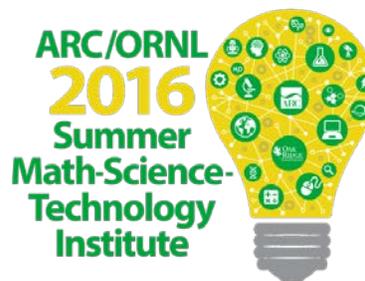




Fermentation Challenge...How Plants Matter

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Target Grade: 9-12, Biology

Time Required: 3-5 50 minute class periods

Standards:

NGSS

- HS-LS2-3 - construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-7 - Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-ETS1-2 - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Lesson Objectives:

Students will:

- identify different types of carbohydrates found in plants
- list the products of fermentation
- explain that due to enzyme specificity yeast can only metabolize sucrose, not starch or cellulose
- infer metabolic rates through measurement of carbon dioxide production.
- propose methods, such as heat and enzymes, to digest complex carbohydrates into simple sugars

Central Focus:

This lesson uses an understanding of the process of fermentation as a basis of discussing the production of ethanol as a biofuel. Through research, pre-work, and a lab, students will be able put themselves in the shoes of biofuels researchers to discuss why certain techniques and stocks are better for the production of biofuels than others.

Background Information:

Students should have a foundational knowledge of Photosynthesis, fermentation, biofuels, metabolism, as well as basic lab skills.



Materials

- Balloons
- Pint sized soda bottles (or similar container)
- Dry yeast packets
- Very warm water
- Yeast feedstocks (i.e. sugar, cornmeal, sawdust, grass clippings, etc)
- String
- Ruler
- Technology to access internet
- Textbook

Instruction

Day 1:

Photosynthesis Webquest (Appendix A): Intended to be used as a review to photosynthesis, but could also be used as a general introduction. The webquest can be done either in a group or individually, which ever meets the needs of the specific class better. Give the students time to investigate photosynthesis and the importance of its' role to plants and our environment. Connect our (mammals) use of glucose and our need for energy to the process of Photosynthesis.

Review the webquest. It can be reviewed as a class discussion or by having students grouping and using the jigsaw strategy.

Day 2:

Structure Review (Appendix B): If time permits, allow students to do their own research on the plants. Another option is to give students different plant materials to investigate and get them back together to share information. If time is an issue, teacher can fill in parts of the information ahead of time or lead the class in discussion to provide the information.

Have students work on the Prelab sheet (Appendix C) for the next day's lab and allow them to ask any procedural questions they may have.

Day 3:

Teacher should go over answers to Structure Review and Prelab with the whole class. Next, students should go into the lab and begin the set-up and execution of the experiment (Appendix D). Experiments should be left over night for final measurements previous day. Note: Day 3 and 4 should not be separated by multiple days such as a weekend or holiday.



Day 4:

Students should complete their final measurements and lab analysis.

Day 5:

Teacher lead class discussion about experimental error and how the experiment could be improved upon, including what other plants or materials could be tested. This is a good point to bring in discussion related to biofuels.

Assessment

Formative: Webquest, structure review, and classroom discussion

Summative: Post Lab with the possibility to assign formal lab report

Safety and Cleanup Required

Students should label their experimental variables. These labels will help make the experiment and a clear.

Before each of the following labs, be sure to discuss safe, sterile technique with the students as they will be working with fungus and bacteria. Students should wear protective eyewear, gloves and aprons as appropriate.

Check with maintenance department before pouring anything down the drains.

Name: _____

Group Members Names: _____

Date: _____ Period: _____

Photosynthesis and Cellular Structure Webquest

Directions: Using reliable internet sources (no blogs, student data or Wikipedia) and your text book answer the following questions.

1. What is photosynthesis?
2. What is the formula?
3. What gas is taken in by the plant during photosynthesis what gas is given off by the plant from photosynthesis?
4. What is the sugar used/created during photosynthesis?
5. How do plants meet their energy needs during photosynthesis?
6. Why is photosynthesis important for the planet?

7. What is glucose?

8. What can mammals (you) get from carbohydrates?

What does this give us?

9. Plants use that energy to build what?

Name: _____

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Date: _____ Period: _____

Let's Look at the Cell Wall

Directions: Using reliable internet sources (no blogs, student data or Wikipedia) and your text book answer the following questions.

1. A cell wall is composed of Lignocellulose, lignin cellulose, hemicellulose and chitin.

Investigate each of these materials and answer the following questions about each:

	Lignocellulose	Lignin	Cellulose	Hemicellulose	Chitin
Composed of					
Used in plant wall					

2. Why would a plant have one material in their cell wall over another (think from and function)?

3. Let's look at 4 different plants (look at different parts, different leaf types, break the leaves apart) and predict how their cell walls are similar and different:

Make your own notes below about each plant

Plant 1 _____

Plant 2 _____

Plant 3 _____

Plant 4 _____

4. How do you think these plants cell walls similar?
5. How do you think these plants cell walls different?
6. Thought Question: Which parts of the plant contain carbohydrates? Do all these parts contain the same type of carbohydrates? Explain your answer in paragraph form.

Adapted from: Great Lakes Bioenergy Research Center - www.glbrc.org/education

Name: _____

Group Members Names: _____

Date: _____ Period: _____

Prelab

Yeast metabolize carbohydrates for energy for their own growth and reproduction. In anaerobic conditions they produce ethanol as a by-product, which can be used as a transportation fuel. Due to concerns of dwindling supplies of fossil fuels and global climate change, scientists are investigating using yeast to produce large quantities of ethanol for transportation fuels. However, yeast can only metabolize certain food sources due to biological constraints. In this activity, you will investigate the ability of yeast to metabolize a variety of carbohydrates originating from different feedstocks (plant materials).

In order to create ethanol, yeast must have a good source of digestible sugars. Plants contain a tremendous amount of carbohydrates (about 50% of a plant is carbohydrates) but not all of this is digestible for yeast. The chemical formula for fermentation is:



Glucose ---> ethanol + carbon dioxide + energy

1. Which parts of a plant contain carbohydrates? Do all these parts contain the same type of carbohydrate?

2. Look at the materials list provided by your teacher for this activity. How will we measure the metabolic activity of the yeast? Why is this measurement an indication of metabolic rate?

3. What are the plant materials (also known as feedstocks) to be tested in this experiment? Compare the carbohydrate composition of table sugar (sucrose) with the other feedstocks and hypothesize what some of the differences may be.

4. Which of the feedstocks to be tested in this experiment do you think will be metabolized the fastest by the yeast? Why? Make your hypothesis below.

Name: _____

Group Members Names: _____

Date: _____ Period: _____

Simple Demonstration to Compare Metabolic Rates of Different Feedstocks:

This introductory activity demonstrates that yeast can digest some sugars but not others. Your job is to determine why this happens. After the demonstration, discuss why the results varied for different feedstocks (plant materials) and join other scientists in the field of biofuel production to develop your own experimental methods to increase CO₂, and therefore ethanol, production rates from cellulosic biomass.

Procedure – Anaerobic Respiration with Balloons

1. Stretch out 3 balloons by blowing them up a few times and then lay them aside.
2. Add one packet of dry yeast to one cup of very warm tap water and stir. Repeat this twice so that 3 cups of warm water are activating yeast. Allow yeast to activate for about 5 minutes.
3. Add 2 tablespoons of sugar to the 1st bottle, 2 tablespoons of ground corn or cornmeal to the 2nd bottle, and add 2 tablespoons of corn stover or other plant material to the 3rd bottle.
4. Add the one cup of the yeast water mixture to each bottle and gently swirl until the sugar/ corn/plant is as dissolved as possible.
5. Attach a stretched out balloon to the mouth of each bottle, securing with a rubber band if necessary.
6. After 10-20 minutes, the balloons may stand upright. Eventually the balloons may begin to inflate. Allow experiment to run for a minimum of 1 hour, and for as long as desired afterwards.
7. Record visual results at 20-minute intervals. Measurements of balloon circumference maybe taking for quantitative analysis.

Record Data in the table below

Feedstock Tested	Balloon Circumference (cm)					
Time						
Water (control)						
Sucrose						
Cornmeal						
Stover						

Calculate class average respiration rates and record results in the table below

Feedstock Tested	Class Average Balloon Circumference (cm)
Water (control)	
Sucrose	
Cornmeal	
Stover	

Analysis Questions

1. What is the chemical formula for the metabolism observed in this experiment?
2. Which feedstock fermented the most? How do you know?
3. Was your hypothesis supported by the experimental results? Use data to support your answer.
4. Think about the differences in metabolic rates for the feedstocks you observed. What can you infer about the enzymes in yeast from the different results you observed?
5. Table sugar is pure sucrose, which is fermentable by yeast. What do you think the carbohydrate content is for the other feedstocks you tested? Are they homogeneous or heterogeneous? What evidence do you have?
6. What are some of the limitations of this demonstration as a model of fermentation?

