Fermentation in the Food Industry:
An Introduction to Biotechnology

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I. INTRODUCTION

In designing this project, one of the primary objectives is the creation of an activity that will have application in both Biology and Agriculture curricula. The activity can be incorporated into a Cell Biology Unit in Biology or Advanced Biology, into a Food Processing Unit in Agriculture, or as a Fermentation Unit in Biotechnology. The intent is to use this activity as an introduction to fermentation and will be followed by the introduction of some modern techniques and applications of biotechnology.

This unit is designed so that the individual teacher can easily make modifications according to:

- limitations of time and space
- budget
- equipment
- instructor comfort level
- student experience or ability
- teacher and student interest
- local industries

Before beginning this unit, students are expected to have experience in basic lab procedures, lab safety procedures, library research skills, oral presentation skills, and class journal expectations.

II. ACTIVITY DESCRIPTION

This activity will introduce the students to fermentation as well as provide hands on experience with a variety of food fermentation processes. In this exercise, students will study fermentation as a natural biological process and also its implications in the food and agricultural industries. Included in this exercise will be laboratory activities designed to explore the production of everyday foods which are produced by fermentation processes.

Students will be choosing a group fermentation project which will include an inquiry based lab, a personal journal, and a presentation based on their lab results and research. In addition to the project students will be exposed to the history, chemistry, economics, culture, and careers associated with fermentation. Because of its importance in the food industry, food safety information and activities will be shared with the students.

III. OBJECTIVES

A. TEACHER’S OBJECTIVES

In the presentation of this unit the teacher will:

1. determine the level of instruction appropriate for student assimilation
2. determine the amount of information appropriate for student assimilation
3. instruct students in laboratory protocol relevant to this exercise
4. evaluate student objectives
5. integrate the activity with appropriate curricula
6. facilitate discussion and student involvement
7. learn and follow all food safety guidelines in the classroom
8. meet National Science Education Standards for content, assessment, and program, Benchmarks for Science Education, National Resource Council recommendations for agricultural education, and the School-to-Work Initiative

B. STUDENT OBJECTIVES

At the completion of this activity the students will be able to:
1. explain fermentation in its general form
2. define respiration in words
3. write the formula for respiration
4. contrast aerobic and anaerobic respiration
5. identify 3 types of microorganisms which are used in food production
6. list and describe the processes used to produce several fermented foods
7. identify ways that biotechnology may be used to improve our food and food supply
8. maintain a journal comprised of daily observations, reactions, activities, self observations and peer observations.
9. demonstrate proper food safety techniques.
10. observe, record, and analyze student generated data.
11. coordinate lab and research data into a coherent presentation.

IV. TIMELINE

The following outline is a sample designed for classes that are approximately fifty minutes in length. If your class period is shorter or longer than this, you may need to change this schedule. The assumption is that the students have already worked in the laboratory setting and are familiar with procedure and aseptic techniques. The students in the class will be divided into groups of four or five. This grouping can be based on grade average, technique, appropriate behavior in the lab, and any other criteria the teacher is comfortable with. Each group will be responsible for one lab project (found at the end of the packet, or use your own). The fermentation of yeast lab (Day 6) can be done as a class laboratory experiment or a teacher demonstration. Suggestions have been made concerning videos, outside speakers, and field trips. The students will be expected to check the...
progress on their lab each day and record this information in their daily journal (discussed later in the packet.)

Day 1
- Unit expectations explained
- Journal requirements explained
- Students put into groups
- Topic selection and distribution of lab materials
- Proposal sheet

Day 2
- Food safety guest speaker
  -- county home extension agent
  -- public health inspector
- Collect and discuss proposal sheets

Day 3
- Lab setup
  -- Each group will set up and begin their experiment
  -- Remind the students of lab procedure and aseptic technique

Day 4
- Anaerobic fermentation lecture or video
  -- video: The History of Cheese Making (Wisconsin Milk Marketing Board)

Day 5
- Lab work and research
  -- Use the library to find information for your project

Day 6
- Fermentation of yeast lab/demo
  -- Teacher choice of demo or lab experiment

Day 7
- Research

Day 8
- Research

Day 9
- History of fermentation lecture/discussion
  -- discussion of history
  -- student discussion on how cheese making began
  -- student discussion of expectations from their lab
Day 10
• Field trip or speaker on careers in biotechnology
  --local hospital
  --local laboratory
  --local veterinarian
  --area tech school with a bioscience technician program
  --area college with a biotechnology or food science degree
  --local fermentation industry (cheese plant, kraut plant, bakery)

Day 11
• Food safety case studies
  *Please consult “Safe handling Beyond the Retail and Wholesale Shelf” Unit 11 pages 1-15 from Food Science, Safety and Nutrition by the National Council for Agricultural Education
  *Case studies are included in this reference which can be read and discussed in class or written about in student journals. These case studies discuss the following topics:
    • Staph outbreak at a convention
    • Botulism in chili peppers killing twelve
    • Salmonella poisoning from restaurant
    • Clostridium poisoning meals on wheels
    • Listeriosis from coleslaw in Canada
  *Class discussion or lecture on consumer responsibilities such as food purchasing safety, storage, preparation and serving, proper cooking temperatures, leftovers safety and how fermentation relates to these safety issues.

Day 12
• Work on presentations

Day 13
• Presentations

Day 14
• Presentations

Day 15
• Evaluation/closing
  --Students will be asked to write a response to several questions. The questions will ask the students to synthesize the information from their lab with other groups and teacher presented information. The students will also have to evaluate their lab project and propose future research.

V. TEACHER BACKGROUND

History of Fermentation
  The use of natural biological processes to obtain useable products is certainly not new. Since recorded history, microbes have been involved in the preparation and processing of items in man’s daily diet.

  Lacking any knowledge of microorganisms, or of ways in which contamination of food by them could be avoided, man learned to live with microbially infected foods. Usually the actions of these
microbes ultimately made the food unacceptable, either by altering the appearance or odor of the food to a point which it was no longer appetizing or by producing poisonous toxins, some of which were lethal. Occasionally, however, microbial infections of food materials made it appear more appetizing and the taste enhanced. Ultimately, microbial infections of these foods were exploited, so the fermented foods and beverages now form a large and important sector of the food industry. Today the main groups of microbes involved in the industry include the yeasts, molds, and bacteria.

Nobody knows exactly when cheese making began, but legend generally has it that its origin lies in the Middle East. A Bedouin, preparing for a journey across the desert, filled his skin pouch with ewe's milk for refreshment along the way. After hours in the hot sun, and weary from the jostling ride on the camel, the Bedouin opened the pouch made from the dried stomach of a sheep only to discover that the rich milk was no more. In its place lay a thin watery fluid surrounded by a thick white mass - whey and curds. Having nothing else to drink, he tried the liquid and found it tasted good; then he nibbled at the gummy curds and was equally pleased with the discovery. Arriving at his destination, he shared the remaining curds with his tribesmen, who were no less satisfied then he. Thus, quite by accident, cheese was introduced into man's diet. Today, the manufacture of cultured dairy products represents the second leading fermentation industry (next to alcoholic beverages), accounting for approximately 20% of all fermented foods produced world wide.

While no such legend exists for the discovery of sauerkraut, it undoubtedly was also discovered by accident and trial and error methods.

In the days before refrigeration facilities became available, a number of techniques were devised for preserving seasonally produced vegetables. One of the most efficient of these involved packing vegetables tightly in a vessel with salt or brine. This technique is thought to have originated in the Orient where, even today, it continues to be used extensively. Only in the last 60 years has it been shown that this method of preserving vegetables involves a microbiological fermentation.

In cheese making, the mystery surrounding the nomad's discovery can be easily explained. The four essentials of cheese making were acting together that memorable day in the desert: milk plus a slight churning motion coupled with heat and rennet (the product of an enzyme produced in the membrane lining of ruminate animals stomach). The cheese discovered by the Bedouin was probably what we would call cottage cheese or cheese curds. Similar legends attend the origin of aging, curing or ripening which has lead to the many various cheese flavors we have today.

We now know that in the production of sauerkraut, lactic acid bacteria proliferate in the brine. These bacteria produce acids which lower the pH. The combined action of the salt and acid lowers the activity of enzymes responsible for the breakdown of vegetable tissue. At the same time oxidative changes in the tissues are inhibited and thus prevent spoilage.

**Anaerobic Fermentation**

Although respiration and breathing are often thought of as the same, they are in fact two different processes. Breathing is the exchange of gases between an organism and its external environment. Respiration occurs within all living cells. Cellular respiration involves breaking the chemical bonds of organic molecules and releasing energy that can be used by the cells.

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \xrightarrow{\text{enzymes}} 6\text{CO}_2 + \text{energy} \]

Most students are not familiar with fermentation which occurs in some of the less complex organisms such as bacteria and yeasts. Fermentation reactions are anaerobic, proceeding without oxygen being present. Anaerobic reactions involve cellular food products and/or glucose sugar as their
reactants. And without oxygen they can produce combinations of ethyl alcohol (C₂H₅OH), carbon dioxide (CO₂), and lactic acid (C₂H₄OCOOH) as their products.

We have used the products of anaerobic respiration (fermentation) to our advantage, supplying ourselves with food, drink, and even fuel for automobiles. Yeasts are used as tiny "fermentation factories" producing carbon dioxide and alcohol. Certain bacteria and molds ferment milk, producing carbon dioxide and lactic acid.

It has been stated that the fermentations are the result of growth of bacteria, yeasts, molds, or combinations of these. Stated more precisely, the changes that occur are caused by the enzymes liberated by these microorganisms. Some foods usually said to be fermented are actually cured by the enzymes naturally inherent in the foods. Throughout the centuries fermentation has been one of the most important methods for preserving food; it still remains one of the most important methods. Relatively few people, however, are aware that the many food products consumed regularly are prepared and/or preserved by fermentation processes.

It is essential to understand that the lactic acid bacteria produce acid which in effect inhibits the growth of many other organisms. Most species convert sugars to acids, alcohol, and carbon dioxide. The fermentative yeasts produce ethyl alcohol and carbon dioxide from sugars. They require oxygen for growth but not for fermentation. The molds have the greatest array of enzymes, are aerobic, and will grow on most foods to produce various types of digestion.

The changes that occur during fermentation of foods are the result of the activity of enzymes. The enzymes arise from three sources: Those that are produced by the microorganisms that are involved in the fermentation, those that are native to the food, and those that are produced by the microbial flora that happen upon the unfermented food. A good fermentation is one in which the enzymes produced by the fermentative microorganisms play the primary role.

There are relatively few pure culture fermentations. An organism that initiates a fermentation will develop until its by-products of growth inhibit further growth and fermentation. During this initial growth period other organisms develop. They in turn are followed by other more tolerant species. This succession of growth of different species may be referred to as a natural sequence of growth. The use of starters or inocula should be based upon these facts. In general, growth will be initiated by bacteria, followed by yeasts and then molds, if conditions are suitable for growth of these microorganisms.

Now let us try to relate these biological processes to biotechnology. What is biotechnology? "In the broadest and simplest terms, biotechnology is defined as the collection of industrial processes that involve the use of biological systems." (Harlander, 1991).

We have been using bacteria, yeasts, and molds for centuries to produce a host of fermented foods including buttermilk, yogurt, sour cream, butter, cheese (over 700 kinds), pickles, sauerkraut, sausage, breads, crackers, pretzels, doughnuts, grape nuts (you thought it was a cereal brand name?), wines, beer, spirits, soy sauce, coffee, cacao, vanilla, tea, citron, ginger, and more.

Biotechnology is also used in some food processing related areas including processing aids, ingredients, rapid detection systems, and biosensors. Enzymes acting as protein catalysts, are used extensively in the food processing industry to control texture, appearance, and nutritive value, and for the generation of desirable flavors and aromas. Because they are isolated from plants, animals, or microorganisms, their availability is dependent upon the availability of the source material. Using
genetically engineered microorganisms for the production of enzymes eliminates the need to rely on source materials while ensuring a continuous supply of enzymes (Harlander, 1991).

The new technologies have allowed researchers to target the genetics of plants, animals, and microorganisms and to manipulate them to our food production advantage. What might be in store for tomorrow's food advancement? Predictions include:

1. Environmentally hardy food-producing plants that are naturally resistant to pests and diseases and capable of growing under extreme conditions of temperature, moisture, and salinity.

2. An array of fresh fruits and vegetables, with excellent flavor, appealing texture, and optimum nutritional content, that stay fresh for several weeks.

3. Custom designed plants with defined structural and functional properties for specific food-processing applications.

4. Cultures of microorganisms that are programmed to express or shut off certain genes at specific times during fermentation in response to environmental triggers.

5. Strains engineered to serve as delivery systems for digestive enzymes for individuals with reduced digestive capacity.

6. Cultures capable of implanting and surviving in the human gastrointestinal tract for delivery of antigens to stimulate the immune response or protect the gut from invasion by pathogenic organisms.

7. Microbially derived, high-value, "natural" food ingredients with unique functional properties.

8. Microsensors that accurately measure the physiological state of plants; temperature-abuse indicators for refrigerated foods; and shelf-life monitors built into food packages.

9. On-line sensors that monitor fermentation processes or determine the concentration of nutrients throughout processing.

10. Biotechnologically designed foods to supply nutritional needs; meat with reduced saturated fat, eggs with decreased levels of cholesterol, and milk with improved calcium bioavailability. (Harlander, 1991)

Additional Information on Food Fermentations

Sausage

Semi-dry fermented sausages
   Summer sausage: *Pediococcus cerevesiae* and *Lactobacillus plantarum*

Dry fermented sausages
   Pepperoni: *Pediococcus cerevesiae* and *Lactobacillus plantarum*
   Genoa salami: *Micrococcus spp.* mixed with either *Pediococcus cerevesiae* or *Lactobacillus plantarum*
   Snack sticks: *Pediococcus cerevesiae* and *Lactobacillus plantarum*

Lactic acid is produced, lowering the pH of the sausage to preserve and flavor.
Enzymes

Chymosin
Replaces rennet in over 80% of the cheese produced. Rennet is extracted from the stomachs of milk-fed veal calves. The supply is linked to the veal market, causing wide shifts in availability and price of the rennet. Recombinant chymosin is produced by an *E. coli*. The gene for chymosin was transferred from a calf to *E. coli*.

Amylase
Amylase is the enzyme that will break starch into its separate glucose components. Amylase is used in the brewing industry for malting and used in baking.

Glucose isomerase
The enzyme glucose isomerase converts or isomerizes glucose, (an aldehyde), to fructose, (a ketone), which is a sweeter product. The fructose is 1.8 times sweeter than glucose, so less is needed for the same taste.

Pectinase
Pectinase is the enzyme that breaks down pectin a polysaccharide found in fruit. Pectinase is used to remove particulate matter, or clarify, fruit juices.

Glucose oxidase
Glucose oxidase is an enzyme used in the production of dried egg whites. When drying egg whites the glucose present in the white can react with amines in a reaction known as Maillard browning. This will cause the dried egg whites to turn brown. The addition of glucose oxidase will breakdown the glucose and prevent the glucose from reacting and causing the off color of the egg whites.

To produce these recombinant enzymes, the gene is first transferred into bacteria. The bacteria are then grown in fermenters. The enzyme is then purified and sold.

Other additives
Commercial Gums: (Dextran, Gellan, Rhansan, and Welan) thickeners and stabilizers

Xanthan gum:
Xanthan gum is a polysaccharide produced by the bacterium *Xanthomonas campestris* on the cell wall. *Xanthomonas campestris* occurs naturally on the leaves of plants in the cabbage family. Commercially xanthan gum is produced by aerobic submerged fermentation. The bacteria are mixed with sugar, a nitrogen source, trace elements, and other growth factors in a large stainless steel tank. During fermentation aeration, agitation, pH, and temperature are precisely controlled. After fermentation the solution is pasteurized to kill all bacteria. The gum is separated using alcohol to precipitate the gum. Xanthan gum is used in many products including cakes, muffins, ice cream, sherbert, sour cream, salad dressings, sauces, gravies, syrups, and toppings. Taken from "Xanthan Gum, 5th Edition", by Kelco, 500 W. Madison, Suite 3180, Chicago, IL 60661, phone 1-800-535-2687
VI. Labs Included for Use in This Unit

Root Beer
- demonstrate the action of yeast on a mixture of sugar, water and flavorings through aerobic and anaerobic respiration

- materials:
  Bottles--washed and sterilized
  Wine corks or caps and crowns
  Stirring spoon
  Large (20 liter/5 gallon) enamel kettle or pot--DO NOT USE ALUMINUM!!
  *59 ml Schillings root beer concentrate
  *2.27 kg Sucrose (table sugar)
  *19 l Chlorine-free water
  *Containers to measure out needed volumes of materials--your choice--see procedures
  *9.5 g Yeast dissolved in 236 ml warm water
  *Use proportions to suit needs

- possible variations:
  Flavorings other than Schillings Root Beer Extract
  Amount of sucrose
  Amount of root beer extract
  Quick rise yeast vs. normal
  Amount of yeast
  Different sources of sugar (ie.: dextrose)
  (Nancy Heitel, et. al., 1988)

Making cheese
- prepare cheese from milk and buttermilk
• materials:
  500 ml whole milk
  50 ml, 500 ml, & 600 ml measuring devices
  hot plate
  thermometer
  fine-mesh cheesecloth
  cotton twine
  labels
  50 ml buttermilk
  50 ml, 500 ml, & 600 ml containers

• variations:
  Milk—goat, sheep, 2%, 1%, skim, cream enriched
  Rennin/rennet addition at day 1, step 1
  Specific bacteria inoculation
  Mold inoculation at day 1, step 1
  Addition of flavorings/salt/colorings

Kimchee
• using 2 liter bottles to study lactic acid fermentation

• note to teacher:
  Cabbage should be kept covered with its own juices at all times. Gas bubbles will escape each
day as the lid is pressed down onto the cabbage. This gas is produced as bacteria grow on the
sugary contents of the Chinese cabbage juice in the salty solution. As pickling proceeds, there
will be an increase in and change in acidity. Windows to air out classroom would be nice to have
when doing this lab!! Let students know that anaerobic lactobacilli are found almost everywhere
in our environment.

• materials:
  Chinese cabbage (cut into 5-7 cm chunks)
  1 red hot chili pepper, chopped
  2 cloves garlic, thinly sliced
  3 tsp. non-iodized (pickling) salt
  one 2 liter soda bottle
  large plastic lid (petri plate lid)
  pH indicator paper
  small plastic pipette

• variations:
  different cabbage types
  change seasonings or ingredients
  place bottles in various temperatures

• reference:
  1990 Fast Plants & Bottle Biology Projects, Department of Plant Pathology, University of
Wisconsin, 1630 Linden Dr., Madison, WI 53706.

Sauerkraut
• lactic acid fermentation of cabbage

• Note to Teachers:
  Containers used in making kraut should be cleaned and rinsed well. Crock should have
shiny glaze to the surface, and not be cracked or chipped. Metal containers are definitely not
to be used. If plastic is used, only use food-grade plastic. The dyes in a nonfood plastic are not intended for food use, and should not be used for food.

- **materials:**
  - Cabbage sliced into thin strips
  - Non-iodized salt
  - Container (Consider the fact that cabbage will require anaerobic conditions while fermenting in this container. If a fermenting crock is your container of choice, be careful that it is not chipped or cracked. Food-grade sturdy plastic pails are excellent containers. Do not use metal containers of any type)

- **variations:**
  - Different types of cabbage can be used.
  - Cabbage can be cut into different sizes to see how size varies the resulting product.
  - Spices or seasonings can be added for a variety of kraut flavors.
  - Sauerkraut can be canned for long-term storage.

- **references:**
  - Mennes, Mary E., "Make Your Own Sauerkraut" , Food Science, University of Wisconsin-Madison, Food Management Specialist, UW-Extension.

**Fermenting Power of Bread Yeasts**

- **materials**
  - 50 or 100 ml/graduated cylinder (to measure 30 ml distilled water)
  - 100 ml graduated cylinder, greased with Vaseline
  - Flour
  - Two brands, A and B, of active dry yeast. (either A or B should be a yeast cake)
  - *Saccharomyces cerevisiae*, young streak culture (solid medium)
  - Square sheets of brown wrapping paper
  - Buffered methylene blue stain:
    - Mix 1 part of 1:5,000 methylene blue & 1 part of a phosphate buffer solution (99.75 ml of 0.2 M KH₂PO₄ to 0.25 ml of 0.2 M Na₂HPO₄) to give pH of 4.6.
  - microscope
  - microscope slides & coverslips

- **variations**
  - Different brands of yeast
  - Different forms of yeast
  - Rapid Rise vs. normal
  - Different temperatures

- **References and Resources:**
  - Grula, Dr. Mary M., Oklahoma State University, Dept. of Botany/Microbiology, Stillwater, OK 74078-0289.
Yogurt
• Simple lactic acid fermentation

• materials:
  Food grade containers, washed  pH paper or meter
  Food grade thermometer  Microscope slides
  Hotplate  Bunsen burner
  Beaker tongs  Innoculating loop (a toothpick will work)
  2 cups milk  Crystal violet stain
  1/3 cup nonfat dry milk  Microscope (oil immersion if available)
  2 tablespoons plain yogurt (Old Home Black Label works well)

• Possible variations:
  Type of milk (whole, 2%, skim, chocolate)
  Different temperatures for incubation
  Different brands of yogurt for starter culture
  Different levels of starter
  Different levels of non-fat dry milk

• Adapted from:
  "Bacteria in Yogurt" pages 44-47 of Laboratory Experiments in Biotechnology and Related Areas Volume III: Experiments with Microorganisms, Dept. of Biological Sciences, Mankato State University, Mankato MN, 1988.
  "Homemade Yogurt, Sour Cream, and Buttermilk" by M. Wagner, R. Bradley, and M. Mennes, University of Wisconsin Extension publication B2768, available from Agricultural Bulletin, Rm. 245, 30 N. Murray St, Madison, WI, 53715, 608-262-3346.

Yeast Fermentation, Variation in CO₂ production by yeast
• glucose consumption and CO₂ production by yeast

• materials:
  15 mL plastic centrifuge tubes with caps
  7% yeast solution (4 packages yeast and 400 mL water)
  5% glucose solution (20 grams glucose in 400 mL water)
  TES-TAPE (available at Wal-Mart and pharmacies)
  large beakers (250 to 500 mL)
  water bath at 40 degrees C
  permanent fine point lab markers

• possible variations:
  regular vs. Rapid-Rise yeast
  levels of sugar
  type of sugar
  other temperatures (ice water, boiling water)

• adapted from
**Alternative labs:**

- "Dinner Date with a Microbe" by A. Gillen and R. Williams, *The American Biology Teacher*, May 1993, pages 268-274. Provides kitchen microbiology recipes and health information for yogurt, sauerkraut, and root beer.

- Silos and Sauerkraut from The AgriScience Institute and Outreach Program published by the National Association of Biology Teachers, 1994, pages 5-1 to 5-28. Bottle biology labs for making mini silos and fermentation chambers.

**VII. Evaluation Guidelines for Student Activity**

Students will be evaluated on their daily journal writings, their lab techniques, the written presentation, and the oral presentation.

- The daily journal writings will be evaluated on the answer to the daily focus question, and a detailed description of all lab procedures and observations. The journal must also include self evaluations, group evaluations, definitions to vocabulary words, and summaries of at least three recent articles related to their topic.

- The oral presentations will be evaluated on the delivery and content. The content must include procedures, results, and a description of two careers related to the topic area.

- The written presentation must include a more detailed description of the information from the oral presentation plus a section describing the importance of fermentation to the economy of the area.
**UNIT EVALUATION SHEET**

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>PERCENTAGE GUIDELINE</th>
<th>PERCENTAGE RECEIVED</th>
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<tbody>
<tr>
<td>Laboratory setup</td>
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<tr>
<td>Daily Journal</td>
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<td>focus questions</td>
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<td>record of lab procedures and observations</td>
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<td>peer grade</td>
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<td>response to outside activities</td>
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<td>Glossary</td>
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<td>Article summaries</td>
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<tr>
<td>Unit summary</td>
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<td>oral</td>
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<td>Extra credit (point total up to teacher)</td>
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<td>multiple variations of experiments</td>
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<td>current event articles (3 minimum)</td>
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<tr>
<td>find information on schools or careers in biotech</td>
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UNIT GUIDELINES

Daily Journal:
• In your daily journal you are required to include:
  the date
  response to the day’s focus question
  a record of all lab procedures and observations
  any questions that arise during the period
  all unit vocabulary words (on glossary page)
  self and group evaluation
  response to non-lab activities including guest speakers, case studies, field trips,
  summaries of at least three articles related to your topic area or fermentation taken from
  recent (within 2 years) publications

Group Presentation:
• The 5-10 minute oral portion will include:
  an explanation of your lab procedures
  a summary of your lab results
  a brief overview of two careers associated with your topic area
• The 4-8 page written report will include:
  an introduction to your topic record of lab activities including materials, procedures followed, observations, and conclusions descriptions of at least two careers in your topic area
  importance of fermentation to the economy of the area, state, or country
STUDENT PROPOSAL SHEET FOR FERMENTATION LAB

Name: __________________

Who is the leader of your laboratory group?

What will you vary in your experimental project(s)?

What is your hypothesis for the effects your variable will have on each experimental project as opposed to the control?

What steps will you follow to complete your projects?

What materials will each member of the group be responsible for?
Every day of this unit you are expected to write at least one page to your journal. Each day you should record what you do and what you see.

You are expected to:

Each day summarize the day’s activities in complete sentence/paragraph form. Be thorough. Include procedures and pertinent vocabulary as well as any questions which you come up with.

* answer the day’s focus question found on the board.
* record physical data such as what you see, what you smell, etc.
* record what your group does with your project each day.
* add the word(s) of the day to your glossary. Use this/these words in your entry for the day.
* individually evaluate yourself/your partners effort for the day on a Scale from 1-5. (1=no effort, 5=high effort)
DAILY JOURNAL PAGE

Name: ____________________________

Date: ____________________________

Response to today's focus question:

Record of today's procedures and observations:

Any questions from today's class:

Group evaluation (1-5). Place your partners' names in the blanks.

Your name: ____________________________  Your score: _____
Partner's name: ____________________________  Partner's score: _____
Partner's name: ____________________________  Partner's score: _____
Partner's name: ____________________________  Partner's score: _____
GLOSSARY SHEET

Write in vocabulary terms associated with this unit and define.

UNIT TITLE_________________________
SAMPLE DAILY FOCUS QUESTIONS

Why is it important to lower the pH of fermented foods?

How do fermentation and oxidative respiration differ?

Why is the legend of the Bedouin and his discovery of cheese plausible?

Why might have the development of fermented foods progressed relatively slow until the 20th century?

What is the best way to avoid a Salmonella infections?

What are some of the industries built on fermentation?

What is the chemical equation for fermentation?

What is the difference between breathing and respiration?

List several foods which that are produced by fermentation?

What factors contribute to food spoilage?

How is food safety monitored?

Can you tell if food is safe just by the smell and appearance? Why or why not?
Sample Vocabulary Words

fermentation
respiration
biotechnology
enzyme
lactic acid
alcohol
microbe
bacteria
yeast
anaerobic
aerobic
pathogen
**VIII. FULL LABORATORY EXERCISES**

**ROOT BEER PRODUCTION.**

**Introduction:**

In this laboratory you will be demonstrating the action of yeast on a mixture of sugar, water, and flavorings through both aerobic and anaerobic respiration. Your yeast are microbes that will break down sugar into water and carbon dioxide—the latter causing the root beer to become carbonated. The oxygen present will eventually be depleted, causing the yeast to revert to anaerobic respiration. Be sure to follow aseptic technique and use only food-grade containers for this experiment. You will be responsible for making a control sample following the formula below and at least one other batch of root beer in which you have changed one factor. You need to hypothesize what differences your experimental group will have as compared to your control. You must submit a proposal on what your experimental group(s) will entail before beginning this laboratory work.

**Materials:**

- Bottles—washed and sterilized
- Wine corks or caps and crowns
- Stirring spoon
- Large (20 liter/5 gallon) enamel kettle or pot—DO NOT USE ALUMINUM!!
- *59 ml Schillings root beer concentrate*
- *2.27 kg Sucrose (table sugar)*
- *19 l Chlorine-free water*
- *Containers to measure out needed volumes of materials—your choice—see procedures*
- *9.5 g Yeast dissolved in 236 ml warm water*

*see Caution 2. below

**Cautions:**

1. Wash hands thoroughly with antibacterial soap and water before and after completing each step of the laboratory.
2. Alter the volumes and measures (by using proportions) to best suit your needs.
3. Wear goggles and laboratory apron.

**Control Group Procedure:**

*Day 1*

1. Make sure all materials, equipment, and your hands are as clean as possible. Wash hands before handling any materials.
2. Place sucrose and root beer extract into kettle
3. Gradually add chlorine free water
4. Add yeast/warm water mixture and stir well.
5. Immediately place mixture in clean/sterile bottles, leaving approximately a 5 cm airspace at the top.
6. Tightly cork or seal the bottles and place them on their sides in a warm (25-30°C) location.

Day 2
• Record observations

Day 3
• Record observations

Day 4
• Once refrigerated, your root beer should be ready for consumption!!

Adapted from:
• Nancy Heitel, et. al., "Production of Home Brewed Root Beer," Mankato State University, Mankato, MN, 1988
CHEESE MAKING

Introduction:

In this activity you will be fermenting milk products. The action of bacteria in milk causes a buildup of lactic acid. This lactic acid causes the milk to curdle, forming a solid curd, and a liquid whey. The curd is then separated from the whey and aged to make cheese. The physical characteristics of the cheese depend on many factors. Below is a basic “recipe” for making cheese. You will be responsible for making a control sample following this formula and at least one other batch of cheese in which you have changed one factor. You need to hypothesize what differences your experimental group(s) will have as compared to your control. Be sure to follow aseptic technique and use only food-grade containers for this experiment. You must submit a proposal on what your experimental group(s) will entail before beginning this laboratory work.

Materials:

- 500 ml whole milk
- 50 ml buttermilk
- hot plate
- thermometer
- fine-mesh cheesecloth
- cotton twine
- labels
- 50 ml, 500 ml, & 600 ml measuring devices
- 50 ml, 500 ml, & 600 ml containers

Cautions:

1. Wash hands thoroughly with antibacterial soap and water before and after completing each step of the laboratory.
2. Be aware of shock and burn hazards when using the hot plate.
3. Wear goggles and laboratory apron.

Control Group Procedure:

Day 1

1. Make sure all materials, equipment, and your hands are as clean as possible. Wash hands before handling any materials.
2. Pour 500 ml whole milk into your 600 ml container and 50 ml buttermilk into your 50 ml container.
3. Heat the whole milk to 37°C.
4. Add the buttermilk to the whole milk and stir well.
5. Cover the container with cloth or paper.
6. Incubate at between 25°C and 35°C for 48 hours or until a firm curd has separated from the whey.

Day 2

1. Prepare a piece of cheesecloth that will be thick enough and large enough to hold your curd.
2. Pour your curd into the cloth. Collect the whey in the 500 ml container. Gather the edges of the cloth to form a bag. Tie the bag with the twine and hang it to continue draining. After it has fully drained, discard the whey and place the bag in the refrigerator.

Day 3

• No work necessary today.

Day 4

• Remove the cheese and enjoy!

Adapted from:

**KIMCHEE: KOREAN DELIGHT**
**FERMENTATION EXPERIMENTS WITH BOTTLE BIOLOGY**

**Introduction:**
Pickling is one of the most ancient forms of preserving food. You will be using microbes to convert sugars into lactic acid. The microbe involved is called lactobacilli. As the population of lactobacilli grows, they eat the natural sugars in plant juices and produce lactic acid as a waste product. As the lactic acid levels increase, so does the acidity. This highly acidic environment prevents the growth of other bacteria that would under normal conditions feast on the food causing spoilage. In this lab, you will be making kimchee and study lactic acid fermentation.

**Materials:**
- Chinese cabbage (cut into 5-7 cm chunks)
- 1 red hot chili pepper, chopped
- 2 cloves garlic, thinly sliced
- 3 tsp. non-iodized (pickling) salt
- one 2 liter soda bottle
- large plastic lid (petri plate lid)
- pH indicator paper
- small plastic pipette

**Procedure:**
1. Cut the bottle top off from base 10-15 cm from the top.
2. Alternate layers of cabbage, garlic, pepper and sprinkling of salt in the soda bottle. Press each layer down firmly until the bottle is packed full.
3. Place the lid, rim side up, on top of ingredients and press down again.
4. Press down occasionally for the next few hours. When there is space, fit the bottle top inside the bottle bottom, forming a sliding seal. Air should bubble out around the edge of the petri plate when you press down on the lid. Press daily on the sliding seal to keep the cabbage covered by a layer of juice at all times.
5. Measure and record the acidity of the fresh juice on top each day with a pH indicator paper.
6. When the pH drops to 3.5, your kimchee will be ready. (About 3-7 days) Enjoy!

**Cautions:**
- When working with chili peppers, take care not to touch eyes of mouth. Wash hands thoroughly when finished.
- Bottle used to ferment kimchee in should be cleaned and rinsed well.
MAKE YOUR OWN SAUERKRAUT

Introduction:

Sauerkraut is a naturally fermented cabbage. Natural fermentation is one of the oldest means of food preservation, and reduces the risk of foodborne illness and food spoilage. The juice extracted from shredded cabbage by adding salt* contains fermentable sugars, and in the absence of air, the microorganisms feed on the cabbage leaves and will produce lactic acid. This lactic acid creates an acidic environment unsuitable for other organisms to survive. In this lab you will make your own sauerkraut.

*The salt used should be a non-iodized pickling or canning salt. Iodine, which is in table salt, prevents the bacterial fermentation necessary to change cabbage into sauerkraut.

Materials:
Cabbage sliced into thin strips
Non-iodized salt
Container (Consider the fact that cabbage will require anaerobic conditions while fermenting in this container. If a fermenting crock is your container of choice, be careful that it is not chipped or cracked. Food-grade sturdy plastic pails are excellent containers. Do not use metal containers of any type)

Procedure:

1. Clean off cabbage head to remove residual insecticide spray or dust. There are important bacteria existing on the cabbage leaves which are necessary in the fermenting process, therefore, do not overclean the head.

2. Cut, slice, or shred the cabbage.

3. Place cabbage in container and sprinkle with salt. Add 2.25 to 2.5 percent salt by weight.

4. Cover and weight down the cabbage to produce anaerobic conditions for the fermenting process to take place.

5. Set the cabbage back and allow fermentation process to proceed. Remember the effects temperature can play on fermentation.

6. Check the container daily for film yeasts or molds which may appear on the surface. This can be removed by skimming the surface of the cabbage. Kraut should be ready in 3 to 4 weeks.
Fermenting ("Dough-Raising") Power of Bread Yeasts

Introduction:

Bread dough is usually leavened by bakers’ yeast (actively gas-producing strains of *Saccharomyces cerevisiae*). Yeasts ferment the sugar in the dough, producing ethanol and carbon dioxide. CO₂ is the leavening agent and the alcohol evaporates off during baking. Sometimes other gas-producing microorganisms are involved in bread leavening--these usually are heterofermenting lactic acid bacteria (sourdough bread or salt-rising bread).

Commercial yeast is prepared and sold in two forms: yeast cakes and active dry yeasts. Yeast cakes contain, in addition to yeast cells, small amounts of starch, vegetable oils, and some lactic acid bacteria. Active dry yeast is made by drying the yeast cells to less than 80% moisture. These yeast cells are dried carefully at low temperatures so the cells will survive. When these yeast cells are stored at room temperature, they will retain their "dough-raising" ability for many months. You will be studying the difference between the active dry yeast and the yeast cakes.

Materials:

- 50 or 100 ml/graduated cylinder (to measure 30 ml distilled water)
- 100 ml graduated cylinder, greased with Vaseline
- Flour
- Two brands, A and B, of active dry yeast. (either A or B should be a yeast cake)
- *Saccharomyces cerevisiae*, young streak culture (solid medium)
- Square sheets of brown wrapping paper
- Buffered methylene blue stain:
  - Mix 1 part of 1:5,000 methylene blue & 1 part of a phosphate buffer solution (99.75 ml of 0.2 M KH₂PO₄ to 0.25 ml of 0.2 M Na₂HPO₄) to give pH of 4.6.
- Microscope
- Microscope slides & coverslips

Procedure:

A. Examine yeast cells
   - prepare wet mounts of yeasts
   - stain slides using methylene blue stain
   - microscopically examine yeast cells
   - record the percent of living cells (will appear white)
   - record the percent of dead cells (will appear blue)

B. Fermenting ("dough-raising") power of yeasts
   - combine 50 g flour, 1 g dry yeast A, and 30 ml water on brown wrapping paper knead vigorously for 5 minutes
     --repeat step above using yeast B
     --place into separate greased cylinders and record volume
     --incubate at room temperature and record volume at intervals of time
Introduction:

Yogurt production demonstrates fermentation by *Streptococcus thermophilus* and *Lactobaacillus bulgaricus*. Heated milk is innoculated and maintained at a given temperature causing bacteria to grow and ferment lactose, the sugar in milk. The bacteria produce lactic acid which causes the milk to coagulate and adds a sour flavor.

Be sure to follow aseptic technique and use only food-grade containers for this experiment. You must submit a proposal on what your experimental group(s) will entail before beginning this laboratory work.

Materials:

Food grade containers, washed       pH paper or meter  
Food grade thermometer            Microscope slides  
Hotplate                           Bunsen burner  
Beaker tongs                       Innoculating loop (a toothpick will work)  
2 cups milk                        Crystal violet stain  
1/3 cup nonfat dry milk            Microscope (oil immersion if available)  
2 tablespoons plain yogurt (Old Home Black Label works well)

Procedure:

1. Combine milk with nonfat dry milk and heat in a double boiler to 190° F. Hold at that temperature for 10 to 20 minutes so that the protein in the milk mixture will take up more water and make a better gel. Cool to 115° F (warm) and record the pH of the mixture.

2. Place the plain yogurt in a jar and gradually blend in the warm milk.

3. Cover. Place in a bowl of warm water (115° F), a slightly warm oven or a styrofoam cooler. The temperature within the oven or cooler should be about 110° to 120° F to provide optimum conditions for yogurt culture activity.

4. Allow to stand undisturbed until the mixture is firm when the jar is gently wiggled. This may take as long as 6 to 8 hours. Note the time so that less care will be needed for the next batch. Record the pH of the yogurt.

5. Chill yogurt as soon as it is set. It can be stored in the refrigerator for up to 3 weeks.

6. Place a drop of water on the slide. Use the innoculating loop to mix a little yogurt with the water and spread it around the middle 1/3 of the slide.

7. Let the slide air dry.

8. Quickly pass the slide through the flame of the Bunsen burner 3-4 times.

9. Let the slide cool.

10. Cover the slide with 2-3 drops of crystal violet.

11. After 30 seconds rinse the slide with water.
12. Examine the slide under the microscope and draw the bacteria.

13. Add 2 tablespoons sugar and 1/4 cup fresh, crushed or frozen fruit.

14. Taste your yogurt. (Do not eat any yogurt that smells or looks bad! If in doubt, throw it out!)
Yeast Fermentation Lab

Introduction:
During anaerobic conditions high levels of NADH develop, leaving a shortage of NAD\(^+\). Low levels of NAD\(^+\) slow the rate of glycolysis. Fermentation restores NAD\(^+\) levels while producing alcohol and CO\(_2\).

During aerobic respiration glucose is broken down into water and carbon dioxide.
\[
\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \rightarrow 6\text{H}_2\text{O} + 6\text{CO}_2
\]
Under ideal conditions most eukaryotic cells produce 36 ATP molecules from one molecule of glucose.

During fermentation baker’s yeast breaks glucose into ethyl alcohol and carbon dioxide.
\[
\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2
\]
This process only yields 2 ATP per glucose molecule.

Materials:
- 15-ml plastic centrifuge tubes with caps (Corning #25319)
- 7% yeast solution (4 packages of yeast and 400 ml of water)
- 5% glucose solution (5 grams of glucose in 400 ml of water)
- TES-TAPE (Lilly, available at Wal-Mart and pharmacies)
- large beakers (250 - 500 ml)
- Water bath at 40°C
- permanent fine point lab markers

Prelab preparation:
1. Poke 3-4 small holes in the centrifuge tube caps using a pin or thumbtack
2. Prepare the yeast solution by mixing 4 packages of active dry yeast in 400 ml of tap water
3. Prepare the sugar solution by mixing 20 grams of glucose in 400 ml of tap water
4. Preheat the water bath and the solutions to 40°C
5. Fill 12 beakers with water and place in the water bath to preheat
6. Fill 12 beakers with water and leave at room temperature

Procedure:
1. Fill each tube halfway with sugar solution.
2. Fill the rest of each tube with yeast solution, extending the fluid level above the top of the tube.
3. Take a small piece of TES-TAPE and measure the amount of glucose.
4. Screw the cap on the tubes (a few drops will spurt out the holes).
5. Check to make sure there are no bubbles visible in the tube
6. Invert the tubes and mark two tubes L and the other two tubes C
7. Place one L tube and one C tube in each beaker
8. Return the 40°C beaker to the water bath
9. After 5, 10, 15, and 20 minutes
   take the L tubes out of the water,
   dry the tops with a paper towel
   mark the level of the gas bubbles (include any foam as part of the bubble)
   return the L tubes to the beakers
   take the C tubes out of the water
   turn the tubes upright and remove the caps
   take two small pieces of TES-TAPE and measure the amount of glucose
   recap the tubes and return to the beakers
10. After 20 min. empty the contents of all tubes into the waste beaker
11. Record the ml of CO₂ at each mark
12. Wash and rinse out your tubes
13. Graph the change in glucose and CO₂ over time in your journal
14. Answer the following questions in your journal
   • Why did you have two tubes at each temperature?
   • What was the variable in this experiment?
   • What was the gas that formed in the tubes?
   • Describe an experiment that you could use to test if a different type of sugar would give the
     same results.

Variations:
• Regular vs. Rapid-Rise Yeast
• Levels of sugar
• Type of sugar
• Other temperatures (ice water, boiling water)

Adapted from:
"Fermentation, Respiration, and Enzyme Specificity: A Simple Device and Key Experiments
with Yeast" by L. Reinking, J. Reinking, and K. Miller, The American Biology Teacher, Vol. 56,
### IX. National Standards

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**Descriptions of the individual standards:**

**Benchmarks for Science Literacy**

- **3A Technology and Science:**
  
  *Technology usually affects society more directly than science because it solves practical problems and serves human needs…*

- **10I Discovering Germs:**
  
  *Pasteur wanted to find out what causes milk and wine to spoil…*

- **12D Communications skills:**
  
  *Locate information in reference books, back issues of newspapers and magazines, compact disks, and computer disks.*
  
  *Use tables, charts, and graphs in making arguments and claims in oral and written presentations.*
National Science Education Standards
Content
• A Science as Inquiry:
  Abilities of scientific inquiry
• B Physical Science:
  Chemical Reactions
• C Life Science:
  Cell biology
• F Science in Personal and Social Perspectives:
  Science and technology in local, national, and global challenges.
  Personal and community health
• G History and Nature of Science:
  Historical perspectives

Assessment Standards
• A Coordination with Intended Purposes:
  Deliberately designed
  Explicitly stated purposes
• B Measuring Student Achievement and Opportunity to Learn:
  Achievement data collected focuses on the science content that is most important for students to learn
• C Matching Technical Quality of Data with Consequences:
  The feature that is claimed to be measured is actually measured
  Assessment tasks are authentic

Program Standards
• B Curriculum
  Inquiry is emphasized as a tool for learning science
  The curriculum connects to other school subjects

National Resource Council recommendations for agricultural education
• Ongoing efforts should be expanded and accelerated to upgrade the scientific and technical content of vocational education courses.
• New curriculum components must be developed and made available to teachers addressing the sciences basic to agriculture, food, and natural resources...

School-to-Work Initiative
School Based Learning
• Career exploration to help students in the career identification process
• High academic content enabling admission, if desired, to post-secondary education
• Applied and integrated technical and academic curriculum
X. References


Harlander, Susan K. "Biotechnology - A Means For Improving Our Food Supply." Food Technology, April, 1991


Oklahoma State University, Dr. Mary Grula, Fermenting Power of Bread Yeasts.

Pearl, Anita May, Cuttle, Constance and Deskins, Barbara B. Completely Cheese, Jonathan David Publishers, Inc. Middle Village, New York, 1978


