It All Comes Down to Glucose

Bioenergy Education Initiative

Levels:
Grades 6-12

Content Areas:
Chemistry; Physical Science

Lesson Time:
45 -60 minutes

Next Generation Science Standards:
PS3.D
MS-LS1-7
HS-LS1-7

Objectives & Outcomes:
Students will identify glucose, starch and fat in a variety of foods and tie their presence to that food's suitability to make ethanol.

After completing this activity students will be able to:

- Describe the characteristics of a variety of biomass types that contain glucose and starch.
- Explain in broad terms how glucose from plants can be converted into biofuels.

Contact:
Bioenergy Education Initiative
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Description:
In this lesson students will conduct experiments to identify glucose, starch and fat in a variety of foods. They will learn that energy, in the form of glucose, is stored in all plants. The glucose in some plants is being used to make biofuel.

Using This Lesson:
The experiment in this lesson is done in small groups. An advanced student option is available.

The background information has been written so it can also be used as reading material for students. Vocabulary words are highlighted in the text and defined. Additionally, leading questions are included to promote discussion and critical thinking.

A link with supporting video material can be found on the Resources page.

The Power in Plants

Humans use enormous amounts of energy everyday; from heating and cooling homes, to fueling transportation, to powering factories, performing the countless other energy dependent activities of our daily lives. Because of our energy dependence, it is vital that we discover more efficient and sustainable ways to meet our energy needs. Power from plants and other organic materials and waste (i.e., bioenergy) is part of a sustainable future.

The glucose and cellulose found in plants can be converted into fuel for transportation. Plants and other organic materials are renewable, unlike nonrenewable fossil fuels. Scientists are also looking for plants to use in biofuel production that require less water and chemicals (pesticides and fertilizers). This could mean better plants for producing fuel, while conserving precious natural resources.

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Set Up:
To make it easier to manage multiple student groups, create stations where students can get their supplies.

Directions:
1. Have students number six Dixie cups 1-6 with a Sharpie and fill with the material described in the following steps.
   Cup 1: Use a spoon to crush one of the oyster crackers on the plate. With the spoon, transfer the cracker crumbs to Cup 1. Add 2.5 grams (½ tsp.) water and mix to create a semi-liquid mixture. Add more water if needed.
   Cup 2: Place a marshmallow in Cup 2. Use a clean spoon to mash it into small pieces. Add 2.5 grams (½ tsp.) water and mix to create a semi-liquid mixture. Add more water if needed.
   Cup 3: Place 2.5 grams (½ tsp.) of peanut butter in Cup 3.
   Cup 4: Place 2.5 grams (½ tsp.) of applesauce in Cup 4.
   Cup 5: Mash corn kernels with a spoon on the plate. Transfer to Cup 5 and add 2.5 grams (½ tsp.)water and mix to create a semi-liquid mixture. Add more water if needed.
   Cup 6: Add ground biomass to Cup 6. Add a 2.5 grams (½ tsp.) water and mix. Add more water if needed to make a semi-liquid mixture.
2. Fats Test: Have students number six brown paper strips 1-6. Then have them use forceps to rub each food sample, corresponding to its cup number, against a brown paper strip. They place the strips on a paper towel to dry.
3. Glucose Test: Have students number six TesTape strips 1-6 and then dip each into its corresponding food's cup. Students place each strip on a paper towel to dry. Note: If the brand of strip being used tests multiple items, make sure students are using the correct pad for glucose.
4. Starch Test: Have students place two drops of iodine on the food remaining in each cup.
5. Have students observe the reactions in each test. They record their observations on the attached worksheet.
   a) If an oil stain is observed on the brown paper, the sample tests positive for fat.
   b) If a color change is observed on the TesTape, the sample tests positive for glucose.
   c) If a color change is observed when iodine is added, the sample tests positive for starch.
6. Have the different students groups compare results.
7. What other foods would students like to test? Develop a list of 10 additional foods. Arrange to bring them in for testing. Have students test them using iodine, TesTape strips and brown paper squares. Have them add their results to the worksheet table.

Materials: Per Group
- Eye dropper
- Iodine (0.1%)
- 6 TesTape strips (2 inch or 5 cm strips) or glucose urine test strips
- 6 brown paper 2 inch strips (e.g., paper bag)
- 4 spoons
- Forceps or tweezers
- ½ & ¼ measuring teaspoons
- 6 small disposable cups (2 oz. Dixie cups)
- Small paper plate
- 1-2 oyster crackers
- 1-2 mini marshmallows
- 5 grams (1 tsp.) smooth, unsweetened peanut butter
- 5 grams (1 tsp.). unsweetened applesauce
- 2 corn kernels (fresh, frozen, or canned)
- 5 grams (1 tsp.) ground biomass (cornstalks or grass)
- Paper towels
- Water

Students test these items for the presence of glucose, starch and fat.

Expected Outcomes:

The photo to the right shows the results you can expect from each sample. Paper strips will show oil spots if they contain fat. TesTape strips will change color if they detect glucose. If a food contains starch, it will turn a blue/blackish color.

The completed worksheet below indicates expected research results.

FOOD SOURCE	OBSERVATIONS	GLUCOSE (+/-)	STARCH (+/-)	FAT (+/-)
Crackers	Crackers are dry and may take extra water to become liquid enough to measure with TesTape strips.	-	+	- minor
Marshmallows	Marshmallows should only be positive for glucose. However, manufacturers may coat them with starch to keep them from sticking. As a result, students will sometimes get a positive starch reaction.	+	+ (sometimes)	-
Peanut Butter	Peanut butter should only be positive for fat. However, manufacturers add sugar to certain brands, causing them to test positive for glucose.	+ / -	-	+
Applesauce	The apple sauce has a thicker consistence and can take time to dry on the brown paper strips. Some students may be confused by its slow drying and think it tested positive for fat.	+	-	-
Corn	Corn tends to be pasty and may take extra water to make it liquid enough to test.	-	+	+ minor
Biomass	Biomass does not test positive for anything, even glucose. This is because it needs to be broken down first before glucose can be accessed.	-	-	-

Experiment Questions:

Below are basic and advanced level questions and observations students should make from the experiment.

BASIC LEVEL

1. Identify whether each food contains starch, glucose or fat. (*See above chart*)
2. What part of the plant does each food come from? Can you infer anything about which parts of plants contain starch, glucose or fat? (*Starch is found in seeds and grains, fat is present in nuts/oil, glucose is present in fruit or plant sap.*)
3. How did your results compare to other groups? Were the results a surprise? (*Various answers*)
4. How is the glucose in these foods formed, or where does it come from? (*Photosynthesis in plants, using sunlight, carbon dioxide and water*)

5. Which of these foods could be used to produce biofuel? Why? (*The glucose in apple sauce, marshmallows and sugars could easily be converted into alcohol to make biofuel. Starch must be broken down into its glucose subunits first, but this is easy to do with enzymes. Corn, a source of starch, is currently the most common type of biomass used to manufacture ethanol in the U.S. Fat could be burned in a diesel engine*)
6. Can the grass be turned into biofuel? (*Since the glucose in grass and woody biomass is in the form of cellulose, it is a more complex process to make ethanol from it. Breaking down cellulose into glucose subunits is harder to do than breaking down starch. However, cellulose, many materials that contain cellulose, such as wood, can be burned for energy*.)

ADVANCED LEVEL

1. Have students test other foods like dairy and meat and then record their results. Then have the students determine, based on their findings, if these sources they tested would make good ethanol producers. Why or why not? (*Various answers*)
2. How could biofuels be produced on a large scale from the materials tested in this experiment? (*Peanuts could be crushed and made into peanut oil. This could then be made into biodiesel. The starches could be broken down into glucose and fermented into ethanol. Glucose can be fermented without breaking it down, but it is difficult to get it in large quantities from plants. Woody plants (leaves, branches, trunks) can be broken down into glucose by being pretreated in an enzymatic digester, then fermented into ethanol. They can also be burned.*)
3. What is the purpose and composition of the TesTape strips? Why does a color change occur? (*The TesTape strips are designed to measure the level of glucose in urine. The TesTape strips are used in this lesson to measure the amount of glucose present in the marshmallows and applesauce. The strip has glucose oxidase that converts glucose into gluconic acid and hydrogen peroxide. The hydrogen peroxide then reacts with a dye in the strip to create a color change. The color will be darker when more glucose is present.)*

It All Comes Down to Glucose

Directions:

1. Label six Dixie cups with the numbers 1-6 with a Sharpie. Then fill the cups with the material described in the following steps.
   Cup 1: Use a spoon to crush one of the oyster crackers on the plate. With the spoon, transfer the cracker crumbs to Cup 1. Add 2.5 grams (½ tsp.) water and mix to create a semi-liquid mixture. Add more water if needed.
   Cup 2: Place a marshmallow in Cup 2. Use a clean spoon to mash it into small pieces. Add 2.5 grams (½ tsp.) water and mix to create a semi-liquid mixture. Add more water if needed.
   Cup 3: Place 2.5 grams (½ tsp.) of peanut butter in Cup 3.
   Cup 4: Place 2.5 grams (½ tsp.) of applesauce in Cup 4.
   Cup 5: Mash corn kernels with a spoon on the plate. Transfer to Cup 5 and add 2.5 grams (½ tsp.) water and mix to create a semi-liquid mixture. Add more water if needed.
   Cup 6: Add ground biomass to Cup 6. Add a 2.5 grams (½ tsp.) water and mix. Add more water if needed.

2. Number six brown paper strips 1-6. Use forceps to rub each food, corresponding to its cup number, against a brown paper strip. Place the strips on a paper towel to dry.

3. Number six TesTape strips 1-6 and then dip each into its corresponding food's cup. Place each strip on a paper towel to dry.

4. Place two drops of iodine on the food remaining in each cup.

5. Observe the reactions in each test. Record your observations on the attached worksheet.
   a) If an oil stain is observed on the brown paper, the sample tests positive for fat.
   b) If a color change is observed on the TesTape, the sample tests positive for glucose.
   c) If a color change is observed when iodine is added, the sample tests positive for starch.

Materials: Per Group

- Eye dropper
- Iodine (0.1%)
- 6 TesTape strips (2 inch or 5 cm strips) or glucose urine test strips
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- Paper towels
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Below, images show the three types of tests that will be run on the six sample materials in this experiment to determine if they contain fat, glucose or starch.

STUDENT WORKSHEET:
It All Comes Down to Glucose

DIRECTIONS:
In this experiment your group will test six items to find out if they contained starch, glucose or fat. Record your observations in the chart below and complete the additional questions.

FOOD SOURCE	OBSERVATIONS	GLUCOSE (+/-)	STARCH (+/-)	FAT (+/-)
Crackers				
Marshmallows				
Peanut Butter				
Applesauce				
Corn				
Biomass				

1. What part of the plant does each food come from? Can you infer anything about what parts of a plant contain starch, glucose or fat?

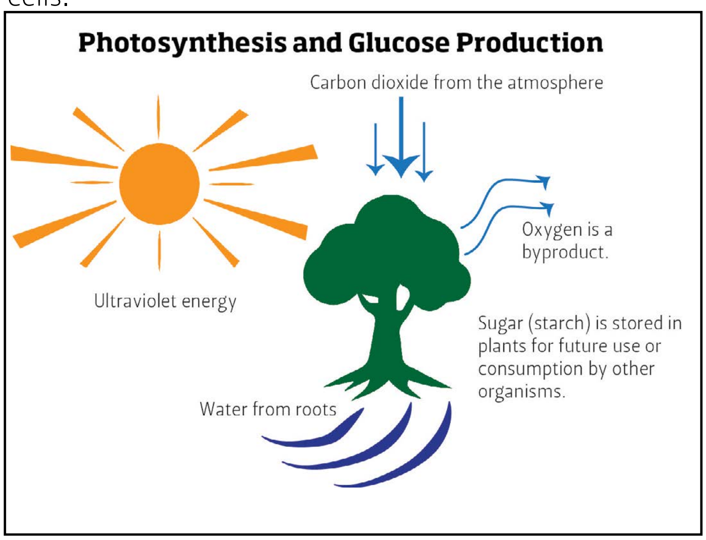
2. How did your results compare to other groups? Where you surprised by any results?

3. What does the glucose in the foods provide us with?

4. Which of these foods could you use to produce biofuel? Explain.

Glucose and Energy

Glucose plays a key role in the biological world. ***Glucose*** is a simple sugar that is a part of many carbohydrates. Plants can make glucose via ***photosynthesis***. Using energy from sunlight, plants make carbon dioxide in the air into glucose. The energy trapped from the sun during photosynthesis is stored in the chemical bonds of glucose. Many living organisms use glucose as a source of energy. For example, the primary fuel our bodies burn is glucose. Our bodies release and use the energy stored in glucose through cellular respiration, which is done inside our cells.



Plants can store glucose for later use in the form of ***starch***. Starch is a ***polymer*** (long chemical chain composed of repeating chemical subunits) made up of many glucose molecules. Most of us are familiar with starch in rice, potatoes, corn and wheat bread. Starch is relatively easy to digest, or break down into glucose.

Plants also link together glucose molecules to construct cellulose, an important part of plant cell walls. Plants produce almost one hundred billion tons of cellulose per year, making it the most abundant organic compound on Earth.

Cellulose uses a different type of chemical bond between the glucose than starch, and it is very difficult to digest or break down because of this bond.

If you have ever chewed on a piece of sugar chain, you are familiar with plant sugars. These sugars come out of the plants easily and are easy to digest, but the plant cell walls, made of cellulose, are very hard to break down and digest and are left over after you chew the sugar out of the cane. Starch and cellulose molecules are called ***polysaccharides***, (polymers made of many linked simple sugar molecules).

Yeast (single-celled fungus) derives energy from glucose by breaking it down in the process of ***alcohol fermentation***, forming CO_2 and ethanol as byproducts. Yeast can also ferment other simple sugars such as fructose. Yeast can ferment some ***disaccharides*** (two sugar molecules bonded together), such as sucrose, by converting them to monosaccharides first.

Glucose & Biofuels

Because of our energy dependence, it is vital that we discover more efficient and sustainable ways to meet our energy needs. Bioenergy produced from plants and other organic materials and waste is one possible source of alternative energy. There are many different kinds of bioenergy, such as heat released by burning wood.

However, since humans use liquid transportation fuels for everything from cars and trucks, to tractors and jets, scientists are particularly interested in developing bio-based alternatives to liquid transportation fuels. Ethanol is an important liquid biofuel that is already very widely used. Did you know that ethanol already accounts for 10% of the total volume of the gasoline sold in the U.S.?

Biofuels like ethanol can be produced from plant materials containing glucose. Because the glucose was made from carbon dioxide from the air, fuels made from plants release less net carbon dioxide (a gas that impacts global warming) than fuels made from petroleum pumped out of the ground. Plants such as sugarcane, corn, and even poplar trees can be made into fuel. Adding yeast to plant material containing glucose or other simple sugars allows the yeast to convert the glucose into ethanol.

Plants containing starch (such as wheat and corn) are much more common than plants containing sugars. However, yeast is not able to directly ferment starch into alcohol because the glucose is linked together in a complex structure. The glucose must first be released from starch using an enzyme to break apart the network of sugar molecules. Enzymes to digest starch are readily available.

Biofuels made from potential food crops are called ***first generation biofuels***. However, making first generation biofuels could deplete critical food sources or compete for land needed to grow food. ***Second-generation biofuels*** are made from agricultural and forestry wastes or residues, or purpose-grown non-food feedstocks. While this allows plants and trees (such as corn stalks, poplar trees and switchgrass) to be converted into fuel, the conversion process is more complicated and expensive than for first generation biofuels because second-generation feedstocks containing cellulose must first be physically broken up and then enzymatically digested into glucose.

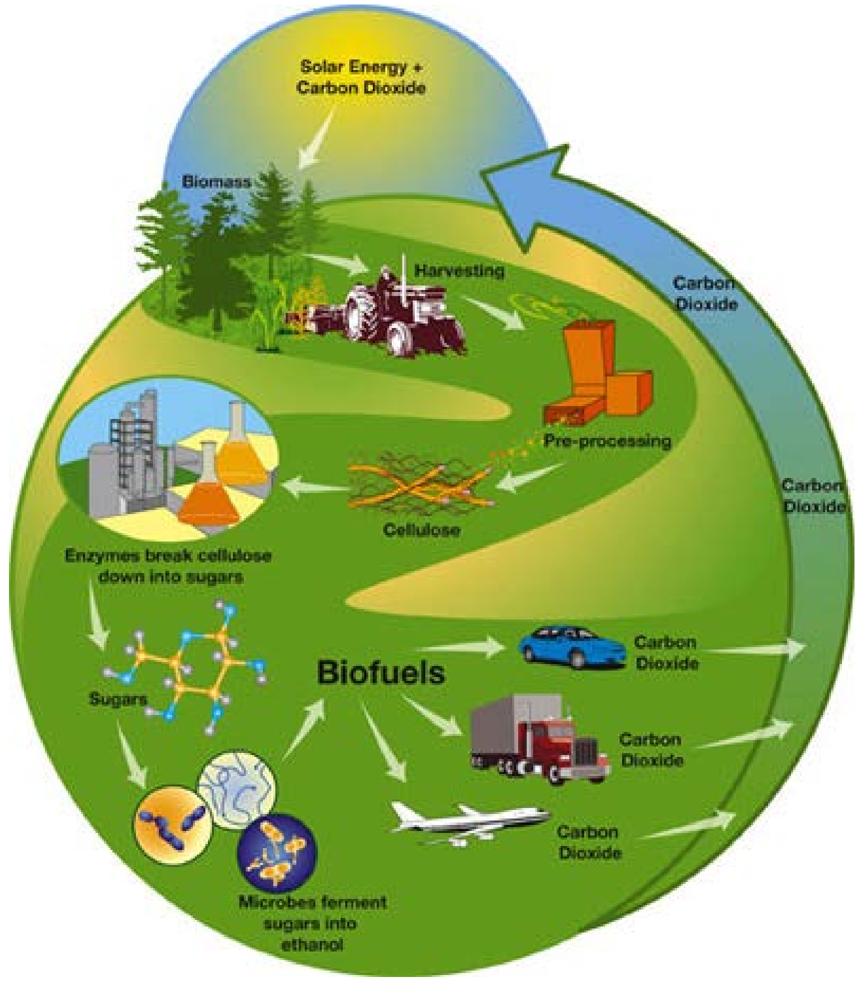


Image Source: Ars Technica

Summary

Glucose is a key molecule for biofuel production. Yeast uses glucose to make ethanol, an important biofuel. Plants create glucose in many forms (sugars, starch and cellulose). Sugars and starches, easier and less expensive to process, are found in high-value plants used for food. Cellulose, the most common and least expensive form of glucose, is the form that requires the most complex and expensive processing to make biofuel. This is a pressing problem for biofuels research.

Next Generation Science Standards

DISCIPLINARY CORE IDEAS:
PS3.D: Energy in Chemical Processes and Everyday Life

PERFORMANCE EXPECTATIONS:
MS-LS1-7: Develop a model that describes how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

HS-LS1-7: Using a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a new transfer of energy.

PRACTICES:
- Developing/using models
- Engaging in argument from evidence.

CROSSCUTTING CONCEPTS
- Cause and effect: Mechanism/explanation
- Energy/matter: Flows, cycles, conservation

VIDEO RESOURCES
Lecture 7: Biomass Chemistry; Times: 1:55 – 4:20, 5:30 – 6:55
These video links provide supporting information. Note the relevant times appropriate to this experiment.

GRANT SUPPORT
This work is part of the Advanced Hardwood Biofuel Northwest project (hardwoodbiofuels.org) and is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30407 from the USDA National Institute of Food and Agriculture.

Resources:

Cellulosic Ethanol - Biofuel Beyond Corn, Nathan S. Mosier, (December 2006) Purdue Extension, Department of Agriculture and Biological Engineering, Purdue University. Retrieved from https://www.extension.purdue.edu/extmedia/ID/ID-335.pdf

Additional Resources:

Education Homepage, Office of Energy Efficiency and Renewable Energy. Refer to http://energy.gov/eere/education/education-homepage.