on bioethanol has been completed. Unfortunately, the experiment has not undergone a complete test run, so it should be run several times to get an idea of what exactly the students should be getting for results, but the process should not have any problems.

Conclusions

This report summarizes a biodiesel experiment for upper-class undergraduates in an engineering program. The experiment detailed was designed as part of a lab-based course on alternative energy and energy sources. The experience will teach students several safety precautions as well as proper lab techniques such as how to make good observations and take proper notes. The experiment will then teach students how to write a lab report and analyze the results gathered and how to extrapolate those results to a more meaningful scale.

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Appendices

Pre-lab Reading

Biodiesel:The New Energy Lifeline

Aruna. J and Geetika Pant

Introduction

The world's energy demand continues to increase as we use more and more machines in our day-to-day lives. Short supplies of fossil fuel energy are already being strained to capacity to meet the burgeoning demand of energy posed by developing countries such as India and China. How we supply our energy needs and with what fuels is becoming more and more of an issue, both economically and environmentally.

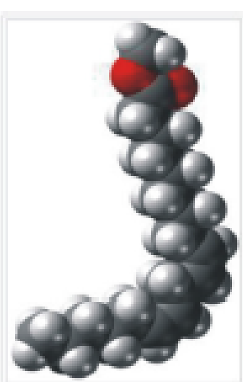
Digging into the past annals we found that, during the twentieth century, energy consumption increased dramatically and an unbalanced energy management came into being. As a result of this inequilibrium and rapid declining of fossil fuels, a considerable interest was focused on the further development and expansion of an alternative source of energy.

The most early attention was trapped by using nonfossilized organism or byproducts of these organisms. These were categorized as biofuels, a sustainable energy source with continuous growth/burn cycle.They have emerged as a new alternative source of energy, satisfying both economic and environmental requirements.

Earlier, the focus of commercial sector was on ethanol,but interest is now growing in the area of biodiesel production. Reasons for this growing interest include its potential for reducing noxious emissions, contribution to rural economy, as a demand center for agricultural commodities and a way to reduce reliance on foreign oil.

What is Biodiesel?

Biodiesel generally refers to the mono-alkyl esters of fatty acids, which can be derived from a variety of vegetable oils and animal fats. It is the product of chemical reaction between the basic feedstock (vegetable oil or animal fat) and alcohol (methnol) in the presence of a catalyst (NaOH or KOH)1. The reaction results in a compound called fatty acid alkyl ester (biodiesel) and a byproduct, glycerol.



Space filling model of Linoleic acid methyl ester (biodiesel)2

The general conversion of feedstock to biodiesel

100 lbs. of feedstock+ 10 lbs. of methanol → 100 lbs. of biodiesel+ 10 lbs. of glycerol

The chemical reaction includes Transesterification :

During transesterification a basic catalyst breaks the fatty acids from the glycerin one by one. If a methanol contacts a fatty acid they will bond and form biodiesel.

Sources of Biodiesel:

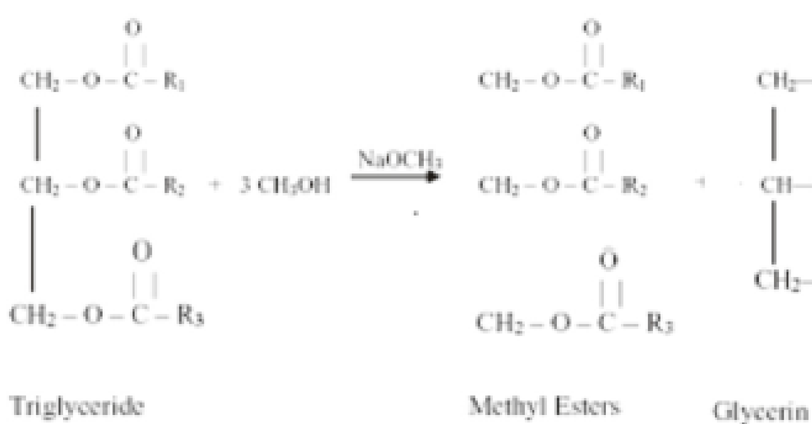
A variety of oils that can be used to produce biodiesel are as follows:

- Virgin oil feedstock: Rapeseed and soybean oils are most commonly used, soybean oil alone accounting for about 90% of all fuel stocks in the US. It also can be obtained from field pennycress, Jatropha, other crops such as mustard, flax, sunflower, palm oil and hemp.
- Waste vegetable oil (WVO).
- Animal fats, including tallow, lard, yellow grease, chicken fat, [3] and the by products of the production of Omega-3 fatty acids from fish oil.
- Algae, which can be grown using waste materials such as sewage[4] and without displacing land currently used for food production.

How to Make Biodiesel?

Biodiesel is made by chemically altering the molecular structure of any organic oil through the use of a chemical catalyst and an alcohol.

Biodiesel production involves the following procedure[5]:



Transesterification of Triglyceride with Alcohol

A. Prerequisites :

Determining the pH of biodiesel:

Myth : It is not possible to truly determine the pH of biodiesel because it is not an aqueous solution (and pH is the measurement of hydrogen ions in water).

Fact : Biodiesel is hygroscopic and will always have a tiny bit of water (about 1200 ppm) absorbed from the atmosphere, if from nowhere else. It is possible to measure its pH.

Titration

A method of determining the concentration of a dissolved substance (vegetable oil), in terms of the smallest amount of a reagent (potassium hydroxide) to bring about a given effect (i.e., Neutralize the FFAs) is the aim of titration. Phenolphthalein is a great indicator for titrating biodiesel. It is colourless unit pH 8.3, then it turns pink (magenta), and red at its maximum of pH of 10.4 (accurate titration pH 8.5).

B. Steps Involved

Step 1: *Titration method for determining how much catalyst needed to neutralize the fatty acids in the used vegetable oil.*

- Dissolve 1 gram of KOH in 1 liter of distilled water.
- Dissolve 1 ml of waste vegetable oil into 10ml isoprophyl alcohol.
- With an eyedropper, set the pH of WVO to 8-9 by adding NaOH one milliliter at a time. you will see an eventual rise in the ph level.
- Record the quantity of KOH solution added until the colour of the oil changes pink and holds for at least 5 seconds (This represents a pH of between 8 and 9).

Step 2: *Preparation of potassium methoxide.*

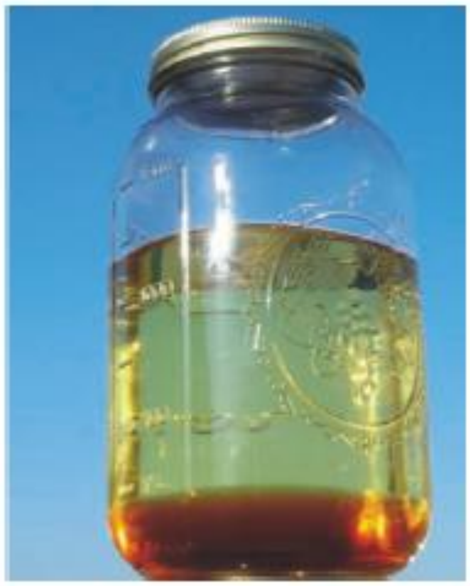
- Carefully pour the KOH solution into 100 ml methanol.
- Agitate the mixture until the KOH is completely dissolved in the methanol.

Step 3: *Mix the reactants*

- Continue mixing under the lab fume hood.
- Carefully pour the potassium methoxide on top of the vegetable oil in the large mason jar and shake vigorously for 15 minutes.

Step 4: *Allow the glycerin to settle*

- Settle the mixture overnight.
- The successful chemical reaction between the oil, alcohol, and the catalyst will have broken down the oil into several layers. The top layer will be biodiesel, chemically called an Ester, the next layer may contain soap, and the bottom layer will be glycerin.(For every 50 gallon batch, we end up with about 11 gallons of glycerine and 50 gallons of fuel.)



Step 5: *Purification of Biodiesel:*

- Once the layering has occured, the glycerin and soap are drained off. The biodiesel is then washed with either a mist-wash, a bubble-wash, or both. The washing is done to remove any additional soap, alcohol, or other impurities in the biodiesel. After it's been washed, it is then dried to remove any water. Commonly it is then filtered through fuel filters and is then ready to be used.

Algae as a Source of Energy

- Algae can prove to be a cheap and renewable source of energy for internal combustion engine. Tropical countries such as India favor algae production, due to high temperature and dry weather coupled with strong winds. Algae can be induced to produce more lipids by controlling supply of nitrogen and silicon, which helps in converting over two-third of its mass into lipids. For instance, in a pond of 20 meters about 80% of the converted lipids can produce 3000 liters of fuel each year. Lipids, in turn, produce fuels such as diesel and petrol. These lipids are hydolyzed on boiling with concentrated hydrochloric acid to fatty acids. Then they are esterified with methyl alcohol by a process called 'transesterification.'

Power generation from algae consists of three stages:

- Algae is grown in a vessel known as biocoil.
- Algae grown is milled to fine powder so that it burns with same efficiency as the fine sprays of fuels and oils traditionally used in engines.
- Wet algae can also be used as a fuel for internal combustion engine after filteration, drying, and milling operation.

Advantages of Biodiesel

Biodiesel has several advantages some of which are enumerated as below:

It helps in reducing the levels of toxins from air and water and also can reduce the advance of global warming.

The plant-based biodiesel adds no CO_2 to the atmosphere. They are 'carbon neutral'.

The ozone harming potential of biodiesel emission is almost 50% less than conventional diesel fuel.

Sulfur dioxide and nitrous oxide emissions are eliminated by using biodiesel.

Biodiesel has a significantly lower flash point than petroleum diesel. This reduces risk of fire in transport, storage, and delivery.

Use of biodiesel results in increased lubricity, adding to overall engine life. Recent research shows that even a 2% biodiesel blend increases lubricity significantly[6].

In addition, research has also verified that exhaust emissions from biodiesel are substantially less than those from petroleum-based diesel. Further, as the percent of biodiesel in a bio/petroleum diesel blend increases, the benefits of reduced emission increase (Figure 1). According to the environmental protection agency (EPA), a

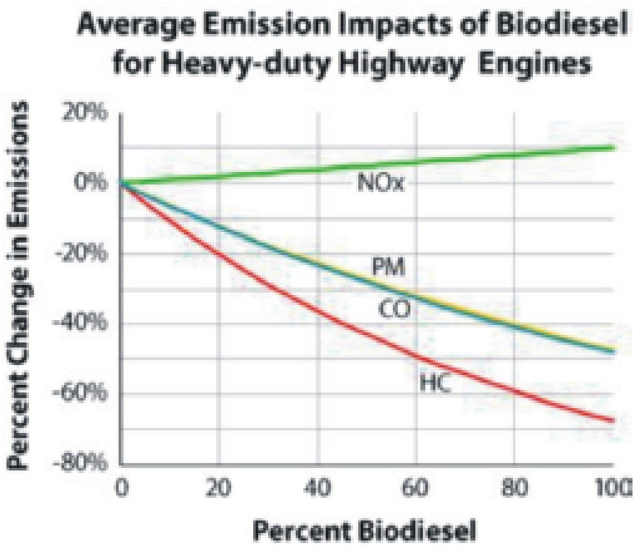


Figure *1Average emission impacts of biodiesel for heavy-duty highway engines. Source: EPA.*

soybean oil diesel product (20% bio/80% petroleum) results in a reduction of 10.1% in total particulate emissions (PM), 21.1% in hydrocarbons (HCs), and 11% in carbon monoxide (CO) emissions. These are offset by a 2% increase of nitrous oxide (NOx) and a reduction in fuel efficiency of 1-2%, but environmental impacts are positive nonetheless.

Disadvantages

In addition to advantages, there are couple of disadvantages posed by biodiesel:

Contamination by water

Biodiesel may contain small but problematic quantities of water. Although it is hydrophobic, it is said to be, at the same time, hygroscopic to the point of attracting water molecules from atmospheric moisture[7]. Hygroscopic biodiesel is formed due to the persistence of mono- and diglycerides left over from an incomplete reaction.

In addition, there may be water that is residual to processing or resulting from storage tank condensation, which may lead to following problems:

- Water reduces the heat of combustion of the bulk fuel. This means more smoke, harder starting, less power.
- Water causes corrosion of vital fuel system components (fuel pumps, injector pumps, fuel lines, etc.).
- Water and microbes cause the paper element filters in the system to fail, which in turn results in premature failure of the fuel pump due to ingestion of large particles.
- Water freezes to form ice near 0 °C. These crystals provide sites for nucleation and accelerate the gelling of the residual fuels.
- Water accelerates the growth of microbe colonies, which can plug up a fuel system. Biodiesel users who have heated fuel tanks therefore face a year-round microbe problem.

Flow properties

Flow properties in biodiesel are increased relative to petroleum diesel. This means that the biodiesel will gel at a higher temperature than 100% petroleum diesel. However, a study conducted in the winter of 2001/02 in Hennepin County, Minnesota found that snow plows burning a B20 product composed of 10% biodiesel manufactured from yellow grease, 10% biodiesel manufactured from soyabean oil, and 80% petroleum diesel performed as well as snow plows powered by 100% petroleum diesel[8].

Conclusion

To move toward a future with a sustainable energy supply and healthy consumer goods production, every solution is important. For this reason, energy use must become more and more efficient, production processes must be improved and the full potential of new technologies must be realized. Fuel biotechnology with its competitive, clean, and clever use of bio-based technologies can play a key role in making biofuels more sustainable.

"Earth is ours and preservation of fuel our utmost duty"

"One good invention today results in a revolution tomorrow"

"If bios be saved from dying it is biodiesel

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Sample Lab Report

Introduction

In order to calculate the energy density of biodiesel, the biodiesel needs to be made before it can be placed into the cone calorimeter and tested. Mixing the feedstock with methanol will produce the biodiesel we require. Then the cone calorimeter will gives us the energy that was contained in our sample, from which we can calculate the energy density of the biodiesel.

Procedure

The vegetable oil is first run through a simple filter to make sure no large particles get into the experiment. Then the catalyst needs to be prepared for the reaction. This is done by measuring out 0.35g of sodium hydroxide as well as 20ml of methanol. Then place a stir bar into a clean 250ml Erlenmeyer flask along with the 0.35g sodium hydroxide and 20ml methanol and place the flask onto a stirring plate to dissolve the sodium hydroxide into the methanol.

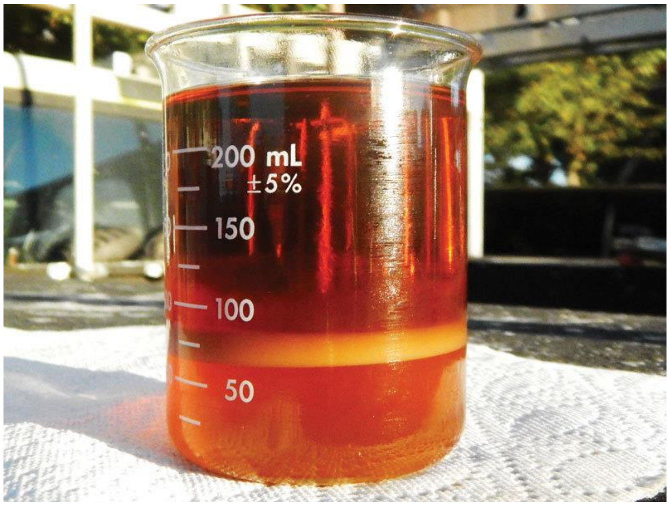
While the catalyst is being prepared, 100ml of the filtered vegetable oil is measured out and then heated up to 40°C. Once the sodium hydroxide-methanol mixture is dissolved, the heated oil should be added to the mixture. This new mixture is stirred for 15 minutes. Once the stirring is completed, the flask is removed from the stirring plate and the stir bar is extracted from the flask.

Now repeat the process again, but do one of the following differently: use a different feedstock, use a different catalyst, or run the experiment the exact same way again and alter the experiment later in the process.

The flask is then set aside and left to sit overnight while the glycerol and biodiesel separate into two very visible layers with the biodiesel on top. Once the flask is separated, the biodiesel should be drained off into a clean 100ml beaker. 50ml of water is then added to the mixture and it is set aside again to separate. The biodiesel is drained off the top of the water and brought over to the cone calorimeter. The biodiesel is placed into the cone calorimeter which then gives the caloric content of the biodiesel that was produced.

Results

The cone calorimeter revealed that our soybean feedstock biodiesel made with NaOH contained 3.74MJ. Our second sample, also made from soybean feedstock, also used NaOH as a catalyst, however we did not wash it. The caloric content of that sample ended up being 3.17MJ. Our first sample matches up with the energy density of biodiesel, which ranges between 33.3MJ/L and 37.7MJ/L, but the second sample does not.



(Hobden, 2014)

Above is our first sample of biodiesel before it was skimmed off from the glycerol.

Discussion

Upon examination of our results, we determined that the washing of the biodiesel in the water at the end of the experiment did increase the energy density of the biodiesel. We calculated that it increased the energy density by about 15.24%. On a small scale like this, that may not be a big increase, but when it is ballooned up to a mass production scale that can be a very large improvement in the quality of the biofuel. We also reviewed how filtering the biodiesel before or after the washing took place affected the energy density. There did not seem to be any noticeable difference in the results of the two groups of biodiesels.

When the results of the class were reviewed, we were unable to determine if the different catalysts used made a noticeable difference in the final result of the biodiesel. There did appear to be a slight increase in the energy density of the potassium hydroxide biodiesel, but it was only a 0.03MJ increase over the sodium hydroxide. In addition, both catalysts seemed to take the same amount of time to dissolve into the mixture, so we cannot recommend either catalyst over the other.

We also compared these results with the results of our earlier lab on bioethanol and got some interesting conclusions. We found that the biodiesel we made had a higher caloric content by 0.75MJ on our small scale. This gave us a difference in energy density of 7.5MJ which is close to the accepted difference in energy density of 7.35MJ.

If this project were to be scaled up to an industrial level, we have learned to make several choices between what we tested in this lab. We would pick sodium hydroxide for our catalyst due to the negligible differences between the two and the fact that potassium hydroxide is over 50% more expensive than sodium hydroxide. As far as a feedstock is concerned, we would pick soybean vegetable oil due to its high energy density. However, we do recognize the fact that it does take a relatively large quantity of soybeans in order to generate any noteworthy amount of biodiesel.