SCIENCE

Strange Brew

by Steven Ramirez Fong

Overview

Students will:

- Learn about fermentation and the difference between traditional biotechnology and today's GMOs.
- Perform a controlled experiment in which they select a variable and draw conclusions from their observations.
- Make their own homemade root beer using yeast to supply the carbonation.

Terrain Article: "Fries with That?" page 21, Spring 2006

Introduction

As the science of **genetic engineering** advances and the ability of researchers to create **genetically modified organisms (GMOs)** increases, many groups have begun advocating for the use of organic farming techniques and products. The public has many reasons to fear GMOs. GMOs can pass foreign genes into native species and potentially disrupt the careful balances established in **ecosystems** over millions of years.

One consequence of the controversy over GMOs is the stigma that has been placed upon the term **biotechnology**. While it is true that GMOs are products of biotechnology, biotechnology encompasses much more than genetic engineering. In its broadest sense, biotechnology refers to the manipulation of living organisms to produce new products and processes. We've been doing that longer than we've been writing down our history. Els Cooperrider, featured in the article "Fries with That?" supplies her brew pub with organic foodstuffs and beverages. The cheese on her cheeseburgers and the beer on tap are all organic, but they are also products of biotechnology.

Perhaps the best-known and most common example of biotechnology is **fermentation**. Fermentation is a process that takes place in many different organisms like prokaryotes, yeast, and us! During the **anaerobic** process of fermentation, **enzymes** inside cells break down sugar for energy and produce carbon dioxide gas as a waste product. Humans have used both **lactic acid** and alcoholic fermentation for thousands of years to make everyday products.

In lactic acid fermentation, enzymes inside cells break down sugar for energy and make carbon dioxide and lactic acid as waste products. This type of fermentation happens in our muscle cells. When you exercise and you can't get oxygen to your muscles fast enough, lactic acid builds up from fermentation. This build-up makes it harder for your muscles to do their job and contributes to muscle fatigue.

Lactic acid fermentation also occurs inside **bacteria**, something our ancestors used to make cheese. Long ago, people found that the milk they had stored did not spoil as it usually did, but formed chunks that tasted good. These chunks were cheese. We now know that the lactic acid from the bacteria's fermentation breaks down the milk proteins and solidifies fat into cheese.

In alcoholic fermentation, enzymes inside cells break down sugar for energy and make carbon dioxide and **ethanol** as waste products. This type of fermentation happens inside a type of fungal cell known as **yeast**. There are many types of yeast that carry out fermentation. Baker's yeast, or *Saccharomyces cerevisiae*, is used to make any type of rising baked goods, like bread. The carbon dioxide gas given off in fermentation causes the rising. Brewers yeast is used in the making of alcohol. The alcohol people drink (ethanol) is a waste product of this fermentation process.

When we use yeast to produce alcohol or when we manipulate the **DNA** of an organism to produce higher yield crops, we are using biotechnology. The different tools of biotech may be debated, but we can't have a meaningful discussion until we truly understand how biotechnology and GMOs are interrelated.

CA SCIENCE CONTENT STANDARDS GRADES 9-12: Cell Biology: 1b. Students know enzymes are proteins that catalyze biochemical reactions without altering the reaction equilibrium and the activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings. Investigation and Experimentation 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will: a. Identify and communicate sources of unavoidable experimental error. b. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions. c. Formulate explanations by using logic and evidence.

Taste Test

Warm-up Activity

Students will sample root beer, write down their observations, and discuss GMOs and biotechnology.

Teacher Directions

1. A week before beginning the lesson, announce to students that they will each need to bring in one clean, plastic 500mL bottle **with** its cap. (Or you can purchase a case of drinking water in appropriately sized bottles for the students.)
2. Three days before beginning the lesson, prepare several batches of root beer following the procedure outlined on **page 8**. There should be enough for each student to sample approximately 100-200 mL of root beer. An equal amount of root beer needs to be purchased from the store.
3. The day before beginning the lesson, assign the students to read Terrain article "Fries with That?"
4. Prior to beginning the lesson, set up a lab station for each group with the materials listed in the student procedure and samples of root beer — one from the store, one you prepared.
5. On the day of the lesson, create student groups of four. Direct student-groups to their lab stations. Have the students sample the two types of root beer labeled only "A" and "B."
6. Write the following on an overhead or a chalk board:

Students groups: Taste root beer A and B, take out a piece of paper, and answer the following questions as a group. Be prepared to share your answers with the class.

Root Beer Questions

What do you think is in root beer?
How do you think root beer is made?
What do you think the difference is between these two root beers? (To answer this question, you need to make observations)

Consensus Questions:
(Your answers must include parts of each individual member's answers.)
What is the difference between a GMO and an organic a product that was made using biotechnology?
Why is there so much controversy surrounding GMOs?
What is meant by the term "Biotechnology?"

7. Assign the introductory reading on **page 8** as homework.
8. Pass out a copy of the Root Beer Lab Procedure on **page 10**. Have students make root beer, label the bottles, and tightly cap them.

Glossary of Terms

Anaerobic process: a process that occurs in the absence of oxygen.

Bacteria: single celled organisms with no nucleus or organelles.

Biotechnology: the manipulation of living organisms to produce new products or processes.

DNA: Deoxyribonucleic Acid (the molecule of heredity).

Ecosystem: all the living and non-living things within a defined area.

Enzyme: a protein molecule that catalyzes a reaction.

Ethanol: the organic molecule produced by alcoholic fermentation.

Fermentation: an anaerobic process in which sugar is broken down for energy.

Fungal Cell: a cell of the Kingdom Fungus which absorbs its nutrients from an outside source.

Gene: a segment of DNA that codes for a protein product.

Genetic Engineering: the manipulation of DNA to produce new or altered organisms.

Genetically Modified Organism (GMO): an organism that has been altered through genetic engineering.

Lactic Acid: a waste product of lactic acid fermentation.

Lactic Acid Fermentation: the type of fermentation that occurs in bacteria and muscle cells.

Prokaryote: another name for bacteria.

Protein: an organic molecule composed of amino acids.

Saccharomyces cerevisiae: the common type of yeast known as "Baker's yeast."

Yeast: a single celled fungal organism commonly used in fermentation.

What's in Root beer?

Lab Activity

Students will make their own root beer.

STUDENT ROOT BEER LAB PROCEDURE

At your lab station, you are going to use the following procedure to make root beer using yeast — a living organism — as asource of carbonation. In your 500mL plastic bottle, you need to add all the ingredients in the appropriate amounts and then place your root beer in the sink or other location designated by your teacher. Then all you need to do is wait for a few nights and let the yeast do their work!

Materials

500mL plastic bottle with cap
Water (approximately .5 liter)
Root beer extract*(2.5 mL)
Table sugar (50 grams)
Yeast (.2 grams)
Graduated cylinder
Pipette
Electronic balance
Weigh boat
Spatula/spoon
Funnel
Magic marker for labeling
Measuring cup
Ruler

Directions

1. Label your bottle with your name, the date, and your period.
2. Measure 250 mL of water with a measuring cup.
3. Pour the water into your bottle.
4. Measure out 50 grams of sugar and .2 grams of yeast using the balance.
5. Place the yeast and sugar into your bottle.
6. Measure out 2.5 mL of root beer extract. Add this to your bottle.
7. Mix the contents well. Shake with the cap on.
8. Add more water until the water level is approximately 4 centimeters from the top of the bottle.
9. Tightly cap your bottle and lay it on its side in the sink (or other location) designated by your teacher.

*For root beer extract, we recommend the 100% natural ingredient root beer extract (#2) available from www.hoptech.com, a homebrewing supplier located in Dublin, CA. Historians often credit Charles Hires with creating the root beer flavor we recognize today. The ingredients that went into Hires root beer in 1922 included birch bark, chirreta, dog grass, ginger, hops, juniper berries, licorice, sarsaparilla, sugar, vanilla, wintergreen, and yerba mate.

Warning: If these fermentation activities are performed properly, tiny, trace amounts of alcohol will be produced. These amounts will be so small that the root beer would never be considered alcoholic. If batches are allowed to ferment longer than the prescribed time (beyond 48 hours) they will contain more alcohol.

Fermentation Experiment Demo

Activity

Students will watch the demonstration and hypothesize what increases the rate of fermentation.

Teacher Directions

1. Prior to the beginning of the lesson, set up a demonstration of the yeast balloon experiment using the directions on **page 12**. Set up a few examples so that some balloons are already filled when the students enter the classroom. Make sure the others fill at different times during the first few minutes of class as the students write.
2. Write questions **a** through **d** on an overhead or chalkboard. Give the students some time to answer them on a sheet of paper. Have the groups share their responses to the first three questions **(a-c)**. Demonstrate the yeast balloon experiment and lead the class in a discussion of WHAT is happening and WHY it is happening.
3. Ask the students to share their responses to question **d**. As a class, decide on several ideas that can be tested given the constraints of your classroom. If students have difficulty, you can suggest or lead them to the following ideas:

Temperature
Amount of yeast
Amount of sugar
Motion (stirring)
Salt concentration
pH
Type of water

4. When enough ideas have been generated, assign or allow groups to select one. Instruct them to design a simple experiment in which they test the variable they have been assigned.

Student Directions

After you settle in, take out one piece of paper. Read the questions below. Discuss your responses with your group and write them down. Refer to the article "Fries with That?" from the night before if needed. Be prepared to share your answers with the class.

a. Briefly observe your root beer bottle. What has happened? WHY?

b. What is yeast? Draw a picture of one if you can.

c. What is fermentation? You can describe it or write an equation.

d. What factors do you think might affect the rate of fermentation? (Name at least three.)

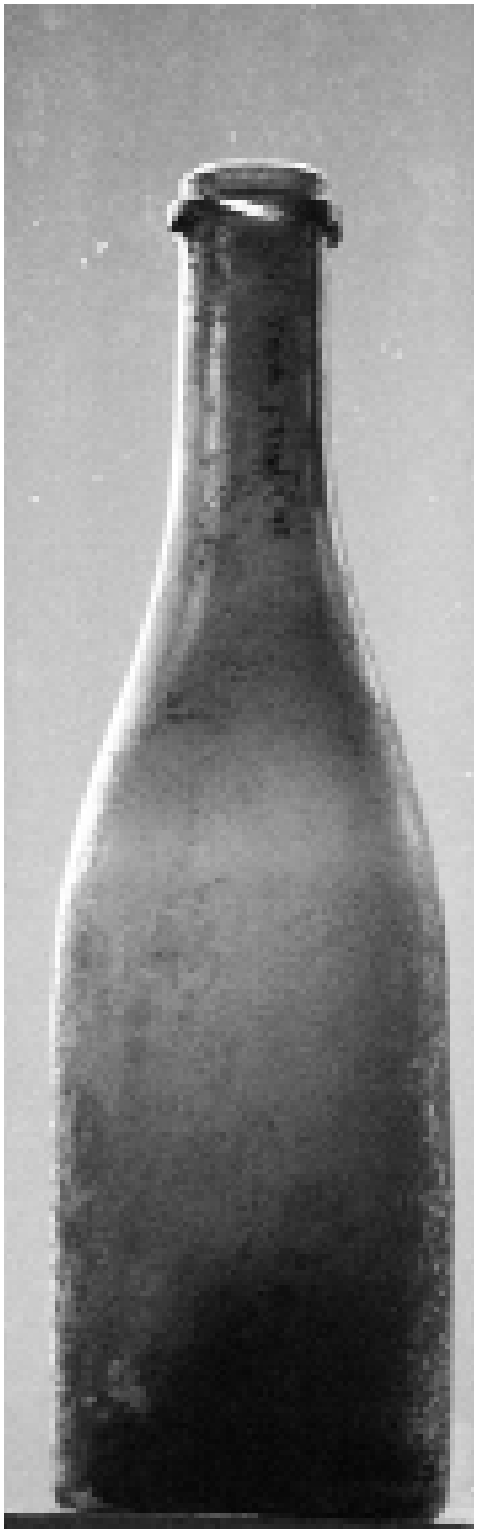
Yeast Balloon Experiment

Lab Activity

Students will design an experiment in which they will test the effect of one variable on the rate of yeast fermentation.

STUDENT YEAST BALLOON PROCEDURE

Directions
With your group, you are going to design an experiment to test the effect of one variable on the rate of yeast fermentation.



Materials: (for ONE yeast balloon set up)
500mL plastic bottle
Large rubber balloon
400mL of warm water (40-45 degrees Celsius)
1 packet of active dry yeast
15 grams of sugar
Hot plate or water bath
Thermometer

Lab Write-Up
As you design your experiment, you must write down the following:
A. Your group's QUESTION
B. Your group's HYPOTHESIS
C. Your group's list of MATERIALS
D. Your group's specific PROCEDURE
E. A table where your group will record its DATA and OBSERVATIONS

Before you begin your experiment please note:
• The basic procedure is for ONE 500mL bottle. You will most likely be making at least 4 bottles as you test your group's variable.
• You will need to change one of the aspects of the procedure depending on your variable. For instance, if you are going to change the amount of yeast used, you'll prepare one bottle following the directions below and three others with varying amounts of yeast.
• Make sure you are only changing one thing (your variable!). Everything else should be exactly the same!

Basic Procedure
1. Use a hot plate or water bath to heat 400mL of water to 40-45 degrees Celsius.
2. While your water is heating, stretch out your balloon by inflating it 10 times.
3. Add 15 grams of sugar and 1 packet of active dry yeast to the water and stir until it dissolves.
4. Transfer your yeast and sugar mixture to your plastic bottle.
5. Place your balloon over the top of the bottle. You can secure it further with some strong tape if you like, but most balloons should work fine if secured tightly.
6. As time passes, observe what happens to the mixture in the bottle and to the balloon. Record your observations.

Designing the Ultimate Root Beer

Wrap-Up Activity

Students will analyze the results of the various yeast balloon experiments and design a procedure for making the ultimate root beer.

Teacher Directions

NOTE: The students' initial batch of root beer should be ready by this activity.

1. Write questions on an overhead or a chalkboard. Give the students 10-15 minutes to answer them as a group. Ask each group to share their findings and write these under the headings:

What Happened?	Fermentation?	Error?	Effect?

2. Following their reflections on the yeast balloon experiment, allow students to CAREFULLY open their bottles and examine their root beer. If possible, you can set aside 10-15 minutes for the class to informally sample the root beers. (You will need small paper cups or other containers for this.)

Student Directions

1. As a group, answer the following questions:

- What happened in your group's experiment? (Hint: how did the variable affect the rate of fermentation?)
- What can your results tell us about fermentation in general?
- What was one possible source of error in your experiment?
- How might this source of error have affected your group's results?

Making the Ultimate Root Beer

Wrap-up Activity

Students will use what they have learned to make the "ultimate" root beer.

Student Directions

Now that the class has explored the effect of several variables on the rate of yeast fermentation, it is your job to design a procedure for making the Ultimate Root Beer. You have creative freedom in your design, but you must incorporate what you have learned. For example, if your class concluded that fermentation works best at a certain temperature, you should take this into account. Some tips:

- Use the standard procedure from the first activity of this lesson as a guide.
- Use every group's results. Your procedure should be as detailed as possible so you should be using all the information available to you.
- Talk to other groups about their experimental error. If their results were affected by errors, you might need to take this into account as you consider their variable in your procedure.
- Be detailed. Someone who has never made root beer before should be able to do it perfectly just by following your written instructions.
- Use you own experience and preferences. If you think people like sweeter root beer, you can change the amount of sugar.