Topic 4: Energetics – 4e. Fermentation Lab

Resources:

Miller, K., Levine J. (2004). *Biology.* Boston, MA: Pearson Prentice Hall.

Scott, R., Sullivan, W. Ecology of Fermented Food [Internet]. *Human Ecology Review,* Vol. 15, No. 1. 2008. Available from: http://www.humanecologyreview.org/pastissues/her151/scottandsullivan.pdf

Building on:

All living things require *energy*. Energy is needed to grow, move, reproduce and to combat *entropy.* The ultimate source of energy on our planet is sunlight. Plants and other *producers* can take the energy of the sun and use *photosynthesis* to store that energy in the form of *organic molecules* like *glucose*. *Cellular respiration* and *fermentation* are needed to release the potential energy in those organic molecules and convert it into a useful form of energy capable of doing *work,* usually *ATP*. Cellular respiration requires oxygen and produces ATP, carbon dioxide and water. When oxygen is not present, cells can continue to break down glucose by means of fermentation. Fermentation produces ATP in much smaller amounts than cellular respiration and it also produces other organic compounds. The type of organic compounds that are the end products of fermentation depend on the type of cell that is fermenting, the enzymes that cell has available to catalyze the reactions, and the type of substance being fermented. Yeast produces ATP, *ethanol,* and *carbon dioxide* in the presence of carbohydrates. Mammals produce ATP and *lactic acid.* Some creatures can live off of the ATP produced by fermentation, and they are called *anaerobes;* while fermentation does not produce enough ATP to sustain life for many cells, they must rely on cellular respiration, and they are called *aerobes.* Although mammals can undergo fermentation, it cannot sustain them; so mammals are aerobes.

Links to Chemistry:

Bond energy
Endothermic versus exothermic reactions
Organic molecules
Conservation of matter
Conservation of energy
Entropy
Oxidation – Reduction reactions
Gas laws
Stoichiometry

Links to Physics:

Work
Potential and kinetic energy
Thermodynamics
Efficiency

Phase changes
Gas laws

Stories: Fermentation brings up thoughts of beer and wine, but there are many other products on the market that are also fermented. Some are fermented by yeast or other fungi, and some are fermented by bacteria. Students may find it interesting to learn that the following items are the product of fermentation:

Sauerkraut
Pickles
Tabasco (hot sauce)
Salami
Vinegar
Soy sauce
Cheese
Yogurt
Butter

Fermentation has long been a good way to preserve food. Prior to refrigeration, it was a challenge to keep food fresh enough to support people through long winters. Mead is a honey-based fermentation product that was popular in Europe during the middle ages. Mead contained alcohol and surely had intoxicating qualities, but it was consumed by young and old alike. Mead provided nourishment and could be kept stored in large barrels, so it had high survival value.

Materials for the Lab:

- Test tubes
- Dry yeast
- One hole stopper connected to rubber tubing
- Beaker
- Warm water
- Sucrose (table sugar)
- Glucose (a.k.a. dextrose)
- Corn Starch
- Paper clips

Instructions to the Teacher for the Lab:

Different students can test different carbohydrate sources or each lab table can set up four beakers, one for each of the carbohydrates and one for the control.

This lab will measure the gas being given off by means of water displacement. The toughest thing for students is to get the collecting test tube upside down in the water of the beaker without allowing any air to get in. A trick that you can demo before they set up the lab is to fill a test tube to the brim with water. Take a small square of brown paper towel and set it

down on the top of the test tube so that the paper towel absorbs the water at the top of the test tube and settles onto the tube. Hold the tube over a sink or a bucket (just in case) and turn the tube upside down; the paper should stay stuck to the test tube and none of the water should fall out. After the test tube is pushed down into a beaker of water, forceps can be used to pull the piece of paper towel out.

When adding water to the sugar and yeast in your test tubes, add a little water at a time and shake to mix up the yeast, sugar and water. Fill the test tube to the brim so that when you insert the stopper with the rubber tubing, it will actually push a small amount of the mixture out and allow very little or no air in your test tube.

Open a paper clip and insert it up the open end of your rubber tubing. Bend the paperclip so that the end of the rubber tubing is now in a J shape. You can lower the J end of the rubber tubing into the beaker of water and up into the collecting tube very carefully. You will want to wait 24 hours to see how much gas has collected in each tube.

Tube 1 should not collect any gas, as it is the control.

When the kids take the lab apart, ask them to smell the contents of the tube. They may smell some alcohol.

Fermentation Lab

Introduction: Yeast carry out fermentation in the absence of oxygen. They convert the energy in the bonds of a carbohydrate to make ATP. They also produce CO_2 and ethanol. The rate of fermentation can be determined by measuring the amount of CO_2 produced in a class period. You will be setting up the yeast with three different carbohydrates.

Hypothesis: Which type of carbohydrate, glucose, sucrose, or starch, do you think will product the greatest amount of fermentation over the class period? Why?

Descriptive List: State the independent variable, the dependent variable, and two constants that are included in the lab

Materials:

- 8 test tubes
- 4 one-hole stoppers with a glass bend and rubber tubing
- 4 250-ml beakers
- Test tube rack
- 4 paper clips
- Dry yeast
- Sucrose
- Glucose
- Starch
- Water

Procedure:

1. Fill each 250-ml beaker ¾ full of tap water.
2. Get four test tubes. Fill each test tube with as much water as it can hold.
3. Take a small piece of dry paper towel and place it carefully on the water that is standing above the rim of one of the test tubes. When the paper towel has formed a wet seal all the way around the rim, you should be able to turn that test tube upside down and place the test tube and paper towel into the water of the beaker.
4. Check to see that there are no air bubbles in the test tube and then carefully remove the piece of paper towel from the beaker. Set the beaker and test tube set up to the side.
5. Follow steps 3 and 4 until you have a test tube set up in each of the four beakers.
6. Get four more test tubes and label them 1 to 4. Place them in the test tube rack.
7. Put two scoops of yeast into each test tube.
8. To test tube 2, add two scoops of sucrose.
9. To test tube 3, add two scoops of glucose.
10. To test tube 4, add two scoops of starch.
11. Fill the four numbered test tubes with water.
12. Make sure your one-hole stoppers already have a glass bend inserted through the hole and that a piece of rubber tubing is attached to the other end of the glass bend.

13. Put a stopper in each of the tubes numbered 1 to 4. This should cause some of the water to leak out of the test tubes. Wipe this water up.
14. Open a paper clip so that it is a fairly straight wire and push it up the open end of the rubber tubing. Now you can bend the rubber tubing into a U shape and it will stay that way.
15. Carefully put the U shaped end of the rubber tubing into the water in the 250-ml beaker, and slowly raise the test tube that is in that beaker just enough so that you can insert the end of the tubing up into the test tube.
16. Repeat this for all four setups.
17. After 24 hours look for the presence of gas in the test tubes that were inverted into the beakers. Use a ruler to measure the cm of water displacement that has occurred in each of the tubes. Record this information in a results table.
18. Construct a bar graph to show the amount of fermentation that took place in each of the four labeled test tubes.

Evidence: You should have an evidence table and a bar graph to show the results of this lab.

Analysis Questions:

1. Which test tube served as the control for this lab? What did this test tube tell you?
2. Review the structure of glucose, sucrose, and starch. Which of these molecules is the simplest and which is the most complex?
3. What are the monomers of sucrose?
4. Use your answers to questions 2 and 3 to help explain the results you got in this lab.
5. How would the results of this lab have differed if you had slightly warmed the test tubes over the class period? Explain your answer.
6. How would the results of this lab have differed if you had heated the yeast to 100 ^{0}C before you set up the lab? Explain your answer.
7. Why does the gas in the tube represent the amount of fermentation that has taken place?

Conclusion: Write a conclusion based on your purpose statement and your hypothesis.

NLQ: If you were going to study yeast fermentation further, what question did this lab raise that you could explore?