Lesson: Population Growth in Yeasts

Different types of yeast

Summary

This lesson is the second of two that explore cellular respiration and population growth in yeasts. In the first lesson, students set up a simple way to indirectly observe and quantify the amount of respiration occurring in yeast-molasses cultures. Based on questions that arose during the first lesson and its associated activity, in this lesson students work in small groups to design experiments that will determine how environmental factors affect yeast population growth.

Engineering Connection

This lesson and the associated activity contain biomedical, chemical and environmental engineering topics covering elements of biotechnology, applications of experimental and analytical techniques in living systems, food processing, in particular, the consumption of alcohol and its effects on the human body..

Contents

Grade Level: 7 (7-10)

Time Required: 45 minutes

Lesson #: 2 of 2

Lesson Dependency :What Do Bread and Beer Have in Common?, Yeast Cells Respire, Too (But Not Like Me and You)

Keywords: yeast, population growth, environmental factors, experimental design

Related Curriculum

subject areas	Data Analysis and Probability Life Science
curricular units	Cellular Respiration and Population Growth
activities	How To Make Yeast Cells Thrive

Educational Standards

- North Carolina Math
- 4.01 Collect, organize, analyze, and display data (including box plots and histograms) to solve problems. (Grade 7) [2003]

- 4.01 Collect, organize, analyze, and display data (including scatterplots) to solve problems. (Grade 8) [2003]
- North Carolina Science
- 1.01 Identify and create questions and hypotheses that can be answered through scientific investigations. (Grade 7) [2004]
- 1.01 Identify and create questions and hypotheses that can be answered through scientific investigations. (Grade 8) [2004]
- 1.02 Develop appropriate experimental procedures for:
  • Student generated questions. (Grade 7) [2004]
- 1.04 Analyze variables in scientific investigations:
  • Identify dependent and independent. (Grade 7) [2004]
- 1.05 Analyze evidence to:
  • Explain observations. (Grade 7) [2004]
- 1.06 Use mathematics to gather, organize, and present quantitative data resulting from scientific investigations:
  • Measurement. (Grade 7) [2004]
- 1.08 Use oral and written language to:
  • Defend conclusions of scientific investigations. (Grade 7) [2004]
- 1.02 Develop appropriate experimental procedures for:
  • Student generated questions. (Grade 8) [2004]
- 1.04 Analyze variables in scientific investigations:
  • Identify dependent and independent. (Grade 8) [2004]
- 1.05 Analyze evidence to:
  • Explain observations. (Grade 8) [2004]
- 1.06 Use mathematics to gather, organize, and present quantitative data resulting from scientific investigations:
  • Measurement. (Grade 8) [2004]
- 1.08 Use oral and written language to:
  • Communicate findings. (Grade 8) [2004]
- 6.01 Describe cell theory:
  • All living things are composed of cells. (Grade 8) [2004]
- 6.02 Analyze structures, functions, and processes within animal cells for:
  • Capture and release of energy. (Grade 8) [2004]
- 6.03 Compare life functions of protists:
  • Euglena. (Grade 8) [2004]
- 6.04 Conclude that animal cells carry on complex chemical processes to balance the needs of the organism.• Cells grow and divide to produce more cells. (Grade 8) [2004]

Learning Objectives (Return to Contents)

- Students will be able to explain why scientific experiments include controls, and be able to give an example of a controlled experiment.
- Students will be able to explain the role of variables in scientific experiments, and be able to state the variable(s) when given a description of an experiment.
- Students will be able to explain why sample size can be important in a scientific experiment.

Introduction/Motivation (Return to Contents)

Questions from students should arise naturally from Lesson 1 of this unit, and provide adequate motivation for students to continue their investigation. If questions do not arise, point out that there seemed to be a connection between the growth of the gas bubbles in the test chambers and the shape of a graph of population growth for asexually reproducing yeast cells. Ask what they think would happen to population growth if the food supply was not adequate for the yeast cells. How would the size of the gas bubbles provide supporting evidence? Make sure students realize that the molasses provided the yeast cells with the glucose they needed to respire and obtain enough energy to reproduce. What if they were given less glucose? Or more? What would they expect to happen to the population size?

Then ask if any students have ever baked bread. If so, ask them to describe the process. The process requires that they start with yeast in a warm liquid. After the dough is mixed, it must be kept in a warm place in order for the dough to rise. What does this suggest about conditions favorable to yeast population growth? How could they test their idea?

Also ask students what happens to their carved Halloween pumpkins after several days. They will probably be able to describe some interesting and colorful, slimy, or fuzzy materials growing inside the carved out pumpkin. Point out that it is primarily fungi that are using the pumpkin as a food source. Mold is the name we commonly use for this form of fungi. Yeasts are also members of the fungi kingdom. Ask what people do to prevent the growth of fungi on fruits, vegetables, and leftovers they don't want to eat right away. Students should be able to answer that such foods are kept in a refrigerator. Since refrigeration seems to slow or prevent the growth of fungi, what would they expect to have happened if the test chambers had been kept in a cold place?

You can also ask students if they have ever eaten pickles. (You could even provide a jar for samples.) Ask them what the liquid is that surrounds the pickles. Some may recognize it as vinegar, an acid. Is the vinegar there only for taste? Or does it act as a food preservative? If it is a preservative, might it affect the ability of a yeast population to thrive?

Lesson Background & Concepts for Teachers

See the Lesson Background and Concepts for Teacher in Lesson 1 (What Do Bread and Beer Have in Common?). Additional information that may be helpful is the fact that chemical reactions in general occur more quickly at higher temperatures than they do at lower temperatures. The chemical reactions involved in respiration are no exception. Since yeasts do not control their internal temperatures, all their metabolic reactions must occur at whatever the ambient temperature is. Therefore, yeast population growth should occur more slowly at cooler temperatures than at warmer temperatures.

The yeast species used in both bread baking and the brewing of ales, Saccharomyces cerevisiae, thrives at temperatures between about 5º C and 55º C (about 40º F to 130º F). Ale makers prefer a relatively slow fermentation process to produce the best taste, so they typically use temperatures around 17-22º C (62º-72º F) for fermentation. This process can take days or weeks before the desired alcohol content is reached. Bread bakers require a much faster process, so they prefer leaving the bread dough to rise in a warmer place, at least 27º C (80º F), but not above 49º C (120º F). Temperatures that are too warm make the bread rise too quickly, resulting in large holes within the finished product.

Body of Lesson:

Tell students they will be working in groups of four to design an experiment that will test for an environmental condition they think would be either favorable or unfavorable for yeast population growth. Tell them that in order to design their experiments, they must have answers to the following questions:

1. What is the specific question you are asking?
2. How exactly will you try to answer it?
3. How many trials will you do?
4. How will you report your results quantitatively?
5. What will be your control(s)?

6. What is your hypothesis?

Before having them start on their own designs, discuss how these questions would have been answered for the initial experiment done in the Yeast Cells Respire, Too (But Not Like Me and You) activity. In that case, the answers to the questions above are:

1. "Can we obtain evidence that in the process of respiration, yeast cells convert the sugar in molasses to carbon dioxide and alcohol?"
2. Students should be able to describe exactly how the experiment was set up. Important aspects of the design were that the chamber included the elements known to be needed for yeast respiration: a supply of glucose and a wet environment, as well as a way to observe and measure the carbon dioxide given off by respiring yeasts.
3. The number of trials done was equal to the number of test chambers set up, since all were set up the same way and exposed to the same conditions. Point out that it is important to have several identical trials in an experiment. Three trials is generally accepted as the minimum number. Multiple trials are needed for several reasons.

First, a mistake could be made in preparing one (or more) of the test chambers, which could produce a misleading result. For example, if only one chamber was set up and observed in an experiment, and the experimenter forgot to add the yeast, the experimenter would have concluded that it was impossible to observe yeast respiration, since no gas bubble was observed. Or it might also be possible that the experimenter did put yeast in the chamber, but a contaminant was somehow present, which poisoned the yeast and resulted in no respiration. On the other hand, if several chambers had been set up, and only one produced no bubble or a very small bubble, the experimenter might suspect that something was wrong with that one chamber.

Furthermore, organisms and biological systems in general exhibit a great deal of variability in anything they do. A biologist would not expect to see gas bubbles of the exact same size in each test tube even if multiple trials were conducted. Instead, variable bubble sizes would be expected because of the natural variation within the yeasts themselves, and also because of the design of the experiment. There was no way to be sure that an equal number of yeast cells was added to each test tube, nor was the volume of molasses solution exactly the same in each tube. Therefore it is reasonable to expect slightly different sizes of gas bubbles to occur in the different test chambers. However, with multiple trials, the experiment did allow the original question to be answered. It also provided additional information, such as how long, on average, it took to produce bubbles of various sizes.

4. The results were reported in the form of the graphs students prepared, which showed how the sizes of the gas bubbles changed over time.
5. There was no control for the initial experiment. However, it is very important to have one! The control that should have been used would be at least one test chamber set up and treated exactly like the rest but containing no yeast cells. The reason a control was needed was because without it, how could we know that the gas bubble collected did not simply come from a chemical reaction within the molasses? It is possible that the yeast did not respire at all, and what we observed was the product of some other reaction occurring in the solution. If a few control chambers had been used, and no bubbles formed in them, then we could state with confidence that the yeast cells in the test chambers were responsible for the gas bubbles instead of the molasses alone.
6. The hypothesis was that the inverted test tube would become filled with a visible gas bubble due to the yeast respiration.

Following this discussion of the design of the previous experiment, divide the class into groups of four. Ask each group to decide on an environmental factor to test, and give them time to discuss their answers to the list of questions. Tell them they will need to prepare written proposals (one per group) for their experiments, but they should first check out their ideas with you orally.

If students want to see if different amounts of food affect population growth, encourage them to consider a logical sequence of molasses concentrations, such as 0%, 25%, 50%, 75%, and 100%. Have the students calculate for themselves how much water and how much molasses need to be combined in order to obtain the desired concentration in 250 ml of each solution. Remind them also that they need multiple trials for their experiment. In this case there should be three or four chambers set up at each concentration to be tested. If two or three student groups want to explore the effects of food supply; they can be combined into one large group to help with the problem of adequate sample sizes.

Likewise, student groups investigating other environmental factors may need to be combined in order to achieve adequate sample sizes if supplies are limited.

Be sure that each group includes controls in its design. A group testing molasses concentrations, for example, should include a chamber set up for each concentration that does not contain yeast. The same is true if students test two or three different temperature conditions: at each temperature there should be at least one chamber without yeast. If students test different pH levels of the molasses solution, they will also need a yeast-free control for each pH level tested.

Be sure that students realize they can only test one environmental variable at a time. If they propose to test different concentrations of molasses at different temperatures, for example, they will not be able to identify which of the two factors is responsible for the results they obtain. Point out that if they want to find out how both temperature and food supply affect population growth, they will have to conduct two different experiments. In this case it would be more efficient to have half the class test molasses concentration, while the other half tests temperature differences.

If students wish to test the effects of pH, encourage them to use a 20% molasses solution for their experiment. That way, if they need to add more than a few milliliters of lemon juice or vinegar to acidify some of their test chambers, it will have a relatively slight dilution effect on the molasses solution. After determining the pH of the 20% solution (which they should make up themselves), they should try to achieve pH changes of only 1 and 2 in either direction, so as to not overly dilute the molasses. (Sodium carbonate can be added directly to the molasses solution; it does not need to be mixed with water first.)

Associated Activities

- How To Make Yeast Cells Thrive - Students set up and run the experiments they designed in the lesson Population Growth in Yeasts, using simple yeast-molasses cultures in test tubes.

Lesson Closure

After students have had time to discuss their ideas and decide on a plan, they should prepare a written proposal for their experiment. This should be in the form of answers to the list of questions discussed earlier. Remind students that the answers need to include very specific information about how they will set up the experiment.

Assessment (Return to Contents)

To assess whether students understand the basic principals of designing experiments, give students the following to read and respond to:

A high school student read on an Internet site that Sprite® soft drink was a good fertilizer for pine trees, so for a science fair project she decided to try to find out if it was true or not. She obtained 12 pine seedlings, each about 20 cm tall and planted in flower pots. She numbered the flower pots 1 through 12, and carefully measured and recorded the height of each seedling. Then she placed all of the seedlings in front of a sunny window. Once a week she watered six of the seedlings with 100 ml of water, but gave the other six seedlings 100 ml of Sprite®. Every two weeks she carefully measured each seedling and recorded its height. She continued to do this until the science fair three months later.

Questions:

1. What was the specific question the student was asking in this experiment?
2. How did she try to answer it?
3. How many trials did she do?
4. How could she report her results quantitatively?
5. What did she use for a control(s)?
6. What is a possible hypothesis for this experiment?

Other Related Information (Return to Contents)

A very readable source of information about yeasts, with some very interesting links to information about other useful microbial fungi is Tom Volk's Fungus of the Month for December 2002, by Tom Volk and Anne Galbraith, http://botit.botany.wisc.edu/toms_fungi/dec2002.

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Supporting Program (Return to Contents)

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