Soybeans As an Energy Feedstock

Making Biodiesel: An Engineering Design Approach

To solve engineering problems, engineers follow a series of steps called the Engineering Design Process.

Ask: What is the problem? How have others approached it? What are your constraints?

Imagine: What are some solutions? Brainstorm ideas. Choose the best one.

Plan: Draw a diagram. Make a list of materials you will need.

Create: Follow your plan and create something. Test it out!

Improve: What works? What doesn't? What could work better? Modify your design to make it better? Test it out!

Activity

Your team has been chosen to create an efficient, clean burning fuel in the form of biodiesel from four common sources of vegetable oils (soybean, corn, canola, and sunflower). In order to determine the best oil to create biodiesel, your team will use the engineering design process to test one of the oils by making biodiesel and report your conclusion back to the class.

Background

Biodiesel is a liquid fuel derived from vegetable oils and fats, which has similar combustion properties to petroleum-based diesel fuel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. Biodiesel is biodegradable, nontoxic, and has significantly fewer emissions than petroleum-based diesel when burned.

Transesterification, the chemical process of exchanging one organic group of an ester with another organic group of an alcohol, is used to create biodiesel. Try the procedure found in ***Modeling Making Biodiesel***, to explain what is happening.

The largest source of suitable oil comes from oil crops such as soybean, corn, canola, and sunflower. Which will make a better biodiesel?

Some resources to watch:

http://illumin.usc.edu/42/biodiesel-a-realistic-alternative/

https://www.youtube.com/watch?v=fSXtq2NU56c

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Materials:

- 1 - 20-32 oz (591-710 ml) clean beverage bottle with cap per group (from sport or vitamin drinks, not water bottles)
- 100 ml Graduated cylinder or beaker
- Glass jar with a tight fitting lid such as a mason jar
- Aluminum foil or weigh boats
- Laboratory scale (0.1 g precision minimum)
- Disposable latex gloves
- Safety glasses or goggles
- Push pin or nail
- Duct tape
- Crock pot to warm the oil (140^{o} F/60^{o} C)
  Use caution: the oil will be HOT. *Place the oil in the crock pot to warm an hour before class. This can be done by a) placing the entire bottle of oil into the pot or b) pouring the oil into the 20 oz bottles and placing them in the crock pot.*
- Funnel or wire strainer
- #2 or #4 coffee filter
- Large beaker or glass container
- Distilled water
- Soybean oil (Wesson™ Vegetable Oil)
- Corn oil
- Canola oil
- Sunflower oil
- Methanol (HEET™ gasoline additive) **CAUTION: Contents very flammable**
- Sodium hydroxide (NaOH, also known as “lye” or “caustic soda”)

Procedure:

Day One

1. Wear safety glasses or goggles. When handling the sodium hydroxide, wear disposable gloves. When handling heated flasks, wear laboratory gloves.
2. Measure 2.0 grams of sodium hydroxide, using the laboratory scale, on a small piece of aluminum foil or weigh boat.
3. Measure out 60 mL of HEET™ using a graduated cylinder or beaker.
4. Mix the sodium hydroxide and HEET™ together in one of the bottles. Place the lid tightly on the bottle. Swirl and shake the **methoxide** mixture until the sodium hydroxide is completely dissolved, approximately 5 minutes. ***Alternative****: let it sit overnight to finish dissolving*.
5. Remove the bottle of your chosen oil from the crock pot and allow it to cool for 5 minutes. When cool enough to touch, measure 210 ml of oil using a graduated cylinder or beaker.
6. Add the methoxide mixture to the 20 oz bottle containing the oil.
7. Place the cap tightly on the 20 oz bottle and shake vigorously for 30 seconds. Place the bottle back into the crock pot or water bath between shakings to help speed up the reaction. Let the mixture warm 2-3 minutes and shake again for 10 seconds. Repeat this for procedure for 15 minutes.
8. The mixture will thicken and darken, then become thinner than the original oil.
9. Let the bottle stand overnight.
10. The mixture will separate into two distinct layers. The clear top layer is the methyl ester (fuel), and the darker bottom layer is the glycerol by-product of the Transesterification process.

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Day Two

1. Take a push pin or nail and punch a hole in the bottom of the bottle. Remove the pin and loosen the cap on the bottle to allow the bottom layer (glycerol) to drain completely. ***Hint:*** *You can control the rate at which the fluid drains by loosening/tightening the cap on the bottle. A tight cap will stop the draining.* Wipe the bottom of the bottle and place a piece of duct tape over the hole and proceed to the next step.
2. "Wash" the biodiesel (methyl esters) to remove any remaining methanol and soap.
    a) Measure an amount of distilled water that is equal to one-half the volume of the recovered biodiesel.
    b) Add the distilled water to the recovered biodiesel by tipping the bottle and slowly pouring the water down the side of the bottle to mix with the biodiesel. Gently rock the bottle 3-5 minutes on its side. *Don't shake it, or you will create an emulsion that will take a long time to separate.*
    c) Allow the biodiesel and water to separate for 10 minutes.
    d) Drain the bottom (glycerol) layer of the mixture by pulling the tape from the bottom of the bottle and loosen the cap. The top layer of the mixture contains the biodiesel. Secure the cap, wipe the bottom and replace the duct tape over the hole.
    e) Do a second washing, repeating steps a through d.
3. Let the mixture sit overnight.

Day 3

1. Drain off the bottom layer that contains glycerol.
2. Construct a filtering system by placing a coffee filter in a funnel or wire strainer. Position it over a beaker/jar to drain.
3. Pour the top layer of the mixture that contains the biodiesel through the coffee filter system and allow it to drain.
4. When finished, pour the biodiesel into the container provided by the instructor. The biodiesel will be used to run a bio-boat.
5. Use the biodiesel to power the bio-boats to see which type of biofuel (choice of oil) works best.

Data:

Oil	Color	Clarity	Performance	Volume of Biodiesel
Soybean Oil				
Corn Oil				
Canola Oil				
Sunflower Oil				

Reflection/Observation:

1. What are some characteristics that make a good fuel?

2. How did the different oils compare in color, clarity, and performance when using the bio-boats?

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3. Which oil made the most biodiesel, and the least glycerin?

4. Using the information below and assuming the soybeans are composed of protein, oil and hulls, how much would a bushel of soybeans weigh?

   Soy protein = 48 lbs
   Soy oil = 11 lbs
   Soy hulls = 1 lbs

5. Biodiesel is made from the soy oil in soybeans. What percentage of a bushel of soybeans is used to create the biodiesel?

6. What are some uses for the remaining soybean products after soy oil is consumed to make biodiesel?

6th Grade Questions

7. A farmer has planted 80 acres of soybeans. If each acre produces 50 bushels soybeans, and one bushel of soybeans can produce 1.5 gallons of biodiesel, how many gallons of biodiesel can this farmer produce from 80 acres?

8. If the price of a bushel of soybeans is currently $9/bushel, how much can this farmer make by selling his soybeans for biodiesel?

High School/advanced JH questions

9. If 1 gallon of biodiesel = 121,650 BTU and 1 gallon = 128 megajoules (one million joules), then how much energy in BTU's and megajoules will the farmers biodiesel produce?

10. How much does each joule of energy cost at this point?

11. How many barrels of crude oil would be saved by this farmer, given there are 5.8×10^6 BTUs in a barrel?

12. Forty billion (40×10^9) gallons of petroleum diesel is consumed in the United States each year. If the United States would legislate that all diesel be B20 (20% biodiesel):

    a. How many acres of soybeans would have to be grown to meet this requirement?

    b. Could the United States realistically meet this goal?

    c. How could Ohio's soybean crop contribute and/or be affected?

    d. Explain/discuss in your group/class the pros and cons of your answers b and c.