Microbial Discovery Activity

Taste Test: Can Microbes Tell the Difference?

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Intended Audience

K-4  X
5-8    X
9-12   X

Activity Characteristics

<table>
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<tr>
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<tr>
<td>Requires special equipment</td>
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<td>Uses hands-on manipulatives</td>
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<td>Requires mathematical skills</td>
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<td>Can be performed individually</td>
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<tr>
<td>Requires group work</td>
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<tr>
<td>Requires more than one class period (45 minutes)</td>
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<td>Appropriate for special needs student</td>
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**Introduction**

**Description**
This inquiry-based activity allows students to explore the scientific process of fermentation using a live microorganism in a classroom setting.

**Abstract**
This inquiry-based activity allows students to explore the scientific process of fermentation. During the investigation, students will be responsible for observing and explaining how yeast utilizes various forms of natural sugar and sugar substitutes to produce energy. Students will also recognize how the type and amount of food sources can directly influence the metabolic activities of living organisms.

**Core Themes Addressed**

<table>
<thead>
<tr>
<th>General Microscopy Concepts</th>
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<tbody>
<tr>
<td>Microbial Cell Biology</td>
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<td>Other - Common properties of life;</td>
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<td>Cellular components</td>
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**Keywords**
Metabolism, Fungi, Yeast, Fermentation, and *Saccharomyces cerevisiae*

**Learning Objectives**
By completing this activity, the student will be able to:
- Demonstrate the use of the microviewer
- Recognize microscopic similarities between materials
- Compare and contrast microscopic characteristics of materials
- Create a classification scheme of like and unlike materials
- Support their critical thinking and organization of their classification system.
- Gain an appreciation for the Science of Taxonomy
- Identify reasons why it is important to classify organisms
National Science Education Standards Addressed

**All Levels of Learning:**
1. Unifying concepts:
   - Systems, order and organization
   - Evidence, models and explanations
   - Change, consistency and measurement
   - Form and function
2. Science as Inquiry:
   - Abilities necessary to do scientific inquiry
   - Understanding about scientific inquiry
3. Science and Technology:
   - Understanding about science and technology
4. History and Nature of Science:
   - Science as a human endeavor
   - Nature of science

**Science Content Standards 5-8:**
1. Physical Science
   - Properties and changes of properties in matter
   - Transfer of Energy
2. Life Science
   - Structure and function in living systems
   - Reproduction and heredity
   - Regulation and behavior
   - Diversity and adaptations of organisms

**Science Content Standards 9-12:**
1. Physical Science:
   - Chemical reactions
2. Life Science:
   - The Cell
   - The interdependence of organisms
   - Matter, energy and organization in living systems
   - Behavior of organisms
Teacher Handout

Taste Test: Can Microbes Tell the Difference?

Student Prior Knowledge
Students should have a basic understanding of the differences between prokaryotic and eukaryotic cells. Because this activity relies on the use of S. cerevisiae, a eukaryotic organism, students should know in some detail the role that eukaryotic organelles play in energy production for growth and reproduction. Students should understand simple chemical reactions (i.e. reactants → products) and the role enzymes play in these reactions.

Teacher Background Information
All living things require an energy source and materials for building their bodies. Consumers use food sources containing organic materials and energy that have been packaged by producers. Producers undergo a process known as Photosynthesis. During photosynthesis, carbon dioxide is captured by plants and algae and converted to sugar and other body materials such as fats and carbohydrates. Eventually these body materials are converted back to carbon dioxide by other organisms. Yeast produce carbon dioxide from sugar. The amount of carbon dioxide gas released is related to amount of food used by the yeast for growth and reproduction. To determine the amount of carbon dioxide produced during the experiment, the amount of inflation within an experimental bag can be measured. A greater the inflation of the bag, indicates a higher production of carbon dioxide by the yeast.

Artificial sweeteners, although they taste sweet, do not contain sugar. Yeast can breakdown aspartame (NutraSweet in soft drinks and powdered Equal), but get very little energy from the amount of aspartame that we use to sweeten a cup of coffee. Aspartame is an organic compound like other molecules that make up living things (a chain of 2 amino acids), but very few aspartame molecules are needed to give the same amount of sweet taste as many molecules of sugar. Saccharin’s (Sweet ‘n Low) structure is very different, and both yeast and humans have difficulty breaking it apart to get energy.

Although Equal and Sweet ‘n Low advertise that there are no calories in their product, both list dextrose (a simple sugar) as the primary ingredient. Table sugar is sucrose, which is a double sugar made of dextrose and fructose linked together. Fructose is found in fruits and is used in some drinks such as grape juice. Dextrose is more commonly known as glucose.

Aside from Equal and Sweet ‘n Low, a new sugar substitute (Splenda) has been introduced to the market. Splenda is a sugar substitute that is produced from sugar. To produce the sugar in Splenda known as sucralose, three hydrogen molecules are removed from sugar and replaced with three chlorine atoms to form a stable sugar substitute with zero calories. Since sucralose is quickly passed through the body, it is not metabolized. Yeast and humans obtain very little energy from consuming sucralose. Although the company claims there is no sugar in Splenda, dextrose is the first ingredient listed.

Class Time
Approximately one hour of class time is required.
Teacher Preparation Time
Teachers will need one hour for introduction and one hour for preparation (2 hours total).

Materials and Equipment
For the facilitator-led preliminary introduction taste test activity, supply the following:
- At least one microviewer (hand held microscope) or microscope
- Pitcher for distributing water
- 2 small paper cups
- 2 sealable sandwich bags (ZipLoc, GladLock, etc.)
- 1 package of yeast
- 1 tablespoon of table sugar
- Marking pens or tape for labeling

For the participant-designed investigations, supply the following for each group:
- Tablespoon for measuring
- Measuring cup (1/3 cup) (Beaker - 80ml)
- Permanent marker or tape for labeling
- Heating pad
- Ruler marked in centimeters
- Microscope (if available)
- Microscope slides and coverslips
- Dropper (pipet)
- Warm tap water
- Sandwich size sealable bags
- Packets of dry granular yeast (Rapid Rise) or bulk yeast
- Packets of sugar
- Packets of Sweet n’ Low (saccharin)
- Packets of Equal (aspartame)
- Packets of Splenda (sucralose)
- Clear, regular and diet soda (Sprite, or 7Up) - remove cap at least 24 hours prior to use
Methods
To facilitate group work, set out on each table the materials for one group or else have one member of each group come to a central distribution point and take back materials for their group.

Introduction to Yeast - Facilitator led demonstration
Begin the activity with a demonstration that would be done forty-five minutes prior to the activity being done by the students.

- Add one tablespoon of yeast (or one package) to a sealable bag.
- Add one tablespoon of table sugar to the bag.
- Add 1/3 cup (80ml) warm water to the bag, mix well and seal, trapping as little air as possible.
- Set the bag on a heating pad, set on low, if the room is cold. The yeast will produce gas, causing the bag to expand.

Explain to the participants what you have done. Have students observe the granular yeast. Show the students that when the yeast granules are placed in water the granule dissolves, but is still present due to a cloudy appearance in the water. At this point, if microscopes are available, have participants observe a wet mount of the yeast. If microscopes are not available, show photographs of yeast cells. While observing the yeast cells under the microscope, explain that the cells are magnified, so that participants recognize that the granules are not yeast. Yeast are much smaller and have a definite structure that can be seen using a microscope.

Begin the inquiry process by asking questions and leading the students in a discussion about food and yeast. Some suggested sample questions include:

- Can you tell the difference between food and non-food substances?
- What is a food? How do you know the difference?
- What would happen if you only drank diet cola for a week?
- What do you know about yeast?
- Where is yeast used? If participants say that they are living, ask them what that means.
- Why is the bag expanding?
- What might the gas be?
- Do humans produce gas? If so, what gas do we produce and give off as a waste?
- Do yeast and humans give off the same gas?
- Yeast may be producing gas like we do. If there is interest and appropriate materials, participants could test the gas produced.
- Do yeast need food? If they do, what food do they use?
- What else, in addition to food, do yeast require?
- How can we measure how much food we are using?
- How much food yeast are we using?
- How can you find out how much energy is available in different foods?

Inquiry-based Lab Activity
Students will design an experiment to investigate the sources of food for yeast and themselves. Students will be able to choose from a variety of food sources for their experiment. The 4-P method may be used to facilitate the experiment (4-P method = Posing, Predicting, Probing, and Persuasion). Students may follow the guided worksheet to complete the 4-P method.

Give the students the basic recipe for the yeast experiment.

- 1/3 cup (80 ml) of warm water
- 1 packet of sugar (1 tablespoon)
- 1 envelope of yeast

Posing Questions (Problem)
Students are encouraged to read the labels for the various liquids and sweeteners. If desired, and allowed, the students may sample the liquids or sweeteners. Students are also encouraged to observe a wet mount of the yeast with a microscope. Once the students have completed various observations, they are to pose questions based on their discoveries.

Predicting (Hypothesis)
Students are to predict the answers to their questions. The questions may be reworded to create their hypothesis.

Probing (Experiment and Analysis)
Students are to design an experiment based on their questions (use the basic recipe for guidance). They should be reminded to use appropriate controls. While conducting their experiment they should record various observations about the changes in each bag (gas production). During the experiment, gas production can be measured by rolling up the bag and measuring the depth of the gas bubble every 15 minutes for 45 minutes. Bags may also be measured at the conclusion of the experiment.

Persuasion (Conclusion)
Students should analyze their collected data and compare their results with their predictions.

Safety Issues
Wash hands at the beginning and completion of the activity. Remind students that although working with yeast is safe, it is a living microorganism. Provide enough packets of sweeteners so that participants who wish to taste them do not have to share. Make sure there are no specific food allergies or medical conditions (Diabetes) among the students.

Assessment and Evaluation of Activity
This activity is inexpensive and easy to work with in the classroom. There are no safety concerns and the experiment is not hazardous. All materials can be disposed of in the garbage can. This activity provided great visual results that help students understand the metabolic process of fermentation and its importance to yeast.

Students are also able to work with yeast (a microbe) from a positive perspective. This activity is also a great way to help students understand the importance of nutrition and metabolic processes within humans. In the past, students have been eager to see the results of this experiment. They enjoy watching the active production of carbon dioxide and the inflation of the bags. This is a great activity to begin the inquiry process among students, especially in grades 5-8. The experiment holds their attention and provides a unique and fun learning experience.

Expected Results
If participants determine that the amount of "food" that yeast will be given in each case is equal to the amount in a cup of coffee, the following results should be seen:

- Diet soda will cause very little if any gas production.
- Regular sodas will produce gas if 1/3 cup of soda vs. 1-teaspoon sugar is used. Gas production will be slightly less than sugar.
- Over time more sugar will permit more gas generation.
- Dextrose - simple sugar permits faster initial growth than sucrose.
- Fructose - simple sugar permits faster initial growth than sucrose.
- Sweet n' Low and Equal show gas production at faster rate than sugar initially, but gas production stops after short period of time.
- Splenda will cause very little if any gas production.
- Fruit drinks results will vary due to the amount of natural sugar in the fruit, amount of sugar added in processing, and other characteristics of the drink which may affect yeast growth, such as pH.
- Starting with more yeast will increase the rate and amount of gas production.
• If sufficient time and expansion space is provided, gas production will stop in each of the bags.

**Assessment**

Students may:

- Complete and hand in the student worksheet.
- Compose an independent, formal lab write-up.
- Write up quiz questions pertaining to the lab and quiz other members of their class. The teacher may also use the student-generated questions to create a test or quiz.
- Prepare a journal.
- Prepare a presentation (verbal or computer-based).
- Create a concept map that describes the lab and its results.
- Participate in a small or large group discussion.
- Create a group portfolio.
- Prepare a notebook to collect data.
- Annotate articles on fermentation — at least 4 — Use annotated article form.
- Prepare a one-paragraph statement from each student — should describe what was learned, including positive and negative experiences. These can be turned in separate if the student feels they are too personal to turn in with the portfolio.
- Prepare a written report following the format of a scientific journal.
- Prepare a poster that summarizes the information within the report and will be used during a 15 minutes group presentation. Creativity is encouraged.
- Use a rubric to assess any of the suggestions above.- See Appendix for example rubrics and several sites on rubrics.

**Supplementary Materials**

**Additional Facilitator Information**

The two sugar substitutes used in this lab were discovered by accident. Saccharin, the first artificial sweetener, was discovered over one-hundred years ago by a scientist named Fahlberg who accidentally spilled some of an experiment on his hand and upon tasting it, discovered it was unusually sweet (Chemists were obviously not as cautious, as we are now, about smelling and tasting in the laboratory). He developed the commercial synthesis of the material, patented it, and named it saccharin after the Latin word for sugar, *saccharum*. Searle chemists discovered aspartame, or NutraSweet, as they prepared a tetrapeptide to be used as a standard in connection with an anti-ulcer project.

Aspartame was a dipeptide intermediate in the preparation and again, a scientist accidentally tasted it when licking his finger to pick up a piece of paper. No one expected it to be sweet since the two component amino acids in the dipeptide have a flat and bitter taste. Unlike saccharin, which is excreted unchanged, aspartame is metabolized into amino acids. Saccharin is the sweeter of the two, and considered to be 300 times as sweet as sugar where as aspartame is only 200 times as sweet.

Splenda (sucralose) was discovered in 1976 via a collaborative effort between Tate and Lyle PLC and researchers at Queens Elizabeth College in London England. By 1998 Splenda was approved by the food and drug administration and has been used in a variety of products such as Ocean Spray fruit drinks, Tropicana Twister, and Swiss Miss Hot Cocoa mix. In April 1999, Splenda was approved for release into the consumer market.

**Additional Facilitator-led Activities**

Since there is a great deal of time between observations of the bags, the facilitator can discuss the consumption of diet drinks with the students. Weight is an important issue for teens, and this activity can stimulate important discussions. Some possible areas of discussion include:

- Why are there diet drinks? What is in diet drinks? What is in the sugar substitutes?
- Babies prefer sweets when given a choice. Why would this be an advantage to survival?
• For an animal that must seek its food, why is it important for foods that taste sweet to have calories? If the foods did not have calories, why would this be a disadvantage for the animal?
• There is controversy as to whether diet drinks actually help people lose weight. Eating sweets may trigger the brain to think food is coming. People may eat more to compensate or may eat more thinking that they have saved calories so therefore they may eat a cookie later.
• Aside from questions and discussions, various short activities may also be conducted in between observations. Each discussion/activity could be structured to take about 10 minutes, or different groups could be assigned a different topic to discuss or investigate.
• Participants can compare and contrast the various diet sweeteners, juices, and drinks that were available for the experiments. They can research the various ingredients to determine what they are and why they are included in the product. Later this information may be valuable as they interpret their results. Have a wall chart set-up for participants to record the number of diet and regular colas that they drink in a week. Participants can make a graph of this information and make comparisons. Do boys/girls drink more diet/regular cola? Older/younger? Have students read several articles and present pros/cons of diet soft drinks and foods made with sugar substitutes. Students may also navigate the internet to find debates over various sugar substitutes.

Suggestions
• Placing experimental bags on trays can minimize cleanup if any of the bags leak.
• Conducting the experiment over two days is more efficient for grades 5-8. It allows the students to concentrate on one part of the experiment at a time.
• If being conducted in a middle school and supplies are short, each group can create one of the experimental bags. Each group is then responsible for recording observations about their specific bag, and reporting their findings to the class. This makes for a great class discussion.
• All research about the ingredients in each of the sugar substitutes can be conducted a full day prior to the investigation.

Possible Modifications
• Students can quantify their data. They can measure the diameter of air space in the bag by rolling the bag until it has just a cylinder of air. Students may also submerge the bag in water, and determining how much water is displaced. A book may be placed on top of the bags (gently!). Looking at the height of the book can also help determine how much gas was produced.
• Students can conduct experiments to determine if the gas produced in each bag is carbon dioxide; carbon dioxide gas is heavier than other gases in the atmosphere, therefore, when the bags are opened, if carbon dioxide is present, much of the gas will stay inside. A lighted match can be lowered into the bag. It will go out, showing a lack of oxygen or the presence of carbon dioxide.
• Red cabbage water can be used if the gas is forced through the water. Cabbage water is red in the presence of an acid. Carbon dioxide becomes an acid in water. Limewater can also be used to test more specifically for carbon dioxide.
• This experiment may be conduct over a two-day period. Use day one to set up the experiment. The teacher needs to watch the experiment throughout the day so that the bags do not explode. Smaller amounts of ingredients may be used if this lab is to be conduct over a two-day period or a larger baggie may be used.
• In addition to artificial and regular sweeteners, participants could use clear regular and diet soft drinks, fruit juices, lemon juice, electrolyte-replacement drinks, etc. Clear products are preferred so, the cloudiness of the liquid, which demonstrated the reproduction of the yeast, can be observed.
• This experiment may also be used to introduce students to a form of asexual reproduction. Students can have a visual connection to how yeast asexually reproduce via budding.
• Students can continue this experiment by adding more nutrients to each bag to determine if the yeast can continue to metabolize.
• By interchanging ingredients in each bag, students can see if there is any affect on metabolism. For example: place sugar in the experimental bag that originally had Equal inside. They can discuss how changes in diet can affect metabolism.
• Students can try different yeasts such as *Torula*, the nutritional yeast, or baker's versus brewer's yeast.
• Sugar is not the only thing we use for food. What would happen if we used other things?
• Most drinks also have their caloric value listed. Is there a direct correlation between numbers of calories and amount of gas produced?
• If a person just wanted to shovel in sugar, can they come up with a quantitative measure of gas production and generate a dose-response curve?
• Research can be completed on various sugars and sugar substitutes to determine their effects on metabolism.

References

Acknowledgements
This activity is adapted from: Can Microbes Tell the Difference? Meet the Microbes through the MicrobeWorld Activities Microbial Literacy Collaborative. Copyright NABT. Draft copy approved for distribution to Microbial Discovery Workshop participants only. Field-tested versions will be available at a later date for wide distribution by NABT. Thanks to John Stolz, Microbial Ecology Professor at Duquesne University, for his assistance in the initial development of this activity.

Other Resources
• Splenda (Sucralose): www.splenda.com
• Aspartame (NutraSweet) Toxicity Information Center: www.holisticmed.com/aspartame/
• The NutraSweet Company Information center: www.nutrasweet.com/
• Yeast (Budding, Fission, and Candida): genome-www.stanford.edu/Saccharomyces/VL-yeast.html
• Cellular Metabolism and Fermentation: gened.emc.maricopa.edu/bio/bio181/BIOBK/BioBookGlyc.html
• Fermentation- Access Excellence: www.accessexcellence.org/LC/SS/ferm_background.html
• Yeast Genetics at Kansas State University: www.phys.ksu.edu/gene/
Introduction
All living things require an energy source and materials for building their bodies. Consumers use food sources containing organic materials and energy that have been packaged by producers. Producers undergo a process known as Photosynthesis. During photosynthesis, carbon dioxide is captured by plants and algae and converted to sugar and other body materials such as fats and carbohydrates. Eventually these body materials are converted back to carbon dioxide by other organisms. Yeast produce carbon dioxide from sugar. The amount of carbon dioxide gas released is related to amount of food used by the yeast for growth and reproduction. To determine the amount of carbon dioxide produced during the experiment, the amount of inflation within an experimental bag can be measured. A greater the inflation of the bag, indicates a higher production of carbon dioxide by the yeast.

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Student Background Knowledge
Students should have a basic understanding of the differences between prokaryotic and eukaryotic cells. Because this activity relies on the use of *S. cerevisiae*, a eukaryotic organism, students should know in some detail the role that eukaryotic organelles play in energy production for growth and reproduction. Students should understand simple chemical reactions (i.e. reactants $\rightarrow$ products) and the role enzymes play in these reactions.
Vocabulary
Yeast
Fungi
Eukaryotic
Fermentation
Metabolism
Sucrose
Dextrose
Artificial sweetener

Safety Considerations
Wash your hands at the beginning and completion of the activity. Although working with yeast is safe, it is a living microorganism. If you choose to taste the supplied artificial sweeteners, do not share your packet with another student. If you have food allergies or medical conditions (Diabetes) check with your instructor before tasting any of the artificial sweeteners.

Materials Checklist and Procedure
In this activity, you will be required to design your experiment using the provided materials listed below. This should be evident after paying close attention to the demonstration your instructor has performed for you.

For the student investigations, the following materials are supplied for each group:
- Tablespoon for measuring
- Measuring cup (1/3 cup) (Beaker - 80ml)
- Permanent marker or tape for labeling
- Heating pad
- Ruler marked in centimeters
- Microscope (if available)
- Microscope slides and coverslips
- Dropper (pipet)
- Warm tap water
- Sandwich size sealable bags
- Packets of dry granular yeast (Rapid Rise) or bulk yeast
- Packets of sugar
- Packets of Sweet n' Low (saccharin)
- Packets of Equal (aspartame)
- Packets of Splenda (sucralose)
- Clear, regular and diet soda (Sprite, or 7Up) - remove cap at least 24 hours prior to use

The basic recipe for the yeast experiment is:
- 1/3 cup (80 ml) of warm water
- 1 packet of sugar (1 tablespoon)
- 1 envelope of yeast
Student Name: _________________________________

A. Posing Questions (Problem):
Write a question concerning an observation you have made about the yeast or food products.

What is the effect of ________________________________
on ________________________________

B. Predicting (Hypothesis):
Write a hypothesis concerning the observation.

______________________________________________________________________________________
______________________________________________________________________________________

Make a prediction based on the hypothesis:
If ________________________________
then ________________________________

C. Probing (Experiment):
Outline the method for the experiment. Think carefully about the controls that are needed. Identify the independent and dependent variable(s). You may use an additional piece of paper if the space below is not sufficient.
D. Gather the data (Analysis):

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Graph your results (Label the axes and provide a title and key)

Follow-up Questions

E. Persuasion (Conclusion):

Was your hypothesis supported?

What can you conclude from your experiment?

Describe the sources of errors if they occurred.