The Invisible World of Yeast---Our Ancient Partner in Bread Making

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Teacher Lesson Plan:

General Description:

Students perform an experiment to understand yeast fermentation of sugar and associated production of carbon dioxide gas. The importance of this process and yeast in general to society will be emphasized. This activity highlights the science and arts/humanities in **S**TE**A**M.

Objectives and Outcomes:

At the completion of this activity, students will be able to….

- Demonstrate the conditions of the experiment that lead to carbon dioxide production.
- Explain why yeast produce carbon dioxide.
- Discuss observations from the experiment that demonstrate yeast are living organisms.
- Relate the process of fermentation with yeast applications in society.

Length of time: 1 hour

Materials:

- Small bottles (3 for each group)
- Sugar packets (2 for each group)
- Warm water
- Yeast
- Balloons (3 for each group)
- **Optional:** Measuring spoons (1 teaspoon and ½ teaspoon for each group)

Background Information: Yeast's Importance in the World

Yeast are microscopic, single-celled organisms found in nearly every ecosystem on the planet. They are seemingly inconsequential beings, but their importance in food and beverage making, science, and art cannot be overstated: yeast have been used for at least 7,000 years in bread making, wine making, and other activities (Frazer, 2013). According to Jennifer Frazer (2013), "Yeasts are fungi. In particular, they are fungi that grow as individual or small clusters of cells instead of in the long, tubular chains of cells called hyphae that compose most fungi." Rather than considering "yeast" as one organism, Frazer refers to yeast as a "lifestyle" that has been embraced by approximately 1500 species of fungi as Earth has evolved (Frazer, 2013). Yeast are important components in food and beverage making because they are efficient at fermentation (the process of converting sugar to energy in the absence of oxygen).

This yeast respiration activity makes fermentation more obvious: the yeast feed off the sugar in the solution and releases carbon dioxide (CO_2) as a byproduct of the fermentation process, causing the balloon to inflate. This same process occurs during bread making; yeast are a leavening agent that cause the dough to rise. Pockets of gas accumulate in the dough due to the breakdown of sugars in the wheat and resulting CO_2 production. This gives bread its light and fluffy texture. Researchers are currently trying to understand how the yeast used by different bakers throughout the world vary, and how those variations impact bread texture and flavor (The Public Science Lab, 2020).

Beyond its uses in food and beverage making, yeast is useful to scientists in a number of ways: genes can be easily inserted into yeast and then studied (Brooshire, 2016); yeast cells share similarities to human cells that allow for the study of diseases (FenoLogica Biosciences, 2017); yeast cells can be used to test new drugs (YourGenome, 2017); and yeast cells are used for the production of important childhood vaccines (College of Physicians of Philadelphia, 2018). Furthermore, some kinds of yeast can cause infection in humans, animals, and plants. More recently, yeast have been used to fuse science and art in a style called "biopointilism," which uses genetically modified yeast cells to create certain pigments and then create a picture (Strickland, 2015). This process was discovered and studied in the Boeke Lab at New York University, and the lab has since created a website (yeastart.org) to highlight the art pieces created using this method. Yeast art and biopointilism continue to gain steam and attract artists.

Figure 1. Using yeast colonies in art. Image from http://www.yeastart.org/the-process.

Procedure:

Opening to Lesson:

1) Discuss with students how they distinguish living from nonliving matter.
    a. Connect ideas they come up with to the properties of life: order, evolutionary adaptation, regulation, energy processing, growth and development, response to the environment, and reproduction.
2) Ask students to come up with possible ways to provide evidence for life in a microscopic sample----guide the discussion to tests/observations related to the properties of life.
    a. This exercise will demonstrate that the seemingly inert granules sold as active yeast are indeed living. Energy processing or metabolism will be evident because the balloon will fill with CO_2 when the yeast are mixed with sugar.
3) Describe the process of fermentation. Yeast produce biological catalysts, or substances that speed up the rate of a chemical reaction, called enzymes. These enzymes convert the starch present in grain into simple sugars like glucose. The process of fermentation breaks down glucose further, resulting in the production of the energy currency of cells, ATP. Ethanol, the alcohol that is the desired product in fermented beverages, and CO_2, the molecule that causes bread to rise, are also produced.

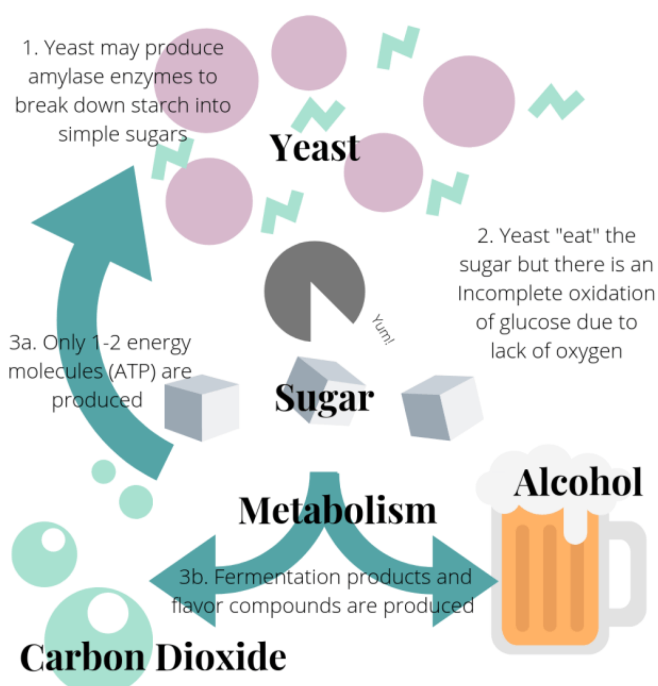

Figure 2. Process of yeast fermentation. Image from https://medium.com/@dani_bauer/how-fermentation-makes-food-delicious-fee48d571fec

In-Class Experiment:

1) Divide students into groups of three. Label the bottles: “sugar”; “yeast”; “sugar & yeast”. (To maintain social distancing, each student can be responsible for adding the ingredients to one of the bottles).
2) Add warm water to each bottle. Bottles should be about 2/3 full (measuring cups can be used if available).
3) Add half of a packet of sugar (~1 teaspoon) to each of the bottles labeled “sugar” and “sugar & yeast”.
4) Add a large pinch of yeast (~½ teaspoon) to each of the bottles labeled “yeast” and “sugar & yeast”.
5) Gently mix the bottles to suspend the sugar and yeast.
6) Cover the lid of each bottle with a balloon.
7) Incubate for 30 minutes at room temperature.

This activity can be modified for virtual learning: 1 bottle, 1 balloon, 1 sugar packet, and 1 teaspoon of yeast can be sent home with each student. The student can then make each treatment (“sugar”; “yeast”; “sugar & yeast”) sequentially and record their observations.

Incubation Discussion:

1) Ask students to develop a hypothesis about yeast.
    a. In biology, hypothesis development generally follows an *observation* made about the natural world that causes a scientist to develop a *question*. If a scientist asks “Which brand of fertilizer works best?”, one possible hypothesis is “Fertilizers with high concentrations of nitrogen and phosphorus best promote plant growth.” Hypotheses are possible answers to these questions, sometimes known as an “educated guess.” Therefore, hypotheses are statements which express a logical outcome. Hypotheses should never be in the form of a question.
    b. If the question in this activity is “Are yeast living?”, one possible answer (hypothesis) would be: “Yeast are capable of energy processing/metabolism.”
2) Ask students to develop a prediction about the experiment based on their hypothesis.
    a. Predictions can be formatted as “If/then statements”. If [restatement of the hypothesis], then [result that would support your hypothesis]. For example: “If fertilizers with high concentrations of nitrogen and phosphorus best promote plant growth, then plants given Trugreen fertilizer will grow taller than plants given Vigoro fertilizer.” Predictions are specific to how you are testing your hypothesis.

   b. In this activity, if yeast are capable of energy processing, then yeast mixed with sugar will produce CO_2 and fill the balloon with gas as compared to bottles with yeast alone or sugar alone.

3) Ask the students why the “sugar” and “yeast” bottles are necessary for the experiment.
   a. Sugar and yeast are mixed with water individually to demonstrate that neither substance alone is capable of energy processing, and, therefore, do not produce CO_2. Yeast requires sugar as an energy source and will remain inert without it. These are experimental controls. Using them eliminates alternative explanations for observations (for example: sugar reacts with water to produce gas).

<u>Recording Observations:</u>

1) The “sugar & yeast” bottle will have a foamy appearance, and the balloon on it will be full of gas. Discuss with students how this process contributes to light and fluffy bread.
2) The “sugar” and “yeast” bottles will have no gas production. Reiterate that these samples allow us to confirm that yeast is capable of energy processing via fermentation, a metabolic pathway that requires sugar.

<u>Example results:</u>

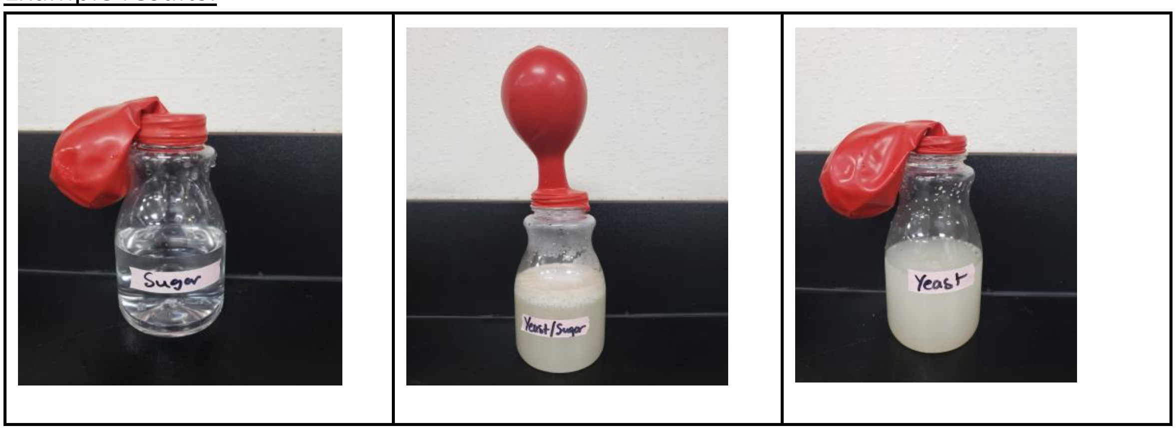

Figure 3. Expected results for the three samples.

Expanded Activities for Upper-level Students:

- Students can test how different amounts of yeast and sugar impact fermentation.
- Students can evaluate the impact of different fermentation conditions, such as time and temperature, on fermentation.
- Students can combine yeast with different types of sugars/sweeteners to observe the impact of different carbon sources on fermentation (Examples: Artificial sweeteners can be compared to sugar; Corn syrup and honey can be compared to sugar).
- Students can evaluate the impact of other baking ingredients (such as table salt, baking soda, or vinegar) on fermentation.
- Students can compare the fermentation of different types of yeast (Examples: brewing and wine yeast compared to baker's yeast).

References and Additional Resources:

For more information about taking a STEAM approach to teaching students about yeast, we recommend the article "Learning about Yeast Through Science, Art, and Poetry" by Lois Kelly and Alison Brade, found in *Primary Science* (https://eric.ed.gov/?id=EJ1035560) and "Yeast: Making food great for 5,000 years. But what exactly is it?" by Jennifer Frazer found in *Scientific American* (https://blogs.scientificamerican.com/artful-amoeba/yeast-making-food-great-for-5000-years-but-what-exactly-is-it/).

For more information and activities related to the science of yeast and bread making, we recommend checking out The Public Science Lab at North Carolina State University (http://robdunnlab.com/projects/science-of-sourdough/).

For more information about how fermentation is used to make many yummy foods, we recommend "How Fermentation Makes Food Delicious" by Danielle Bauer, author of Cravings of Food Scientist (https://cravingsofafoodscientist.com/2019/04/30/how-fermentation-makes-food-delicious/).

For an additional experiment related to yeast activity, we recommend "Make Elephant Toothpaste" by Science Buddies, Ben Finio https://www.scientificamerican.com/article/make-elephant-toothpaste/

Other references:

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