Biofuels

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Unlike other renewable energy sources, biomass can be converted directly into liquid fuels, called "biofuels," to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel.

Ethanol is an alcohol, the same as in beer and wine (although ethanol used as a fuel is modified to make it undrinkable). It is most commonly made by fermenting any biomass high in carbohydrates through a process similar to beer brewing. Today, ethanol is made from starches and sugars, but NREL scientists are developing technology to allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.

Ethanol can also be produced by a process called gasification. Gasification systems use high temperatures and a low-oxygen environment to convert biomass into synthesis gas, a mixture of hydrogen and carbon monoxide. The synthesis gas, or "syngas," can then be chemically converted into ethanol and other fuels.

Ethanol is mostly used as blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions. Some vehicles, called Flexible Fuel Vehicles, are designed to run on E85, an alternative fuel with much higher ethanol content than regular gasoline.

Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking grease. It can be used as an additive (typically 20%) to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines.

Currently biofuel is produced from plants as well as microbes. The oils, carbohydrates or fats generated by the microbes or plants are refined to produce biofuel. This is a green and renewable energy that helps in conserving fossil-fuel usage. But a new research has led to a new discovery of getting the microbes to produce fuel from the proteins instead of utilizing the protein for its own growth.

Biofuels are produced from living organisms or from metabolic by-products (organic or food waste products). In order to be considered a biofuel the fuel must contain over 80 percent renewable materials. It is originally derived from the photosynthesis process and can therefore often be referred to as a solar energy source. There are many pros and cons to using biofuels as an energy source.

Research into the production of liquid transportation fuels from microscopic algae, or microalgae, is reemerging at NREL. These microorganisms use the sun's energy to combine carbon dioxide with water to create biomass more efficiently and rapidly than terrestrial plants. Oil-rich microalgae strains are capable of producing the feedstock for a number of transportation fuelsð biodiesel, "green" diesel and gasoline, and jet fuelð while mitigating the effects of carbon dioxide released from sources such as power plants.

Other Resources

- U.S. Department of Energy Consumer Guideð http://www.energysavers.gov/renewable_energy/biomass/index.cfm/mytopic=50001
- U.S. Department of Energy, Biomass Programð http://www1.eere.energy.gov/biomass/
- U.S. Department of Energy, Alternative Fuels Data Centerð http://www.afdc.energy.gov/afdc/
- U.S. Department of Energy, Bioenergy Feedstock Information Networkð https://bioenergy.ornl.gov/
- National Renewable Energy Laboratoryð http://www.nrel.gov/learning/re_biofuels.html
- Renewable Energy Activities ï Choices for Tomorrow Teacherôs Activity Guide for Middle Level Grades 6-8

http://www.nrel.gov/docs/gen/fy01/30927.pdf

Producing Biofuel In The Classroom: A Simple Experiment to Make Ethanol

Introduction

Itôs difficult to imagine a student getting through high school today without ever having heard of the subject of sustainable energy, or of bio-fuels. At times however, it seems that lab experiences related to such subjects are difficult to perform, or are costly, or require apparatus that isnôt common to the college, high school, or middle school environment. For instance, the production of bio-diesel from soy beans requires a reaction step that breaks down tri-glycerides, and the production of any sort of bio-fuel from algae requires a controlled reaction chamber, as well as a significant amount of time, for the algae to grow.(1) We have found though that there is one extremely easy, inexpensive experiment which

produces ethanol that can be run in almost any classroom, at any school level. It is the production of ethanol from sugar, using only water and yeast. (2) In connection with this, and very importantly, there is an inexpensive means by which the student can verify that he or she has produced ethanol. It is a form of paper chromatography. In it, a sample set-up in which ethanol has been produced can be compared to a similar set-up that is lacking the alcohol.

Necessary Equipment

A single set-up requires the following items. All materials can be purchased at a grocery store. Scaling up is simply a matter of multiplying that which is listed below by the number of students in a class.

1. Sugar. A ten-pound bag is usually enough for an entire classroom. A sample of about 10g works for a single experiment.

2. Water, about 100 mL per experiment.

3. Yeast, about 0.5 g per experiment.

4. A beaker or jar, 250 mL or 500 mL beakers work. But any jar works as well.

5. Filter papers for a coffee maker.

6. Permanent black marking pens.

The experiment is quite ñforgivingò in terms of the quantities listed for numbers 1 ï 3, above. In general, a set-up does not need so much sugar that there is solid sugar resting at the bottom of the mixture as it settles.

On the subject of coffee filter papers and permanent black markers: you might wish to try different brands of both prior to running the experiment in class. Some filter papers absorb water very quickly, while other will require several minutes for absorption from one end to the other. Likewise, some black markers have ink made from a single, black pigment, while others have a blend of colored components. Neither is better than the other. But it is usually good to see the phenomenon for yourself before it is attempted as a classroom or laboratory exercise

Materials:

- 10 pounds Sugar
- 100 mL water per experiment
- 0.5 g Yeast per experiment
- 500 ml Beaker or 250 mL Jar
- Coffeemaker Filter
- Permanent black marking pens

Credits:

University of Detroit Mercy & MSTA-MICH.org

Experimental

1. Measure the sugar samples and dissolve in water. As mentioned above, it isnõt wise to put so much sugar in a sample that some rests on the bottom. Other than that, just about any amount of sugar will work for a sample. Note, this first step is a good opportunity to assign different quantities of sugar (and yeast) to different students or student groups. The results of the differing amounts can be compared after the reaction is completed.

2. Add yeast. Usually, 1/10th the mass of yeast is desired, when compared to the amount of sugar. But other ratios can be used also.

3. Stir the mixture thoroughly.

4. Discuss the process and chemistry of fermentation with your class. The unbalanced reaction: C6H12O6 à C2H5OH + CO2 is a simplified version of the fermentation of sugar, but it is one that adequately describes the phenomenon. This is a good point at which to discuss that the reaction produces two products: the ethanol, C2H5OH, and the by-product CO2. The reaction can be balanced to: C6H12O6 à 2 C2H5OH + 2 CO2

5. Leave all the mixtures for at least one night.

6. The next class period, note and record any visible changes to the sample mixtures. Depending on amounts of sugar and yeast, the solution will appear cloudy, and foam may have formed at the top.

7. Using two pieces of white paper (a coffee filter paper generally works well) and some permanent black marker, draw a black line approximately 1ò from the bottom of the each piece of paper, without touching the sides of the paper.

8. Pour an aliquot of the ethanol solution into a beaker or other container. This should be enough of the fermented mixture to cover the bottom of the beaker to a depth of 1 ï 3 mm. The amount poured should definitely be lower than the line inked on the papers.

9. Pour the same amount of water into a different container of equal size. This is the comparison, and thus uses just water.

10. Stand either of the papers with the marker line into the container with your ethanol solution, and the other into the container that holds water. Be absolutely sure that neither black, permanent marker line starts out wet (as the water and the solution elutes, the lines will get wet, but shouldnõt start out so).

11. Observe what occurs as the liquids absorb into the papers and creep upward. The paper immersed in water should have not move or smudge the permanent marker line (if the line was mistakenly drawn right to the edge of the paper, the water may not elute above it, since the markerõs ink is permanent, and is saturated through the paper). The paper immersed in the fermented alcohol solution should make the black, permanent marker line move (it may even separate into various pigment components, if the marker ink is not a single black dye).

12. The movement and possible separation of the permanent, black ink is a simple indicator that some material has formed ï in this case, ethanol ï in the solution in which sugar and yeast were mixed during the previous class.

Discussion

This is a multi-class activity, as it requires one class period to set up the fermentation container, some time for the yeast to produce ethanol from sugar, and a second period in which to determine whether ethanol has been made. That can actually work to the teacherõs advantage, since the fermentation time in turn provides time to discuss the chemistry and biology of yeast and fermentation, what is required to make this chemical reaction run, and what role bio-fuels are playing and will play in peopleõs lives.

This experiment, while simple in concept and execution, does link in well with several of the points mentioned in documents such as the Vision Statement of the Michigan Curriculum Framework. Specifically, this connects well with the idea that students should be, ñable to think scientifically and use scientific knowledge to make decisions about real-world problems,ò and that they should be, ñable to reflect in an informed way on the role of science in human affairs.ò(3) The experiment is also well connected to the National Science Education Standards, for example, ñTeaching Standard A: Teachers of science plan an inquiry-based science program for their students,ò as well as, ñTeaching Standard D: Teachers of science manage learning environments that provide students with the time, space,
and resources needed for learning science.ò(4)

For the teacher who is working on balancing chemical equations with his or her students, fermentation provides an excellent example of a reaction involving a carbon-based starting material that is more complex than a hydrocarbon, and that can still be balanced with relative ease. The experiment is also well suited to biology classrooms, and a discussion of how a living organism such as yeast is used to produce a desired material. For an introductory science class, this experiment lends itself well to an understanding of the scientific method through the comparison between the resulting alcohol solution and the control, using water.

For the teacher who wishes to expand this to a semi-quantitative experiment, the following can be added without a large expenditure of time or resources:

- After setting up the yeast-sugar-water mixtures, make a series of standards of ethanol solutions of known percentages. For example, volume-percent solutions can be made that are 99 mL water and 1 mL ethanol, 98 mL water and 2 mL ethanol, 95 mL water and 5 mL ethanol, and 90 mL water and 10 mL ethanol. A teacher is certainly free to make as many standards as she or he wishes, but bakerøs yeast usually does not produce ethanol to a concentration higher than 15%.

- When the yeast mixture is ready to test, run not only the clear water and lined coffee filter as a comparison, but perform the same with the 1%, 2%, 5%, and 10% ethanol solutions that have been made.

- Have students compare how far their black ink line has moved in the ethanol produced from yeast with those lines from the standards you have prepared. From this, you should be able to obtain a good estimate of the percentage of ethanol in the yeast-alcohol solution, either by extrapolation or interpolation to the black lined paper that was inserted in it.

Perhaps obviously, the production of a series of standards may be a portion of this experiment that a teacher chooses to do either with groups of students, or perhaps only once for the entire class. There is no need for each student to make a set of standards, but doing so gives each student a chance to work through the math needed to produce such solutions for themselves.

Overall, this has proven to be a simple, cost effective experiment that introduces students to the idea of how a bio-fuel can be produced. While there is much more that goes into the industrial production of bio-ethanol from corn and other feed stocks than just what is presented here, the chemistry and biology is essentially the same.

References

1. A good start point for information on bio-diesel is: http://en.wikipedia.org/wiki/ Biodiesel, which appears to be a well-written entry with a very extensive reference list and external links list of its own.

2. Likewise, a great deal of information on bio-ethanol is located at the following web sites:
   a. http://en.wikipedia.org/wiki/Biofuel, which also has an extensive reference.
   b. http://www.e85fuel.com/index.php, provides extensive information about E85 fuel.
   c. The Canadian Renewable Fuels Association: http://www.greenfuels.org/.
   d. Renewable Fuels Association: http://www.ethanolrfa.org/.

3. Michigan Curriculum Framework can be found at: http://www.michigan.gov/ documents/MichiganCurriculumFramework_8172_7.pdf

4. National Science Education Standards can be found at: http://www.nap.edu/openbook.php?record_id=4962

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