

Purpose: Students explore alcoholic fermentation and its connection to aerobic cellular respiration. Students are also challenged to act as food scientists to develop a recipe for quick-rising bread dough.

Level: 9-12

Materials:

Activity 1

- Sandwiched sized sealable bags
- Yeast
- Warm Water
- Hot plate or microwave
- 100 mL beakers
- Sugar
- 1 T measuring spoon
- Paper Towels
- Permanent Markers
- Plastic Spoons
- Activity 1 Handout
- Cellular Respiration Concept Map

Activity 2

- Soup sized bowls
- Mixing spoons
- ¼ tsp measuring spoon
- ½ C measuring cup
- Flour
- Selection of variables to test.
Options:
 - Sugar
 - Non-caloric sweeteners such as stevia, NutraSweet (aspartame), Splenda(sucralose)
 - Different yeasts (rapid rising, active dry yeast)
 - Vital Wheat gluten
 - Different flours (rice, oat, etc.)
 - Different oils or butter
 - Milk or carbonated water
 - Salt
 - Baking soda or powder
 - Heat lamp or sunny window
- Beakers (250-400 mL) or pint jars
- Computers with graphing software
- Activity 2 Handout

Food Science – Bread Dough Challenge

Minnesota Science Standards and Benchmarks

9.1.1.2.1 Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations and draw conclusions supported by evidence from the investigation.

9.4.2.2.1 Use words and equations to differentiate between the processes of photosynthesis and respiration in terms of energy flow, beginning reactants and end products.

Background

Cellular respiration can be a difficult topic for students to understand because it cannot be directly observed. In this lesson, students who have studied the basics of aerobic cellular respiration will be introduced to alcoholic fermentation and will conduct a simple experiment to determine how yeast get energy from sugar. Students who aren't familiar with using yeast in baking may wonder if it's alive, which is another great opportunity for discussion.

Yeasts are unicellular fungi that reproduce asexually. The species *Saccharomyces cerevisiae* is used in bread baking, and wine and beer brewing. *S. cerevisiae* is also used as a model organism in many laboratories because it is easy and inexpensive to culture. It is a facultative anaerobe, meaning that it undergoes both aerobic and anaerobic fermentation. In the absence of oxygen, yeast and other organisms undergo alcoholic fermentation, producing CO₂ and ethanol and regenerating the NAD⁺ needed to continue glycolysis. While this produces less ATP than aerobic respiration, some ATP is still produced.

Students may be interested to learn that yeast is all around us; sourdough bread is made by allowing yeast in the air and in the flour to colonize a mixture of flour and water. The CO₂ produced during yeast metabolism is captured in bread dough, causing it to rise. The protein gluten provides a structure for the bubbles of CO₂. Kneading is necessary to develop and strengthen the crosslinks between gluten molecules. If dough is not kneaded enough, it won't be elastic enough to capture the CO₂ bubbles, resulting in a flat loaf. Gluten is not found in some grains, such as oats and rice. Students who try to make a dough with gluten-free flour may find that it won't rise at all.

In Activity 2, students are challenged to act as food scientists to develop a recipe for quick-rising bread dough. It is a good idea to test the original recipe first, as the amount of water it takes to make a kneadable dough will vary depending on your flour and humidity. Students groups will choose what

variable they want to test to change the basic dough. Many possibilities are included in the lesson, but depending on individual classroom resources, you could include more or fewer options. Adding sugar to the basic recipe and allowing the bread to rise in a warm environment will usually have the greatest effect on the rising time in 30 minutes, but your students' results may surprise you! If Activity 2 must be broken up over two class periods, it might be helpful to have students mix together the dry ingredients of their doughs (Step 11.) on the first day so they are ready to start right away on day two.

Procedure

Activity 1. Fermentation in Yeast

Before you begin, set up each lab station with 2 bags, a measuring spoon, a mixing spoon, and a 100-mL beaker. Warm the water and have it in a central location for students to access, along with the sugar and yeast. Set up a dishpan or designate sinks for disposing of the yeast mixture and rinsing out the bags. The bags can easily be rinsed and reused.

How do yeast cells get energy?

1. Introduce yeast by passing around small Ziploc bags of yeast and asking students if they know what it is and what it is used for. If no one knows, explain that it is yeast and that humans use it for many purposes, especially in cooking.
2. Review cellular respiration by asking students to work with a partner to write the overall equation for cellular respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$ Explain that in today's activity, we will be finding out how yeast cells get energy.
3. Display the diagrams of alcoholic fermentation and lactic acid fermentation (presentation slide 1). Explain that these processes are anaerobic, meaning that they don't require oxygen. Ask students to compare and contrast the processes. Tell students that in today's activity, they will be making observations to determine what process yeast uses to get energy.
4. Pass out the Activity 1 Handout. Working in groups, have students discuss and make predictions about how yeast get energy. Then, introduce the materials and procedure for the experiment:
 - a. Label one of your snack bags "W" for water and one "S" for sugar using the marker.
 - b. Measure 100 mL warm water into your beaker and pour it into the snack bag labeled "W."
 - c. Measure another 100 mL warm water into your beaker and add **1 T** sugar. Stir with the plastic spoon to dissolve. Pour this sugar water into the snack bag labeled "S."
 - d. Measure and add **1 T** yeast to **each** bag.
 - e. Close both bags and carefully mix the contents by smooshing the bag.
 - f. Open up both bags and carefully push out the air. Reseal the bags.

- g. Observe what happens to your bags over 20 minutes.

Note: depending on how accurately students measure, the temperature of the room, etc. the bags may inflate faster than 20 minutes. Have students monitor closely and make sure they bags are opened before they explode!

5. (Optional) While students complete the lab and observations, have them fill out the Cellular Respiration Concept Map. The concept map includes connecting phrases between concepts that can be read as sentences, and a word bank is provided in the Activity 1 Handout. A blank version, a version with some hints filled in, and an answer key are provided. Allow them to use their notes, textbook, internet or other resources if they need to complete the concept map.
6. Have students share results and discuss the following questions:
 - Why did the bag expand or “blow up”? *Answer: The bag expands as the yeast produce CO₂, a byproduct of breaking down the sugar.*
 - What gas did the yeast produce? *Answer: CO₂.*
 - What molecule does the yeast use for energy? *Answer: Sugar (glucose).*
 - What type of cellular respiration to yeast use? How do you know? *Answer: Yeast use alcoholic fermentation. You can tell because they did not have access to much oxygen since the air was pressed out of the bag, they produced CO₂ gas, and the contents of the bag have a faintly alcoholic smell.*
 - How do you think you could make this reaction faster or slower? *Answer: Possible answers might involve changing the temperature of the environment, using different liquids, or using different energy sources.*

Activity 2: Bread Dough Challenge

Before you begin, set up each lab station with a mixing bowl, mixing spoons, measuring cups and spoons, and 2 beakers or jars. Warm the water and have the water, flour, yeast, and other variable ingredients set up in a central location for students to access.

How can you make the fastest rising bread dough?

1. Ask students if they can name any food products that are made using yeast and alcoholic fermentation. Examples include bread, beer and wine.
2. Show students where wheat is grown in MN (presentation slide 2) and tell them that Minnesota has historically been a center of grain milling. Many familiar companies that make bread products are based in Minnesota (presentation slide 3).
3. Tell students that one of the challenges of producing bread on an industrial scale is the time that it takes to mix the dough, allow it to rise, bake the bread, cool it, and package it. Food scientists use engineering, biology, and chemistry to improve food products.
4. Tell students:
 - a. Imagine that you are on a team of food scientists at a new bread company. This company needs your help to make the bread rise faster so they can make more bread in a day.

- b. Your team will be splitting up the work to test as many variables as possible in order to recommend a new bread recipe or procedure for the company to use.
5. Pass out the Activity 2 Handout and direct students' attention to the original recipe. As you walk through the original recipe with students, model how to make the dough by mixing a batch in front of the class. Explain that the dough must be kneaded in order to strengthen the proteins, called gluten, that make it stretchy and capable of rising. Students will be testing different variables in order to develop a new recipe with a faster rising time.

Original dough recipe:

½ cup all-purpose flour

2 tablespoons water, 110 °F

¼ teaspoon yeast

Procedure:

1. In a bowl, mix together the yeast and flour.
2. Slowly add the water and stir to combine.
3. Using your hands, mix in any remaining flour in the bowl.
4. Knead dough for 1 minute.
5. Roll dough into a ball and allow it to rise for 30 minutes.
6. Arrange students into lab groups of 2-4 students. Direct students to brainstorm variables that could affect the rising time of bread.
7. Have students share and discuss their lists. Prompt them to think about variables they might not have considered, including:
 - a. *amount or type of yeast (regular vs. rapid rising)*
 - b. *amount or type of flour (all-purpose, whole wheat, rye, rice, etc.)*
 - c. *amount or type of liquid (water, milk, carbonated water, etc.)*
 - d. *temperature of liquid*
 - e. *kneading time*
 - f. *addition of sugar, honey, corn syrup, etc.*
 - g. *non-caloric sweeteners such as stevia, NutraSweet (aspartame), Splenda (sucralose)*
 - h. *addition of oil or butter*
 - i. *addition of salt, baking soda, or baking powder*
 - j. *addition of extra gluten (vital wheat gluten)*
 - k. *rising environment - temperature*
8. Have each lab group decide on a variable to test and sign up to ensure that there are multiple variables being tested in the class.
9. Using the Activity 2 Handout, each lab group writes a procedure to test their variable and a prediction of what will happen.
10. Discuss procedures as a class to make sure everyone will follow the same procedure. Consider especially the method of kneading, whether students will remove an equal amount of flour if they are adding a dry ingredient, and how you will measure the dough rising. One good method would be to use beakers and measure the difference between starting and ending marks after 30 minutes, therefore measuring the increase in volume of dough in mL. Glass jars with starting and ending marks drawn on with marker or tape also work, as shown in the photograph below. In this case, students would measure the difference in height in cm. In either case, students must standardize

how they will pack the dough into the beakers so it is even and there are no air bubbles. Additionally, the process of rising dough presents some challenges to measurement with this equipment, as it will likely be domed on top, and not form a level line. Students can discuss this and may choose to measure to the top of the dome.

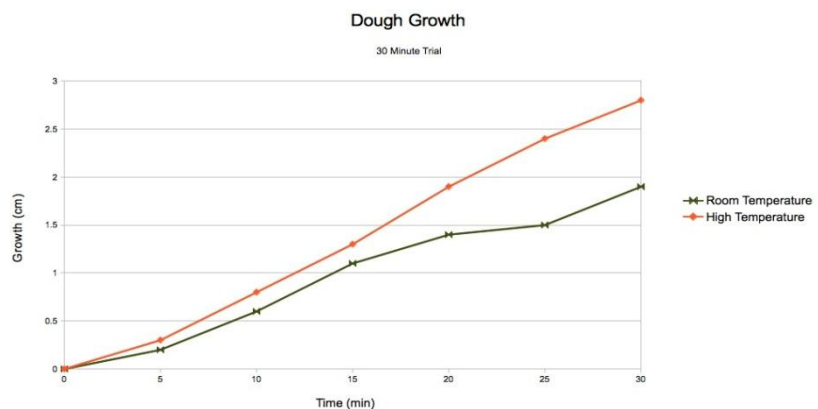
11. Check procedures and allow groups to carry out their experiments. Allow the dough to rise for 30 minutes, measuring the rise in 5-minute increments.



Six treatments of dough after 30 minutes.

1) control - original recipe, 2) original recipe using instant yeast, 3) dough made with 1 T vital wheat gluten in place of 1 T flour, 4) dough made with half all-purpose flour and half brown rice flour, 5) dough made with 1 T sugar in place of 1 T flour, 6) original recipe kept in a heated (100 °F) environment.

12. Have students create graphs of their data, either by hand or using a graphing software such as Google Spreadsheets or Microsoft Excel (see sample below). Have each group display their graph to the class and explain their procedure and results. Discuss as a class which treatments led to the fastest rising time and why that might be.



13. Using the Activity 2 Handout, have students use what they observed and the class data to write a paragraph recommending to the bread company what variables should be changed in the next phase of testing and why those changes would make for faster-rising bread.

Name_____

Hour_____

Activity 1 Handout

What kind of cellular respiration do yeast cells use?

Predict:

What kind of cellular respiration (aerobic, lactic acid fermentation, alcoholic fermentation) do you think yeast cells use? Why?

I think that...because...

Materials:

Sandwich sized, sealable bags (2)
Permanent marker
Warm water
100 ML beaker
Sugar
Measuring Spoon (T = tablespoon)
Plastic spoon
Paper Towels

Procedure:

1. Label one of your snack bags “W” for water and one “S” for sugar using the marker.
2. Measure 100 mL warm water into your beaker and pour it into the snack bag labeled “W.”
3. Measure another 100 mL warm water into your beaker and add **1 T** sugar. Stir with the plastic spoon to dissolve. Pour this sugar water into the snack bag labeled “S.”
4. Measure and add **1 T** yeast to **each** bag.
5. Close both bags and carefully mix the contents by smooshing the bag.
6. Open up both bags and carefully push out the air. Reseal the bags.
7. Observe what happens to your bags over 20 minutes. Record your observations on the next page.

	0 minutes	10 minutes	20 minutes
water + yeast			
water + sugar + yeast			

8. Follow the teacher’s directions to carefully open and clean bags.

Analysis Questions

1. Why did the bag expand or “blow up”?

2. What gas is produced by the yeast cells?

3. What molecule do the yeast cells use for energy?

4. Which form of cellular respiration do yeast use? How do you know?

5. How could you speed up or slow down this reaction? Write a hypothesis that you could test.

Concept Map Word Bank

cellular respiration
2 ATP
2 ATP
32 ATP
oxygen
mitochondria
alcoholic fermentation
electron transport chain

lactic acid fermentation
pyruvate
cytoplasm
NADH
NADH
glycolysis
aerobic respiration
alcohol

NAD⁺
NAD⁺
CO₂
glucose
lactic acid
anaerobic respiration
the Krebs cycle

Name _____

Hour _____

Activity 2 Handout

How can you make the fastest-rising bread dough?

Original dough recipe:

½ cup all-purpose flour

2 tablespoons water, 110 °F

¼ teaspoon yeast

Procedure:

1. In a bowl, mix together the yeast and flour.
 2. Slowly add the water and stir to combine.
 3. Using your hands, mix in any remaining flour in the bowl.
 4. Knead dough for 1 minute.
 5. Roll dough into a ball and allow it to rise for 30 minutes.
-

Variables that could affect rising time:

Variable we will test: _____

Prediction: *If we change the bread dough recipe by ...then we expect...to happen because...*

Procedure:

(Remember to include a control!)

Data:

	0 minutes	5 minutes	10 minutes	15 minutes
Control				
Test Condition _____				

	20 minutes	25 minutes	30 minutes
Control			
Test Condition _____			

Notes and Observations:

Conclusion:

Based on your and the other teams' data, draft a proposal to the bread company outlining what bread recipe or recipes should be tested next in order to produce an even faster-rising dough. What further changes would you make to your recipe? Make sure to include evidence for why you think those changes would be beneficial.

In accordance with the Americans with Disabilities Act, this information is available in alternative forms of communication upon request by calling 651/201-6000. TTY users can call the Minnesota Relay Service at 711 or 1-800-627-3529. The MDA is an equal opportunity employer and provider.

