Food or Fuel? (Lesson Plan)

(The Chemistry and Efficiency of Producing Biodiesel)

Suggested Grade Level 9-12

Overview

After taking a virtual tour of Penn State's Combustion Lab with Professor André Boehman, students will be introduced to the idea of renewable, homegrown fuels. Students will investigate the relationship between fuel properties and chemical structure by making their own batch of biodiesel from virgin olive oil. The suggested time frame for this lesson is three to four (3-4) 50-minute class periods.

Standard Statements

3.4.10 A Explain concepts about the structure and properties of matter.
3.4.12 A Apply concepts about the structure and properties of matter.
3.6.10 A Apply biotechnologies that relate to related technologies of propagating, growing, maintaining, adapting, treating and converting.
3.6.12 A Analyze biotechnologies that relate to related technologies of propagating, growing, maintaining, adapting, treating and converting.
3.8.12 A Analyze the relationship between societal demands and scientific and technological enterprises.
4.8.10 B Analyze the relationship between the use of natural resources and sustaining our society.
4.8.10 C Analyze how human activities may cause changes in an ecosystem.

Content Objectives

Students will know that

1. Biodiesel is a clean, renewable, domestically produced fuel source that could lower United States dependence on imported oil.
2. The properties of compounds are determined by their chemical structure.
2. Biodiesel is derived from three reactants: glyceride (oil), alcohol and a catalyst.
3. The chemical structure of biodiesel is described as a mono alkyl ester of long chain fatty acids derived from natural oils.

Process Objectives

Students will be able to

1. Describe the process of transesterification utilizing chemical formulas.
2. Identify fuel properties and resulting issues. For example, cold weather usability of biodiesel as a function of its chemical structure.
3. Diagram methods of biodiesel production from raw materials for virgin oils.
4. Construct and compare models of chemical structure of the substances involved in biodiesel production such as: alcohols, alkenes, alkanes, alkyls, acids, esters, etc.

Assessment Strategies

1. Completion of *Food or Fuel?* laboratory handout and related calculations.
2. Completion of small group analysis of biodiesel as a viable fuel source for transportation.
3. Informal evaluation of participation in group discussion.

4. Performance assessment of modeling and comparison of chemical compounds involved in biodiesel production.

Materials

- Laboratory Set-up and special materials part of Student Handout and Teacher Notes
    - Note: Several chemicals included to be used with caution: lye and methanol. Sodium methoxide is formed in the transesterification of vegetable oil to make biodiesel and should be performed under a hood.
- Ball-and-stick modeling sets or virtual simulation for each pair of students (not required)
- Teacher computer with internet access
- Computers with internet access:1 per student group
- Projection equipment

Multimedia Resources

- PSU Combustion Lab video series: Segments 1-7 [QuickTime movies]
- Virtual Gasoline engine simulation: http://auto.howstuffworks.com/engine1.htm
- Virtual Diesel engine simulation: http://auto.howstuffworks.com/diesel1.htm
- UNH Biodiesel Group PowerPoint presentation (optional)
- "Biodiesel-O-Matic" Excel spreadsheet (optional)

Procedures

Part 1: Take a virtual tour of PSU's Combustion Lab *(30 minutes)*

1. Share selected segments [1-3] of the PSU Combustion Lab tour to introduce the idea of what engineers researching renewable, homegrown fuels do.
2. Allow student pairs or small groups to explore how internal combustion engines work and compare that to how a diesel engine works using *How Stuff Works?* http://auto.howstuffworks.com/engine3.htm & http://auto.howstuffworks.com/diesel1.htm.
3. Follow up with a discussion to reveal students thoughts on the differences between the two types of engines. Also, make the connection that rotational motion is produced by the crankshaft.

Part 2: Grease Monkeys: Form and Function in a Fuel *(1-50 min Class Period)*

1. Revisit the video collection to view segments 4-7 for specific background on fuel properties and Professor Andre Boehman's "State of Biodiesel" comments.
2. Introduce students to the process of transesterification and the chemical structures of the components of biodiesel (glyceride, alcohol and catalyst).
3. Discuss the role of chemical structure in determining physical properties of a substance. For example, the solvent properties of biodiesel in an engine.
4. Allow students to work in small groups to reflect on the video series by asking: How does biodiesel measure up to today's fuels? Challenge students to make models of the components of the biodiesel production reaction using ball-and-stick sets, Styrofoam and pipe cleaners, or a virtual modeling simulation like ChemStudio if you have access to it. Students should submit their modeling efforts and a journal or written record of their discussion of the video as homework if it cannot be completed in class. A helpful website to direct students to for schematics is: http://www.me.iastate.edu/biodiesel/Pages/biodiesel1.html. (Chemistry is discussed on Pages 2 and 3 of this site).

Part 3: Homework and lab prep *(Homework)*

1. Prompt students to the idea that many individuals are making and using biodiesel to power their vehicles and that energy security relies on a diverse energy portfolio. Explain to students that they will be producing some biodiesel as a lab exercise and that they need to be aware of the process.
2. Give each student a lab handout to review and assign the National Biodiesel Board's article, "Biodiesel and Energy Security," for supplementary reading. The article is available online at: http://www.biodiesel.org/pdf_files/fuelfactsheets/Energy_Security0604.pdf.

Part 4: Lab time! Make some biodiesel… *(2-50 min Class Period)*

1. **Important:** Run through an oral quizzing activity to review lab safety for the group.
2. Allow students to work through the lab handout with a partner to answer the questions and produce biodiesel from virgin olive oil (students are prompted to get your initials after calculating how much NaOH they need to catalyze the reaction for the volume of oil specified).
3. Give students instructions on the next steps for further investigation and storage of their biodiesel.
4. Debrief lab activity and address any questions generated from the reading assignment.
5. Allow students to complete lab handouts and Questions to Consider. Questions to Consider may be assigned for homework if not finished in class.

Extension

1. Visit the Energy Efficiency and Renewable Energy website to compare the fuel properties and trade-offs for biodiesel to other alternative fuels: http://www.eere.energy.gov/afdc/altfuel/fuel_properties.html.
2. Wash and test your biodiesel products for quality and compare to the American Society for Testing & Materials (ASTM) standards.
3. Use the EERE Alternative Fuels locator website: http://afdcmap.nrel.gov/locator/LocatePane.asp to find the closest refueling station and if possible, visit a local vendor and/or find out how to donate your product for use in a diesel engine.
4. Titrate waste vegetable oil (WVO) and try a round of processing with fryolator feedstock (see Mike Pelly's biodiesel method for more information, http://journeytoforever.org/biodiesel_mike.html). The titration procedure is included on the next page.

Titration Procedure:
Approximately 3.5g of NaOH per L of oil is needed when using virgin oil. However when using waste oils (which therefore have free fatty acid (FFA) content), the pH must first be determined (by titration) to calculate the additional amount of NaOH needed.
The *titration* (for used oils, or older oils that could have degraded some, producing FFAs) is done as follows:

Dissolve one gram of NaOH into 1 liter of distilled water. Dissolve 1ml of the filtered oil into 10ml of isopropyl alcohol and add two drops of phenolphthalein, an acid base indicator. Now slowly add, by calibrated dropper or pipette, the NaOH(aq) solution to the oil solution, mix intermittently. When the oil solution turns pink and stays pink for ten seconds the titration is complete. The volume of NaOH(aq) solution in milliliters necessary to neutralize the free fatty acids corresponds directly with the number of additional grams per liter of NaOH needed for transesterification.

5. Use the “Biodiesel-O-Matic” Excel spreadsheet to compute costs for the biodiesel students have produced.