Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Explain the processes involved in fermentation and how organisms obtain energy.
2. Explain the purpose of the pH scale and how pH is calculated.
3. Name three microorganisms that cause fermentation to occur.
4. List a variety of foods and other substances that are created by fermentation.
5. Explain the advantages and disadvantages of fermentation in food processing.
6. Explain factors that can affect the fermentation process.
List of Resources. The following resources may be useful in teaching this lesson:


List of Equipment, Tools, Supplies, and Facilities

- Writing surface
- Overhead projector
- Transparencies from attached masters
- Copies of student lab sheet
- Copies of technical supplement

Terms. The following terms are presented in this lesson (shown in bold italics):

- Aerobic
- Alcoholic fermentation
- Anaerobic
- Autotrophs
- Bacteria
- Buffer
- By-product
- Cellular respiration
- Fermentation
- Gluten
- Glycolysis
- Heterotrophs
- Lactic acid fermentation
- Molds
- Photosynthesis
- pH scale
- Yeasts
**Interest Approach.** Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

*Interest Approach 1—Assign class to bring in containers from any product which has been produced through the process of fermentation. Begin class with a discussion of these products, compiling a list of similarities. Develop a general equation for fermentation which includes inputs and outputs (products and by-products). Have students try to develop specific equations for the products brought to class, using the label information to determine ingredients that are part of the fermentation process. Research may be needed to determine the by-products of their fermentation process.*

*Interest Approach #2—This is a true story—Several years ago I had two students that were conducting a science project that they were preparing to take to an elementary school to show students a particular science concept, but something went wrong. They were busy setting up their experiment one day in class, but had not finished it when the bell rang. They had a 2 liter pop bottle that they had put some corn syrup and yeast into. Since they ran out of time, they screwed the lid on the bottle and went to their next class. The next morning when I came into my classroom, I noticed something all over the tables, chairs, TV, my desk, the floor, everywhere. Then, I noticed the 2 liter pop bottle on the back counter. It was a melted mass of plastic—it had exploded. What do you think happened? What happens to yeast in a nutrient rich environment (corn syrup is full of sugar)? The combination of heat and pressure from the ever growing yeast and the gases inside the bottle caused it to explode sending corn syrup twenty feet in every direction.*

**SUMMARY OF CONTENT AND TEACHING STRATEGIES**

**Objective 1:** Explain the processes involved in fermentation and how organisms obtain energy.

**Anticipated Problem:** How do organisms obtain energy? How does fermentation work?

I. One of the requirements or characteristics of living things is that they require energy in order to live. By-products of these processes can be used to benefit humans.

A. Organisms are classified by how they obtain their energy.
1. **Autotrophs** are organisms such as plants that use the sun’s energy to create energy. Autotrophs use photosynthesis.
   a. The basic equation for **photosynthesis** is
      \[
      6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
      \]
      carbon dioxide + water (in the presence of sunlight) = sugar + oxygen

2. **Heterotrophs** are organisms that consume other organisms to obtain their energy. Animals including humans are heterotrophs.

B. All organisms benefit either directly or indirectly from photosynthesis since this is the lowest level of energy production for organisms. However, all organisms must use the process of cellular respiration to turn food into usable energy.

1. **Cellular respiration** is the process of breaking down molecules of food (i.e. glucose) to release energy.
   a. \[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP} \]
   b. glucose + oxygen \rightarrow carbon dioxide + water + energy

2. The first step of cellular respiration is the process of glycolysis. **Glycolysis** is the first in a series of reactions during respiration in which a sugar molecule is degraded to pyruvic acid. Glycolysis means ‘breaking glucose’ because the glucose molecule is broken down into two pyruvic acid molecules. (Glucose à 2 Pyruvic acid).

3. Fermentation is one process that occurs after glycolysis. Fermentation causes energy to be released from molecules of food to furnish energy for metabolism and growth of microorganisms. Fermentation can occur in the presence of air or not in the presence of air. **Aerobic** means that oxygen is present. **Anaerobic** means without oxygen.

4. **Fermentation** changes the chemical environment of a food. Before man knew much about fermentation, they simply used a small portion of food to add to new batches. This ensured that the microorganisms that are needed were included in the recipe. Fermentation is an important process in the preparation of foods for human consumption. Many plant products undergo a fermentation process in order to produce the final product for the grocery shelf.

5. Alcoholic fermentation and lactic acid fermentation are the two main types of fermentation.
   a. **Alcoholic fermentation** is used by microorganisms including yeast.
      1) The formula for alcoholic fermentation is:
         \[ \text{Pyruvic acid} + \text{NADH} \rightarrow \text{alcohol} + \text{CO}_2 + \text{NAD}^+ \]
      2) \( \text{NAD}^+ \) (nicotinamide adenine dinucleotide) is converted to \( \text{NADH} \) \( (\text{NAD}^+ + 2 \text{high energy electrons}) \) which holds the electrons until they are moved to other parts of the cell to be used as energy.
      3) Alcoholic fermentation is the process used to make bread. Yeast begins the process by using the oxygen. After the oxygen is used up, carbon dioxide is produced producing small air sacs in the dough causing the bread to rise. The alcohol that is produced evaporates.
b. **Lactic acid fermentation** occurs in many cells including the muscle cells and is used to make yogurt. Glycolysis produces pyruvic acid which then can be converted to lactic acid and NAD\(^+\) via fermentation. NAD\(^+\) allows glycolysis to continue so that energy can continue to be produced.

1) The equation for lactic acid fermentation is: Pyruvic acid + NADH -> lactic acid + NAD\(^+\).

2) Oxygen is needed for the production of ATP. During intense exercise the body produces a large amount of lactic acid because the body cannot take in enough oxygen. Lactic acid can build up in the muscle tissue and can cause a burning and sometimes painful feeling. Continued intake of oxygen and ‘cooling down’ will help to use up the lactic acid.

6. A **by-product** is anything produced in the course of making another thing; a secondary or incidental product or result. By-products of fermentation are carbon dioxide, water, alcohol, and lactic acid.

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**Use TM–A and B to illustrate this objective. Start the experiment entitled, “pH and Fermentation” (LS–A) as it will take several days to obtain results.**

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**Objective 2:** Explain the purpose of the pH scale and how pH is calculated.

**Anticipated Problem:** What is the purpose of the pH scale? How is pH calculated?

II. The **pH scale** is used to measure the relative acidity or alkalinity of a substance.

A. The pH scale is used to measure the hydrogen ion (H\(^+\)) concentration in a solution.

B. The scale starts at 0 and ends at 14. A pH of 7.0 is neutral; the concentration of H\(^+\) and OH\(^-\) (hydroxide ions) is equal. A number lower than 7.0 indicates that the solution is acidic and a number higher than 7.0 indicates that the solution is basic or alkaline. Each step from one number to the next on the pH scale indicates a logarithmic increase. For example, a solution of 6.0 is ten times more acidic than a solution with a pH of 7.0; a solution of 8.0 is ten times more basic or contains 10 times as many hydroxide ions as a solution with a pH of 7.0.

C. A **buffer** is a weak acid or base that reacts with a stronger acid or base to help neutralize the substance or bring it closer to 7.0. Buffers are needed because strong acids and bases can disrupt chemical reactions causing the body to not maintain homeostasis (maintaining stable internal conditions in the body).

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**Use TM–C to reinforce this objective. Use (The Chemistry of Food) in Food Science and Safety to reinforce the concept of pH.**
Objective 3: Name three microorganisms that cause fermentation to occur.

Anticipated Problem: What types of microorganisms cause fermentation to occur?

III. The primary purpose of fermentation is to furnish energy for metabolism and growth to microorganisms including bacteria, yeast, and mold.

A. **Bacteria** are typically one-celled organisms that multiply by simple division and can be seen only with a microscope; necessary for some types of fermentation.

B. **Yeast**s are any of various unicellular (single-celled) fungi in which little or no mycelium develops and that ordinarily reproduce by budding; they live on sugary solutions. The dry granules of yeast that are bought at the store become active when they become moist.

C. **Molds** are a fungus that grows in a tangled mass of filaments containing cells. Fungi are not plants and therefore do not photosynthesize. They are eukaryotic (have a cell membrane and membrane bound organelles) heterotrophs (obtain energy by consuming other organisms). Fungi break down their food outside of their bodies and then consume it.

Use TM–D to illustrate this objective. Use (The Microbiology of Food) in Food Science and Safety to reinforce and expand students’ understanding on microbes.

Objective 4: List a variety of foods and other substances that are created by fermentation.

Anticipated Problem: What food and non-food products are created by fermentation?

IV. Fermentation creates a variety of different substances that are used by humans.

A. Foods that undergo fermentation include yogurt, cheese, wine, cider, bread, sauerkraut, flavorings, candy, fruit juice, silage, and beer. Pickling involves fermentation. Foods that are frequently pickled include beans, onions, cauliflower, cucumbers, tomatoes, and cabbage.

   1. Bread is made through alcoholic fermentation. Yeasts eat the sugar from the granulated sugar and the maltose (disaccharide or double sugar; made up of two glucose molecules) from the flour. ATP is created helping the yeast to multiply. One yeast cell can consume its weight in glucose in one hour. The yeast initially uses oxygen to obtain energy and reproduce. As the oxygen is used up they undergo alcoholic fermentation and produce alcohol and carbon dioxide as by-products. The alcohol burns off during baking, but leaves a good flavor in the bread. When flour is mixed with water and then kneaded, an elastic dough is created because of gluten. **Gluten** is a protein found in wheat. This elastic dough holds in the carbon dioxide forming small air pockets or bubbles causing the bread to rise.
2. Alcohol remains in the alcoholic beverages from the fermentation process.
   a. Grape juice is used to make wine. The wine industry is growing in the United States. In 2002, consumers purchased 595 million gallons of wine in the U.S. alone with a value of $21.1 billion. Wine is fermented for about two weeks and then the yeasts are removed.
   b. Water, rice, and malt make beer.
   c. Champagne is fermented twice with the second fermentation lasting around one year.
3. Fermented cucumbers make pickles.
4. Fermented cabbages creates sauerkraut.
5. Spices and stuffed ground meat make sausage.
6. soybeans can be turned into soy sauce.
7. Vinegar is made from alcohol that is fermented by bacteria.
8. Lactose from milk mixed with bacteria create curdled milk or cheese.

B. Non-food items that undergo fermentation include antibiotics, laundry detergent, insulin, growth hormone, cellulose, monoclonal antibodies, compost, Sno-max (makes snow), Ice-minus (keeps ice off plants), medicine to dissolve tumors, and medicine to clot blood. Fermentation is a critical part of our well-being by supplying us with necessities beyond food.

Use TM–E to reinforce this objective. See (The Cereal Industry) in Food Science and Safety for more information on bread making.

Objective 5: Explain the advantages and disadvantage of fermentation in food processing.

Anticipated Problem: What are some advantages and disadvantages of fermentation in food processing?

V. There are several advantages and disadvantages for using fermentation.

A. Advantages include:
   1. Fermentation can increase the shelf life of foods by inhibiting the enzymatic deterioration of plant tissues.
   2. Fermentation improves the dough handling characteristics of bread by softening the gluten because the gluten proteins are hydrated. This allows the dough to be handled easier, especially by machines.
   3. It can enhance the texture, flavor and odor of foods. For example, the compound diacetyl is produced by various lactic acid bacteria during dairy fermentations (i.e.—cottage cheese, sour cream, buttermilk). This compound is responsible for the buttery aroma and taste typically associated with these products.
   4. Fermentation helps food to be stored safely.
5. Fermentation allows humans to enjoy their favorite foods in a different way by creating a variety of flavors, textures, color, and appearance of some foods.

6. Fermentation is also used to create new energy sources such as ethanol.

7. The vitamin content of some foods can be increased.

8. Digestibility can be improved.

9. The toxicity of some foods (particularly oriental) may be decreased.

10. Some scientists believe that particular types of fermented milk products (i.e. acidophilus milk, yogurt) have a therapeutic value and can be beneficial in cases of alimentary disorders (i.e. constipation, diarrhea, etc.) and may even preclude the development and outgrowth of harmful bacteria.

B. Fermentation can also cause problems for growers and food processors. In some cases natural fermentation occurs which makes the original product unfit for consumption. Fermentation produces an acid and a gas. The by-products or end products of fermentation include carbon dioxide, water, alcohol, lactic acid, and other acids. Sometimes these fermentation products create conditions unfavorable to microorganisms to a point where fermentation ceases. For example, fermentation comes to a halt when the percent of alcohol in a solution reaches about 12 percent.

Objective 6: Explain factors that can affect the fermentation process.

Anticipated Problem: What factors can affect the fermentation process?

VI. Several factors can affect fermentation.

A. Fermentation time determines how long the yeast has to act on the sugars. As time passes the rate of fermentation decreases, but never stops under favorable conditions.

B. Yeast cells can tolerate a pH of 4.0-8.5 with the optimum pH between 4.0 and 6.0. Before fermentation begins in bread dough, the pH is around 5.5 – 5.8. As fermentation begins the pH drops to around 5.0. This is caused by the production of organic acids including carbonic acid (carbon dioxide dissolved in water; H₂CO₃). Carbonic acid is more acidic than the dough. Flour and milk act as buffers to help maintain the pH level. Calcium carbonate is a common additive that bakeries use to buffer the pH.

C. The presence of air affects fermentation and is probably the most critical factor in producing some food products. Since fermentation is anaerobic, the presence of air will allow for yeast/mold growth and result in softening, off flavors and darkening of the product.

D. Optimum fermentation occurs at 75-85°F for yeast. The higher the temperature, the faster fermentation will occur, but the flavor can be inferior and the product will darken readily. Scientists estimate that for every one degree increase in temperature that fermentation of yeast will increase three to five percent.
E. The presence of salts affects the fermentation process. The salt withdraws water and nutrients from vegetative tissue in order to enable lactic microorganisms to grow. It also inhibits the growth of undesirable microorganisms and delays enzymatic spoilage. The proper concentration of salt (2.5% for sauerkraut) favors lactics, while low salt results in softening of the tissue because not enough water is pulled from the tissues. High salt (over 3.5% for sauerkraut) inhibits all lactics, including the desirable ones, slows anaerobiosis, and results in undesirable yeast growth. Also, high salt concentration favors lactic microorganisms that produce only lactic acid, resulting in a rather bland product.

F. The amount of water present affects fermentation. Lack of water slows the process.

G. When the concentration of sugar is greater than five percent, fermentation will slow. Maltose (disaccharide) has less of an effect than does glucose, fructose, or sucrose (monosaccharides). Flour contains maltose. High concentrations of sugar cause the concentration gradient (related to osmosis) to be too high for the yeast. Additionally, maltose is not broken down outside of the cell like glucose, thus the concentration gradient is not as severe.

H. Contaminating organisms can also impede the fermentation process.

Use TM–G to reinforce this objective. Contact someone from the local health department, extension office, hospital, grocery store, or a food processing plant. Invite them in to talk about how their job relates to nutrition, food preservation, development of new foods, nutrition education, food processing methods, etc. Be sure to emphasize the science behind the technology, education needed, and the future of food science and nutrition.

Have students research how the food industry is changing. They could research current topics found in the news or have them write a short essay on a food related topic. Topics that could be used are what new foods are being developed, methods of food processing, food preservation methods, packaging, food additives, foods for third world countries foods and medicine, genetic engineering of foods, or history of food processing (i.e.—The Jungle Book, The Great Potato Famine, etc.).

Review/Summary. Focus the review and summary of the lesson around the student learning objectives. Call on students to explain the content of each objective.

Application. Application can involve the following transparency masters, lab sheet, and technical supplement:

- TM–A: pH and Fermentation
- TM–B: Organisms Require Energy
- TM–C: pH Scale
- TM–D: Microorganisms Need Energy
- TM–E: Products of Fermentation
Evaluation. Evaluation should concentrate on student achievement of the lesson’s objectives. A sample test is included.

Answers to Sample Test:

Part One: Matching
1. d
2. h
3. e
4. j
5. b
6. i
7. g
8. k
9. f

Part Two: Fill-in-the-Blank
1. anerobic
2. aerobic
3. water, carbon dioxide, sunlight
4. carbon dioxide

Part Three: Multiple Choice
1. b
2. d
3. a
4. c
5. a
6. d

Part Four: Short Answer
1. Answers will vary.
2. Answers will vary.
3. Answers will vary.
4. Yeast cells can tolerate a pH of 4.0–8.5 with the optimum pH between 4.0 and 6.0. Before fermentation begins in bread dough, the pH is around 5.5–5.8. As fermentation begins the pH drops to around 5.0. This is caused by the production of organic acids including carbonic acid. Carbonic acid is more acidic than the dough. Flour and milk act as buffers to help maintain the pH level. Calcium carbonate is a common additive that bakeries use to buffer the pH.

5. Autotrophs use the sun’s energy to create their own food whereas a heterotroph must consume autotrophs or other heterotrophs to consume their energy. Autotrophs use the process of photosynthesis to change the sun’s energy into food. Both autotrophs and heterotrophs use the process of cellular respiration to change food into energy.
Name ______________________________________

PH AND FERMENTATION

Part One: Matching

Instructions: Match the word with the correct definition.

a. Aerobic  e. Buffer  i. Heterotrophs
b. Alcoholic fermentation  f. By-product  j. Lactic acid fermentation
c. Anaerobic  g. Cellular respiration  k. Photosynthesis
d. Autotrophs  h. Gluten

_______1. organisms that create their own energy
_______2. a protein found in bread that gives bread its elastic texture and holds the carbon dioxide bubbles
_______3. a substance that neutralizes an acid or base
_______4. this type of fermentation occurs in a person’s muscles during strenuous exercise and can cause soreness
_______5. the process used to make bread and alcohol
_______6. organisms that consume other organisms to obtain their energy
_______7. the process of breaking down molecules of food such as glucose to release energy
_______8. the process where plants capture the sun’s energy to create energy
_______9. something that is created through the process of creating something else

Part Two: Fill-in-the-Blank

Instructions: Complete the following statements.

1. ________________ means in the absence of oxygen.
2. ________________ means in the presence of oxygen.
3. Photosynthesis is the process where plants use ________________, ________________, and ________________ to make food.
4. ________________ is a by-product of cellular respiration.
Part Three: Multiple Choice

Instructions: Circle the letter of the correct answer.

1. The following microorganisms cause fermentation to occur, except
   a. bacteria
   b. anerobes
   c. mold
   d. yeast

2. Using the pH scale at the right, what substance is the most acidic?
   a. bleach
   b. soap
   c. milk
   d. stomach acid

3. Using the pH scale at the right, which substance is the most alkaline?
   a. bleach
   b. soap
   c. milk
   d. stomach acid

4. What process is represented by the following equation?
   \[ 6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 \]
   a. alcoholic fermentation
   b. lactic acid fermentation
   c. photosynthesis
   d. cellular respiration

5. What process is represented by the following equation?
   \[ \text{Pyruvic acid} + \text{NADH} \rightarrow \text{alcohol} + \text{CO}_2 + \text{NAD}^+ \]
   a. alcoholic fermentation
   b. lactic acid fermentation
   c. photosynthesis
   d. cellular respiration

6. What process is represented by the following equation?
   \[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP} \]
   a. alcoholic fermentation
   b. lactic acid fermentation
   c. photosynthesis
   d. cellular respiration
Part Four: Short Answer

Instructions: Answer the following questions.

1. Why is it important to study pH and fermentation?

2. List at least five things that are created through fermentation.

3. List and explain three factors that can affect fermentation.

4. How does pH affect the fermentation process.

5. Explain the relationship between autotrophs, heterotrophs, photosynthesis and cellular respiration.
“Whether your sandwich contains bologna or corned beef, you want it to be at its most flavorful. ARS has looked at the source of flavor differences in beef, pork, lamb, and veal to find out what happens when it’s aged in storage. They found, for example, that Lebanon bologna—a traditional Pennsylvania Dutch product—gets its distinctive flavor not from the use of old barrels, as thought. It comes from the amount of salt used in aging the meat.”

“An ARS scientist...found that a bacterial starter stimulates faster, more consistent fermentation than traditional methods and guarantees a better product.”

“Other researchers ... reported that just about all processed meats can be made with 20 to 25 percent less salt with no risk of spoilage. Proper refrigeration, it turns out, is more important than salt level in retarding the growth of microorganisms that cause spoilage.”
ORGANISMS REQUIRE ENERGY

Classification

♦ Autotrophs—organisms that use the sun’s energy to create energy
  ■ The basic equation for photosynthesis is
    \[ 6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]
    carbon dioxide + water (in the presence of sunlight) = sugar + oxygen

♦ Heterotrophs—organisms that consume other organisms to obtain their energy

Photosynthesis vs. Cellular Respiration

♦ Cellular respiration—the process of breaking down molecules of food to release energy when oxygen is present
  ■ \[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP} \]
  ■ glucose + oxygen \rightarrow carbon dioxide + water + energy
♦ Glycolysis—reaction in which a sugar molecule is degraded to pyruvic acid (Glucose → 2 Pyruvic acid)
  ■ Aerobic—oxygen is present

♦ No oxygen → fermentation occurs
  ■ Anaerobic—without oxygen

♦ Fermentation
  ■ Fermentation—changes the chemical environment of a food
  ■ foods, medicine, and more

♦ Two main types
  ■ Alcoholic fermentation—used by microorganisms including yeast
    • Pyruvic acid + NADH → alcohol + CO₂ + NAD⁺. NAD⁺
    • Bread
  ■ Lactic acid fermentation—muscle cells
    • Pyruvic acid + NADH → lactic acid + NAD⁺.
    • Oxygen vs. Carbon Dioxide

♦ By-product—anything produced in the course of making another thing
  ■ Carbon dioxide, water, alcohol, and lactic acid
pH SCALE

- pH scale—measures the relative acidity or alkalinity of a substance
- 7.0—Neutral – equal numbers of hydrogen ions (H⁺) and hydroxide (OH⁻) ions in the solution
- Lower than 7.0—acidic
- Higher than 7.0—basic or alkaline
- Logarithmic increase
- Buffer is a weak acid or base that reacts with a stronger acid or base to help neutralize the substance or bring it closer to 7.0
- Homeostasis
MICROORGANISMS NEED ENERGY

♦ Bacteria
♦ Yeasts—fungi
♦ Molds—fungus
PRODUCTS OF FERMENTATION

Foods—yogurt, cheese, wine, cider, bread, sauerkraut, flavorings, candy, fruit juice, silage, and beer

- Pickling—beans, onions, cauliflower, cucumbers, tomatoes, and cabbage

- Bread
  - alcoholic fermentation
  - Yeasts eat the sugar
  - ATP helps yeast reproduce
  - Fermentation—produce alcohol
  - Water
  - Gluten—a protein found in wheat
  - Carbon dioxide

- Alcoholic Drinks
  - Grape juice → wine
  - Water, rice, and malt → beer.
  - Champagne

(Courtesy, Agricultural Research Service)

Yeast-raised breads will benefit from research on the genes in wheat and wheat’s wild relatives that produce high-molecular-weight glutenins—proteins that are important to baking quality.
Cucumbers → pickles
Cabbage → sauerkraut
Spices and stuffed ground meat → sausage
Soybeans → soy sauce
Alcohol and bacteria → vinegar
Lactose (milk) and bacteria → curdled milk or cheese

Non-food items—antibiotics, laundry detergent, insulin, growth hormone, cellulose, monoclonal antibodies, compost, Sno-max (makes snow), Iceminus (keeps ice off plants), medicine to dissolve tumors, and medicine to clot blood

(Courtesy, Agricultural Research Service)
Microbiologist Rodney Bothast adjusts a laboratory fermenter that uses glycerol from vegetable oil. After fermentation and a couple of intermediate steps, the glycerol becomes acrylic acid that can be used to make plastic goods.
ADVANTAGES AND DISADVANTAGES OF FERMENTATION

♦ Advantages
  - Increase shelf life of foods
  - Improves dough handling characteristics of bread
  - Enhance the texture, flavor and odor of foods
  - Safely store food
  - Creates a variety of flavors, textures, colors, and appearances
  - New energy sources
  - Increased vitamin content
  - Improved digestibility
  - Decreased toxicity
  - Decreased ailments

♦ Disadvantages
  - Product becomes unfit for consumption
  - Acid and gas
  - Unfavorable conditions for microorganisms
FACTORS AFFECTING FERMENTATION

♦ Fermentation time
♦ pH of 4.0–8.5
  ■ Carbonic acid (H₂CO₃)
  ■ Calcium carbonate
♦ Presence of air
♦ Temperature
♦ Salts
♦ Water
♦ Concentration of sugar
♦ Contaminating organisms
pH AND FERMENTATION

Research Problem

How does pH affect fermentation?

Agricultural Applications and Practices

Fermentation is an important process in the preparation of foods for human consumption. Many plant products undergo a fermentation process in order to produce the final product on the grocery shelf. Examples include yogurt, cheeses, wine, cider, and sauerkraut. Many vegetables, such as beans, onions, cucumbers, tomatoes, cauliflower, and cabbage, are processed using a pickling procedure, which involves fermentation. Fermentation not only allows new products to be developed, it also greatly increases the shelf life of these products by inhibiting deteriorative processes.

Fermentation can also cause problems for growers and food processors, because in some cases natural fermentation occurs which makes the original product unfit for consumption. Thus, fermentation plays an important role, both positive and negative, in the storing, handling, and processing of plant and other agricultural products.

Science Connections—Some Questions for Investigation

1. What is fermentation? Why does it occur?
2. What conditions promote/hinder fermentation? Why?
3. Why is fermentation a desirable process in the processing of some plant products?
4. As a restaurant owner you make your own bread each day. However, some of the customers have complained that the bread is too flat. What could you do to make the bread lighter?

Purpose of Lab and Student Performance Objectives

The purpose of this experiment is to observe the process of fermentation and examine the conditions which affect fermentation activity. After this lab students will be able to:

1. describe the fermentation process in terms of the reactions that occur and the biological inputs into the process.
2. explain how fermentation alters food products and enhances their overall quality/taste.

3. predict the extent of fermentation activity, given conditions for storing and processing food products.

Materials and/or Equipment

- 3 Erlenmeyer flasks or dish detergent bottles
- modeling clay
- plastic straws that bend
- 3 beakers or wide-mouth jars
- corn syrup (white)
- yeast (three packets from grocery store)
- vinegar
- distilled water
- ammonia
- limewater (available from any Science Supply store)

Procedure

Give each student or group of students a copy of the worksheet to perform the activity.

Data Summary and Analysis

Several days after setting up the experiments, have students record their observations for each of the three fermentation experiments. Then challenge them to identify the inputs and by-products in each experiment and the reactions that occur.

Anticipated Findings

- Yeast cells can tolerate a pH range of 4.0 to 8.5.
- Vinegar has a pH of around 3.4 and ammonia has a pH of 11.0.
- Because yeast cells can tolerate a pH of 4.5–8.5, they were not able to survive in the vinegar or ammonia environments.
- Distilled water has a pH of 7.0 which allows to yeast to thrive.
Diamond Carbon dioxide is a by-product of fermentation and will cause the limewater to turn milky gray. This change will be observed from the flask which contains distilled water, pH of 7.0, syrup, and yeast but not from the other flasks.

Ideas for Additional Experiments

1. Bromethymol blue indicator can be added to each setup for a more colorful observation.

2. The procedure can be duplicated for pH solutions between 4.3 and 11 so students can determine a more specific pH range favorable for fermentation.

3. Have students return to the products they brought to class that underwent fermentation during processing. Where possible, set up some experiments to replicate the fermentation process used to produce the particular food product.

4. Challenge students to design and conduct experiments to test the effects of other known and suspected conditions upon the fermentation process. Vary the plant product involved.
pH AND FERMENTATION

Procedure

1. Put on your goggles—ammonia and vinegar are irritants.
2. In one flask or bottle, put 200 ml of vinegar, in the second, 200 ml of distilled water, and in the third, 200 ml of ammonia.
3. Add 20 ml of corn syrup and approximately two grams (one packet) of yeast to each flask.
4. Put 50 ml of limewater in each of the three beakers or wide-mouth jars.
5. Construct a stopper for the flasks by forming modeling clay around a straw and inserting the straw into the bottle above the mixture.
6. Bend the straw so that it is below the limewater solution in the beaker.
7. Thoroughly wash your hands.
8. Allow each setup to stand for several days and record observations.
1. What is fermentation? Why does it occur?

Cellular respiration is the process of breaking down molecules of food (i.e. glucose) to release energy. The first step of cellular respiration is the process of glycolysis. Glycolysis is the first in a series of reactions during respiration in which a sugar molecule is degraded to pyruvic acid. Fermentation is one process that occurs after glycolysis. Fermentation causes energy to be released from molecules of food to furnish energy for metabolism and growth of microorganisms. Fermentation changes the chemical environment of a food. Before man knew much about fermentation, they simply used a small portion of food to add to new batches. This ensured that the microorganisms that are needed were included in the recipe. Fermentation is an important process in the preparation of foods for human consumption. Many plant products undergo a fermentation process in order to produce the final product for the grocery shelf.

2. What conditions promote/hinder fermentation? Why?

Fermentation time determines how long the yeast has to act on the sugars. As time passes the rate of fermentation decreases, but never stops under favorable conditions.

Yeast cells can tolerate a pH of 4.0 – 8.5 with the optimum pH between 4.0 and 6.0. Before fermentation begins in bread dough, the pH is around 5.5 – 5.8. As fermentation begins the pH drops to around 5.0. This is caused by the production of organic acids including carbonic acid (carbon dioxide dissolved in water; $\text{H}_2\text{CO}_3$). Carbonic acid is more acidic than the dough. Flour and milk act as buffers to help maintain the pH level. Calcium carbonate is a common additive that bakeries use to buffer the pH.
The presence of air affects fermentation and is probably the most critical factor in producing some food products. Since fermentation is anaerobic, the presence of air will allow for yeast/mold growth and result in softening, off flavors and darkening of the product.

Optimum fermentation occurs at 75-85°F for yeast. The higher the temperature, the faster fermentation will occur, but the flavor can be inferior and the product will darken readily. Scientists estimate that for every one degree increase in temperature that fermentation of yeast will increase three to five percent.

The presence of salts affects the fermentation process. The salt withdraws water and nutrients from vegetative tissue in order to enable lactic microorganisms to grow. It also inhibits the growth of undesirable microorganisms and delays enzymatic spoilage. The proper concentration of salt (2.5% for sauerkraut) favors lactics, while low salt results in softening of the tissue because not enough water is pulled from the tissues. High salt (over 3.5% for sauerkraut) inhibits all lactics, including the desirable ones, slows anaerobiosis, and results in undesirable yeast growth. Also, high salt concentration favors lactic microorganisms that produce only lactic acid, resulting in a rather bland product.

The amount of water present affects fermentation. Lack of water slows the process.

When the concentration of sugar is greater than five percent, fermentation will slow. Maltose (disaccharide) has less of an effect than does glucose, fructose, or sucrose (monosaccharides). Flour contains maltose. High concentrations of sugar cause the concentration gradient (related to osmosis) to be too high for the yeast. Additionally, maltose is not broken down outside of the cell like glucose, thus the concentration gradient is not as severe.

Contaminating organisms can also impede the fermentation process.

3. Why is fermentation a desirable process in the processing of some plant products?

Fermentation can increase the shelf life of foods by inhibiting the enzymatic deterioration of plant tissues.

Fermentation improves the dough handling characteristics of bread by softening the gluten because the gluten proteins are hydrated. This allows the dough to be handled easier, especially by machines.
It can enhance the texture, flavor and odor of foods. For example, the compound diacetyl is produced by various lactic acid bacteria during dairy fermentations (i.e.—cottage cheese, sour cream, buttermilk). This compound is responsible for the buttery aroma and taste typically associated with these products.

Fermentation helps food to be stored safely.

Fermentation allows humans to enjoy their favorite foods in a different way by creating a variety of flavors, textures, color, and appearance of some foods.

Fermentation is also used to create new energy sources such as ethanol.

The vitamin content of some foods can be increased.

Digestibility can be improved.

The toxicity of some foods (particularly oriental) may be decreased.

Some scientists believe that particular types of fermented milk products (i.e. acidophilus milk, yogurt) have a therapeutic value and can be beneficial in cases of alimentary disorders (i.e. constipation, diarrhea, etc.) and may even preclude the development and outgrowth of harmful bacteria.

4. As a restaurant owner you make your own bread each day. However, some of the customers have complained that the bread is too flat. What could you do to make the bread lighter?

Bread is made through alcoholic fermentation. Yeasts eat the sugar from the granulated sugar and the maltose (disaccharide or double sugar; made up of two glucose molecules) from the flour. ATP is created helping the yeast to multiply. One yeast cell can consume its weight in glucose in one hour. The yeast initially uses oxygen to obtain energy and reproduce. As the oxygen is used up they undergo alcoholic fermentation and produce alcohol and carbon dioxide as by-products. The alcohol is burned off during baking, but leaves a good flavor in the bread. When flour is mixed with water and then kneaded, an elastic dough is created because of gluten. Gluten is a protein found in wheat. This elastic dough holds in the carbon dioxide forming small air pockets or bubbles causing the bread to rise. To make the bread lighter, try using flour with a higher gluten content to increase the elasticity and ability of the dough to hold in the carbon dioxide. Or, try decreasing the amount of oxygen that is present during this process to increase the amount of fermentation, check the pH and make adjustments, adjust the amount of salt to optimum levels, and make sure that all utensils and supplies are sterile to eliminate contamination.