Seed to STEM

Kansas Corn: More Fuel - Biodiesel and Renewable Diesel

This lab is made possible with the support and content contributions of the Kansas Corn Commission.

KANSAS CORN COMMISSION

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Kansas Corn: More Fuel
Grade Level: High School

Overview
The main renewable fuel derived from corn is ethanol. Ethanol is produced when yeast ferment the sugars released from starches in the corn. In addition to starch, corn plants also store energy in the form of oil. The extraction and use of these oils as a valuable coproduct is becoming a more common practice in the production of ethanol. These oils can be used in cooking, but also in the production of fuels in the form of biodiesel or renewable diesel. Biodiesel is a renewable, clean fuel that can be mixed with conventional diesel. Biodiesel, like ethanol, is made of carbon atoms that were in the atmosphere as carbon dioxide before being fixed during photosynthesis. Biodiesel is produced when the fatty acid chains of the oil are removed in a reaction with methanol and a catalyst. Renewable diesel is also produced from different oils by a catalyst driven reaction that allows for the precise manipulation of the molecules, producing an even more stable product.

Kansas College and Career Ready Standards
- **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- **HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

Learning Objectives
After completing these activities the student will be able to:
- Explain why biodiesel is an important alternative to petroleum diesel due to the source of the carbon involved.
- Explain how biodiesel is derived from three reactants: triglyceride (corn oil), alcohol and a catalyst, KOH.
- Conduct analyses necessary to determine oil quality.
- Identify and test different fuel properties.
- Determine the density of a liquid.
- Compare the viscosity of bi biodiesel to unused cooking oil and to renewable diesel at different temperatures.

Materials
Biodiesel Production and Separation
- 3 pipette pumps and several Beral pipettes
- 2 50-mL centrifuge tubes with caps
- Test tube rack
- Methanol, absolute 10 mL
- Potassium hydroxide, KOH 0.20-0.30 g
- Corn oil, 25 mL

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Materials for analyzing solvent properties of fuels

- 5 mL of renewable diesel
- 5 mL: of biodiesel (produced in class)
- 2 small test tubes
- Test tube rack
- Styrofoam cup
- 1 hole punch
- 2 10-mL Berol pipettes (may reuse biodiesel labeled pipette from production of biodiesel)
- Berol pipette pump

Materials for analyzing viscosity of fuels

- 2 400-mL beakers (or other container to use as cold water bath)
- Water
- Ice
- Thermometer
- 3 10-mL Berol pipettes (may reuse oil and biodiesel labeled pipettes used in production of biodiesel)
- Berol pipette pump
- Sample of renewable diesel
- Sample biodiesel produced in class
- Stopwatch

Safety Considerations

The production of biodiesel requires the use of hazardous materials. Methanol is extremely flammable and toxic by inhalation and ingestion. Use extreme caution and review the following documents thoroughly before proceeding. Safety tips for handling methanol are available at:
https://www.flinnsci.com/api/library/Download/762ec945eb5744518e71a014f92818cb
Methanol MSDS is available a:
https://www.flinnsci.com/api/library/Download/5cebbc146b164cc9a0e5cb1e15246281

Potassium hydroxide is very corrosive and toxic. When making biodiesel, these two compounds are mixed making potassium methoxide, which is even more corrosive and toxic. Gloves, protective eyewear and lab coats or aprons should be worn.

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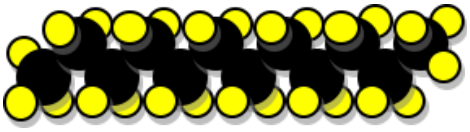
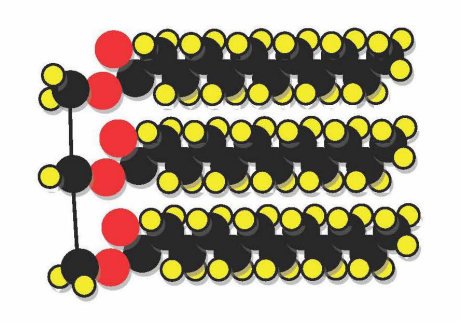
Procedures for Instruction
Length of Time for Preparation: Preparing to have students produce biodiesel from corn oil would be gathering the materials. The teacher may choose to prepare the biodiesel for the class and have the class test the different fuel properties.
Length of Time for Classroom Teaching: 1-2 class periods

Preparation Procedure
- Gather materials.
- Set up water bath, if one will be used.
- Instruct students on safe handling of the various chemicals that will be used.

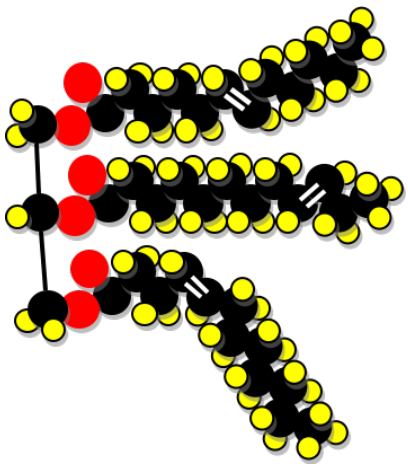
Background Information
Petroleum diesel is a hydrocarbon that is refined from crude oil that is pumped from underground. Diesel is the group of hydrocarbons ranging from C10H22 to C15H28, having an average of C12H24. This fuel is a mixture, typically containing 75% saturated hydrocarbons and 25% aromatic hydrocarbons.



Fats and oils are classified in a group of compounds called triglycerides. These molecules are made up of a glycerol and three-fatty acid molecules. Animal fats tend to be saturated triglycerides, having all single bonds between carbons in the fatty acids. This makes the chains nearly straight and allows them to solidify at higher temperatures. Plant oils are typically unsaturated, having at least one double bond. The fatty acid bends at this double bond and causes the oil to stay liquid at lower temperatures.



Saturated Triglyceride



Unsaturated Triglyceride

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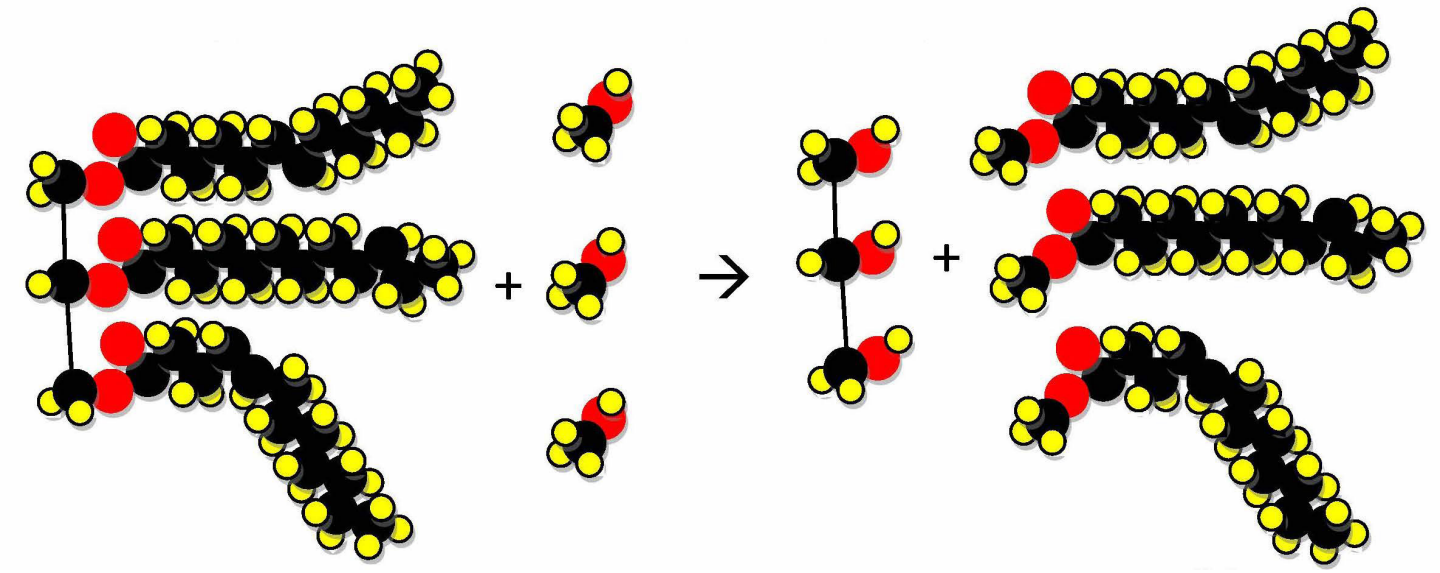
Biodiesel is produced when a catalyst, potassium hydroxide, is used to separate the fatty acids from the glycerol molecules. This produces fatty acid methyl esters, or biodiesel.



Triglyceride + 3 Methoxide → Glycerol + 3 Fatty Acid Methyl Ester (Biodiesel)

Renewable diesel can also be produced from triglycerides, such as those in corn oil. According to the U.S. Department of Energy, the process can involve isomerization, pyrolysis, and other thermochemical and biochemical means. Renewable diesel is formed by removing the hydrocarbon from the fatty acid and saturating the molecule with hydrogen. Methyl groups are then added to the molecule to lower the temperature at which it starts to solidify.

Classroom Discussion

Introduce the topic and assess students for prior understanding. Let students discuss their ideas, and guide the discussion without telling them if they are right or wrong.

- How does a triglyceride resemble a diesel molecule? How is it different?
- Do you think the differences in molecular structure will affect the physical properties of the fuel?
- Why do you think saturated fats are considered to be less healthy compared to unsaturated fats?

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Procedure for Lab

1. Label three of the pipettes, M for methanol, B for biodiesel and O for oil.
2. In a 50-mL centrifuge tube, weigh out approximately 0.25 g potassium hydroxide, KOH (between 0.20-0.30 g).
3. Using the pipette labeled M, carefully add 10 mL of methanol and replace the place cap. This mixture is very caustic and flammable. Use extreme caution handling this substance.
4. Swirl to dissolve potassium hydroxide completely.
5. Add 25 mL of corn oil to the catalyst, replace the cap and mix for several minutes.
6. Occasionally, carefully loosen the cap to release any pressure. Be sure that the mixture has settled from near the cap before opening.
7. After mixing for several minutes, loosen the cap slightly and place in test tube rack to allow reaction to complete.
8. The reaction will take several hours and may be left overnight.
9. The reaction can be sped up significantly by placing the test tube rack in a warm water bath at 50°C.
10. Two layers should form. The lighter colored biodiesel on the top, and darker glycerol should be at the bottom of the test tube.
11. Use a pipette to move the biodiesel layer, adding it to a clean tube. Record the volume.

This biodiesel may still contain some potassium hydroxide catalyst. It would require washing and drying to remove this before it would be ready for use in an engine.

Teachers Tips

Visit www.kscorn.com for videos and resources to assist with this lab.

Lab Analysis

Determine the percent yield by volume of biodiesel from corn oil.

$$\frac{\text{(Volume of Biodiesel)}}{\text{(Volume of Corn Oil)}} \times 100 = \_\_\_\_\_ \text{ \% yield by volume.}$$

Use this percentage to determine the amount of corn oil required to produce one gallon of biodiesel.

If one bushel of corn can produce 700 mL of corn oil, how many bushels of corn would be required to produce one gallon of biodiesel?

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Analysis of Fuel Properties

There are several concerns regarding the use of biodiesel due to its differing properties with petroleum diesel. The difference in molecular structure causes it to be a solvent that is capable of dissolving some plastic components in engines and fuel systems not designed for biodiesel use. This is not a problem in newer diesel engines that have components made for use with biodiesel. Diesel, in general, can encounter problems in extremely cold weather as it can form a gel that is too viscous for fuel systems. Biodiesel can increase the likelihood of forming gel at a higher temperature. Biodiesel blends and the addition of antigel agents reduce this problem. Renewable diesel can remain liquid at lower temperatures as opposed to biodiesel. The cold weather properties are tested in a lab by cooling a sample and determining the point at which it starts to crystallize. This temperature is referred to as the cloud point of the fuel.

Analysis of Solvent Properties

Procedure for analyzing solvent properties

1. Label two test tubes biodiesel and renewable diesel.
2. Place approximately 5 mL of each fuel in its labeled test tube.
3. Use a hole punch to punch two Styrofoam disks from the cup.
4. Drop a disk in each fuel type and start a timer.
5. Observe after 5 minutes and record observations.

Procedure for analyzing viscosity at different temperatures

1. Set up a water bath of room temperature water.
2. Add approximately 20 mL of each sample to a labeled 50-mL centrifuge tube (the biodiesel sample should be ready).
3. Place the three fuel samples in a rack in the water bath.
4. Record the temperature of the water bath in the data table.
5. Using the appropriate Beral pipette, draw up exactly 11 mL of fuel
6. Using the stop watch, record the time required for the fuel to drain to the 1 mL mark of the pipette.
7. Repeat two more trials for that fuel type and average the times.
8. Use the appropriate pipettes to repeat this process for each of the samples.
9. Place samples in salt-ice bath to cool the temperature of the water bath to approximately -3° C to 0°C.
10. When this temperature has been reached, record temperature.
11. Repeat steps 5 through 8 and record results.

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Reflection and Conclusion

- What are the advantages renewable biodiesel provide over petroleum diesel?
- What are the potential drawbacks to using biodiesel in place of petroleum diesel?
- How does renewable diesel compare to biodiesel in these characteristics?

Science and Agriculture Careers

To learn more about agriculture careers, visit agexplorer.com. You can also find career profiles at kscorn.com.

Sources

- https://afdc.energy.gov/fuels/emerging_hydrocarbon.html
- http://www.umsl.edu/~biofuels/Biodiesel%20activites/Lab-Workshop-BIODIESELmicroscale-07.doc
- https://cebc.ku.edu/sites/cebc.drupal.ku.edu/files/docs/RET-CONVERSION_From%20Fryer%20to%20Fuel2010.doc
- https://biodieseleducation.org/Education/HighSchool.html

Any educator electing to perform demonstrations is expected to follow *NSTA Minimum Safety Practices and Regulations for Demonstrations, Experiments, and Workshops*, which are available at http://static.nsta.org/pdfs/MinimumSafetyPracticesAndRegulations.pdf, as well as all school policies and rules and all state and federal laws, regulations, codes and professional standards. Educators are under a duty of care to make laboratories and demonstrations in and out of the classroom as safe as possible. If in doubt, do not perform the demonstrations.