Understanding osmosis, pickling and fermentation by making kimchi

Developed by Adam Fleisher

Grade level: 9 – 12
Number of days: 5 days, if including the optional microbiology activity
Topics: pickling, osmosis, fermentation, culture microorganisms
Essential question: How does fermentation preserve food and keep it safe to eat?

Objectives:

1. Students will be able to explain how osmosis works.
2. Students will be able to explain how anaerobic fermentation works to preserve food.
3. Students will be able to run a controlled experiment and analyze its results. (Optional)

Correlation to Next Generation Science Standards (NGSS):
Science & Engineering Practices:
-Asking questions and defining problems
-Planning and carrying out investigations
-Analyzing and interpreting data
-Obtaining, evaluating, and communicating information

Disciplinary Core Ideas:
HS-LS1.B: Growth and development of organisms

Crosscutting concepts:
Cause and effect

Note:
-Depending on your particular room setup, you may wish to prepare parts of the kimchi yourself, or use a cooking classroom if one is available.

-All referenced recipes, worksheets, videos and photos are provided in the Appendix.

Day 1 Lesson: Introducing fermentation, learning about osmosis

Time	Lesson Sequence
10 minutes	ENGAGE (Warm-up activity): Students are to consider the following scenario in groups of 2 to 4: *Imagine that it is at least 400 years ago, before electricity has been discovered and before the industrial revolution. You are a human who would like to go on living, which means you will need food to eat, even during the cold winter months. Many foods do not grow during the winter. Is there some way that you could preserve food that you collect in earlier months so that you can continue to eat them throughout the winter?* Discuss student ideas as a class. Possible answers: home canning, smoking, salting, drying, and fermenting or pickling. Ask students if they know what can be fermented. Possible answers: kimchi, sauerkraut, sourdough bread, and yogurt. Tell the students that today's lesson is on fermentation (pickling), and the dish that we will eventually taste (and make) is kimchi, the Korean fermented cabbage dish. It preserves uncooked food, in part, by removing oxygen.
5 minutes	The teacher shows **Slideshow #1** (see Appendix) which contains photos of what kimchi looks like, what the dish is made from, and the traditional glazed pots used to make kimchi. The teacher then shows students the setup for the first part of making kimchi, which the class can do that day.
30 minutes	Students working in pairs, following the first 2 steps of the **kimchi recipe** (cutting, salting, and tossing the cabbage). (See Appendix for recipe.) They leave it sitting in a bowl. Students work on **Worksheet #1** (see Appendix), which introduces the concept of osmosis. While students complete the worksheet, they should see that the cabbage is releasing water… due to osmosis! Go over the answers to **Worksheet #1** with the students, and ask if they can explain why the cabbage is releasing water, and where the water came from. Answers: the cabbage is releasing water from within its cell walls due to osmosis because the water molecules are moving to a region of lower water concentration. Students rinse off their cabbage, squeeze it, and store it in containers in a refrigerator for next class.

Assessment:
Following this lesson, consider giving students a graded **entrance ticket** (see Appendix) in which they explain how osmosis works.

Day 2 Lesson: Making kimchi

Time	Lesson Sequence
5 minutes	Give students a graded **Entrance ticket** (see Appendix) in which they explain how osmosis works.
5 minutes	Students taste a variety of purchased kimchi to get a sense of it. They record their impressions on **Worksheet #2** (see Appendix). The teacher takes a sample of the kimchi liquid and tests for pH. It will likely be pH 4, meaning it is acidic. The teacher mentions that this fermentation produces lactic acid, which is why the pH is so low. This will help to prevent unwanted microorganisms from growing, therefore preventing spoilage.
35 minutes	Students work in groups to prepare the rest of their ingredients according to the **kimchi recipe**. The teacher may want to have the paste ingredients already prepared for all groups, in the interest of saving some class time. Do give students the chance to taste the kimchi now, before fermentation. Also record the current pH. Students assemble kimchi in containers, being careful to remove air bubbles. The teacher checks setups and confirms that lids will allow gases to escape. For homework, students complete **Worksheet #2**, which includes questions about a Korean family profiled in a short video on YouTube.

Assessment: For this lesson, an informal assessment is suggested.

Day 3 Lesson: Learning more about lactic acid fermentation

Time	Lesson Sequence
10 minutes	Go over answers to **Worksheet #2**. This may lead to a discussion of the significance of kimchi in Korean life, or important side dishes in other cultures. If so, it is worth mentioning some of the following. These are taken from "K Food" (see appendix). *- Korea's most fundamental side dish and most prominent fermented vegetable is kimchi. In Korea, the phrase 'no side dishes' does not include kimchi, because kimchi is always there.* *- Traditionally, kimchi was served 365 days a year. "No other culture eats as much of a similar food."* *-In addition to kimchi, most Korean side dishes, including soups, are made using fermented foods such as soy sauce, soybean paste, and fish sauce. Often rice is the only Korean food that does not have a fermented taste.* *- "In the Korea of the past, the natural environment was harsh, resources were scarce and humidity was high. Therefore, people often used salt to ferment foods."* *-"If Koreans had been able to get various ingredients in different places over the course of a year, to use high heat to cook, to have abundant supplies or cooking oil for deep-frying and stir-frying or to simply serve a thick steak as a meal, the country wouldn't have developed such a reliance on fermented food."*
10 minutes	Students watch ~5 minutes of "The Science Behind Kimchi" from Bite Scized Education on YouTube while completing **Worksheet #3** (see Appendix) on lactic acid fermentation. After completing this activity, students should be able to explain why they worked to remove oxygen from their kimchi containers, which gas is being generated during fermentation, and predict what will happen to the pH of the kimchi has fermentation continues.
5 minutes	Students taste a sample of their kimchi. Test for pH.
15 minutes	Introduce the experiment we will begin next class. See **Lactic acid bacteria (LAB) experiment.** (See appendix.) Show students what agar plates look like and how we will use them.

Assessment: Consider giving an entrance ticket or quiz during a subsequent lesson on the content in Worksheet 3. Should cover aerobic fermentation, anaerobic fermentation, what bacteria consume and produce, etc.

Day 4 Lesson: Lactic acid bacteria experiment (optional)

Notes:
1. It will likely take days for results to appear in the Petri dishes.
2. Check out the **Teacher Notes** in the Appendix to see what lab materials are required for this experiment.

Time	Lesson Sequence
10 minutes	Introduce **Lactic acid bacteria (LAB) experiment** (see Appendix). With the students, read over the Background, Purpose, and Materials.
5 minutes	Students divide into lab groups of 2 – 4 people and write their method for obtaining bacteria. To be checked by the teacher.
2 minutes	The teacher demonstrates how to use the sterile applicator to obtain the bacteria culture and deposit it onto the Petri dish.
20 minutes	Students perform steps 3 – 6 of the lab.
20 minutes	When the results are visible in the Petri dishes, students can examine the dishes and answer the Post-lab questions.

Assessment: Consider giving students a written summative assessment on osmosis and fermentation.

Slideshow #1 Images

Figure 1 Traditional Kimchi. Image taken from https://sugaryums.com/wp-content/uploads/2023/03/Baechu-Kimchi-Cabbage-Kimchi-Recipe-SugarYums-17.jpg on October 2024.

Figure 2 Different types of kimchi. Accessed from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5039233/ on October 2024.

Figure 3 Typical kimchi ingredients. Image taken from https://www.platingsandpairings.com/wp-content/uploads/2015/01/kimchee-ingredients-683x1024.png on October 2024.

Figure 4 "Onggi," large earthenware jars traditionally used to store kimchi. Accessed from https://bandanapottery.com/onggi on October 2024.

Kimchi recipe

Ingredients
Vegetable Ingredients:
kosher salt for curing
1 large Napa cabbage (2 lbs 2 oz, 980 g)
2 medium sized carrots
1 small daikon radish
1 bunch green onion

Paste Ingredients:
1 large Asian pear (250 g)
6 cloves (20 g) garlic, peeled
2 inch (20 g) piece ginger, peeled
1/4 cup (60 ml) fish sauce
1/3 cup (25 g) Korean red pepper flakes

Directions:
1. Take your Napa cabbage and slice in half lengthwise. Cut each of those halves and cut in half again, making quarters. Cut each of those quarters into 1-inch wide strips.

2. Take your cabbage and place into a large bowl, heavily seasoning it with kosher salt. Squeeze and toss your cabbage really hard, bruising it. Let it sit for at least 30 minutes.

3. While the cabbage is sitting, take your green onions and cut the root bottoms off. Cut the onion into ½-inch segments. Take your carrots and roughly chop them julienne style. Next, peel your medium-sized daikon and cut them like your carrots, but a thicker julienne chop.

4. To make your paste, slice your 2-inch segment of peeled ginger and place into a food processor. Peel and chop an Asian pear into cubes and add to the processor. Add in 6 cloves of peeled garlic, and a ¼ cup of fish sauce. Blend until smooth.

5. Transfer paste to a medium-sized bowl and mix together with Korean red pepper flakes.

6. After your cabbage has been sitting, drain through a colander and rinse with water while squeezing at the same time. Toss and squeeze until you've washed off the majority of the salt.

7. Add your cabbage and all of the vegetables you cut into a large bowl. From there, add in all of your paste and toss to thoroughly coat. Once evenly coated, pack contents into a ½ gallon glass jar that is large enough to fit the mixture. Using a spoon or muddler, press down all of the vegetables so it is packed together, removing any air bubbles in there.

8. Loosely cap the jar off, making sure you don't tighten it all the way down (for it to release gas) and let it sit for 4-7 days. Make sure to press it throughout this time to remove air bubbles that form throughout.

9. Once your kimchi has reached the desired flavor point, tighten the cap all the way and store it in the refrigerator.

Recipe taken from https://www.joshuaweissman.com/post/kimchi on October 2024.

Name _____ Date _____ Period ____
Kimchi project

Worksheet #1

Please match the word with its definition. You may need to use a textbook or the internet.

Word bank: fermentation, osmosis, pickling

1. The process of preserving or extending the shelf life of food by fermentation in brine (salty water).

2. The chemical process by which molecules such as glucose are broken down anaerobically (without oxygen). Products are adenosine triphosphate ("ATP"), carbon dioxide (CO_2), and lactic acid ($C_3H_6O_3$).

3. The process of water molecules moving through a semipermeable membrane from a region of high concentration to a region of low concentration.

In the diagram of the plant cell below, water molecules are the 3-atom molecules with the larger oxygen atom in the center. Note the relative amounts of salt inside and outside the plant cell. The water molecules can pass through the semi-permeable cell wall. The salt cannot.

4. Predict where many of the water molecules will go, and explain why.

5. Predict whether this movement of water molecules will cause the cell to shrivel or expand.

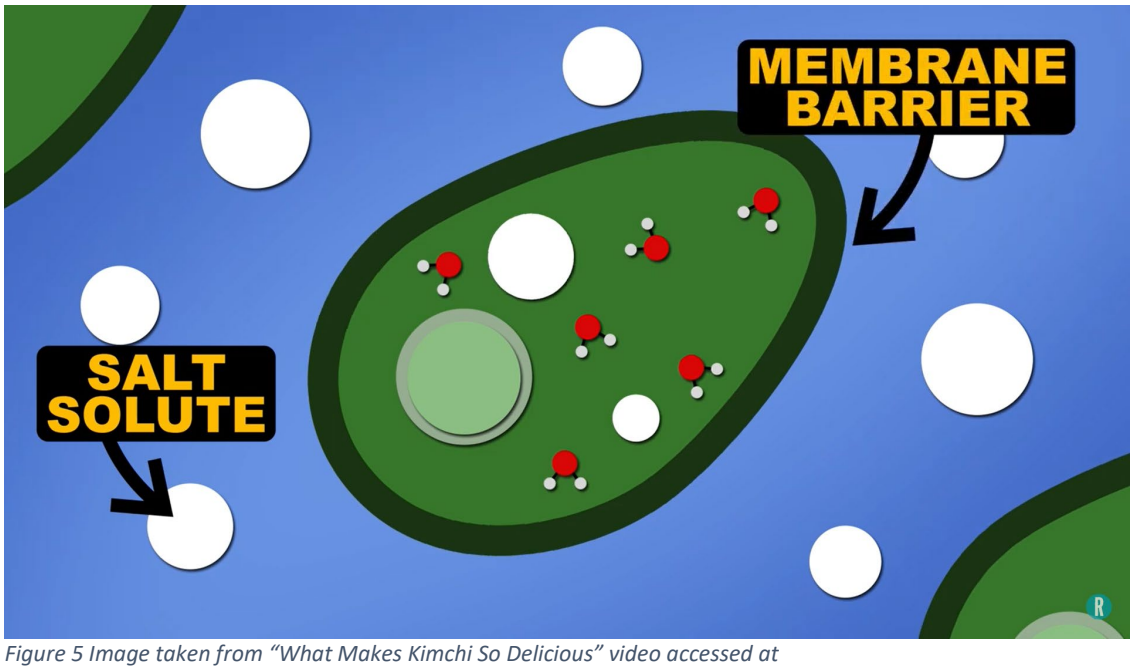

Figure 5 Image taken from "What Makes Kimchi So Delicious" video accessed at https://www.youtube.com/watch?app=desktop&v=DG4afs7C1XI on October 2024.

Name _____ Date _____ Period ____
Kimchi project

Entrance Ticket

Explain how osmosis works. You may explain it in terms of solvent concentration or solute concentration. Be sure to use the words solvent, membrane, lower concentration, and higher concentration.

Name _____ Date _____ Period ____
Kimchi project

Worksheet #2

Please record the name, appearance, and taste of the purchased kimchi varieties you taste.

1. Name _____
   Appearance: Taste: pH:

2. Name _____
   Appearance: Taste: pH:

3. Name _____
   Appearance: Taste: pH:

4. Now your teacher will take a small sample of liquid from each kimchi and test its pH. Record the pH of each kimchi above.

5. Based on what you have learned about fermentation, why do you suppose the pH of kimchi is not neutral? Explain.

6. When you have finished mixing together the ingredients you'd like to include in your kimchi, set aside a bite-sized sample and a few drops of liquid. What does it taste like?

7. Test the pH of the liquid and record it here. Day 1 pH = _____.

8. Watch the 2 minute video on YouTube titled "Kimchi: A Story of Love and Patience" to get a better idea of how kimchi is made in larger batches in Korea. Record your observations here.

Name _____ Date _____ Period ____
Kimchi project

Worksheet #3

Please take notes as you watch "The Science Behind Kimchi" from Bite Scized Education on YouTube.

(45 seconds in)

1. Hyunjoo from Sinto Gourmet learned to make kimchi from her grandmother. How many types of kimchi can be found in South Korea?

   "There's a joke that if you give any vegetable to a Korean, they will make a kimchi out of it."

(8 minutes 30 seconds in)

2. Harvard student Felicia Ho, who is studying molecular and cellular biology, explains that beneficial bacteria transforms the taste of kimchi. Where do the bacteria come from?

3. What do bacteria eat? What do bacteria create?

   Cells have to use _____ (adenosine triphosphate) for energy, not big molecules like glucose.

4. Circle the correct work in each pair:

   Aerobic respiration **uses/doesn't use** oxygen. Anaerobic respiration **uses/doesn't use** oxygen.

5. What are the 4 products of anaerobic respiration?

6. *"The environment that we create inside the jar, one that does not have _____ and is quite _____ is the key to making the kimchi last and not spoil. Microorganisms like bacteria that would cause food spoilage can't survive in that environment."*

_____

7. Try your kimchi today! Set aside a bite-sized sample and a few drops of liquid. What does it taste like?

8. Test the pH of the liquid and record it here. Day 2 pH = _____.

Name _____ Date _____ Period ____
Kimchi project

Lactic acid bacteria (LAB) experiment

Background
Lactic acid bacteria (LAB) are a group of bacteria that are widely used to make fermented foods like sausage, cheese, yogurt, pickles and kimchi. They are naturally found in Napa cabbage—and therefore they are in Kimchi juice!

As the LAB grow during fermentation, the pH drops. This is desirable because an acidic environment inhibits the growth of common food contaminants, which prolongs shelf life. Some LABs make other chemicals that inhibit the growth of other bacteria. This is known as *competitive exclusion*.

Purpose
In this lab, we will attempt to test LAB's ability to inhibit the growth of things that would otherwise spoil food, like "bad" bacteria and mold (fungus). You will try to grow a "bad" bacteria or mold with and without kimchi juice, which contains LAB, to see if the LAB prevents the growth of the contaminant.

You and your partner will be given two sterile Petri dishes that are coated on the inside with agar, a substance that can serve as a surface (called a *medium*) for a variety of different bacteria cultures. You will also be given sterile applicators. You will be able to choose from applying a known bacteria to your agar plates, or by getting bacteria onto your plates some other way: coughing into the plates, touching the plates, swabbing a location around the classroom and then the plate, etc.

Materials
two sterile Petri dishes coated with agar
sterile applicators
Sharpie marker
kimchi juice
known bacteria cultures
incubator (optional)

Procedure
1. With your partner, choose your method for obtaining bacteria. Will you use a known bacteria culture, or obtain bacteria some other way? Describe in detail how you will get your bacteria.

2. Have your teacher check your answer to #1 before you proceed. Your teacher will demonstrate how to use the sterile applicators to apply the bacteria to the Petri dishes.
3. Obtain your Petri dishes and sterile applicators. Use your marker to write your group members' initials on the bottom of your Petri dishes. Also label "with kimchi" on the bottom of ONE petri dish.
4. Use your sterile applicators to apply your bacteria to your Petri dishes. Be gentle when using the applicators on the agar—don't rip the agar!
5. To the Petri dish that says "with kimchi" on the bottom, add 10 mL of kimchi juice.
6. Cover your Petri dishes with lids. Obtain a sealed plastic bag and write your group members' initials on it. Then place the covered Petri dishes in the sealed plastic bag with most of the air removed.
7. Wait several days for bacteria to grow.

Post-lab questions

1. Describe what you see in the Petri dish that does not have Kimchi juice, and provide a drawing.

2. Describe what you see in the Petri dish that does have Kimchi juice, and provide a drawing.

3. Was the Kimchi juice effective in inhibiting the growth of bacteria? Explain.

Teacher notes on LAB experiment

I developed this little experiment after speaking with a coworker who teaches some microbiology at the high school level and is familiar with agar plate experiments.

The teacher should prepare sterile agar plates by following the procedures outlined in this video: https://www.youtube.com/watch?app=desktop&v=h9ViwEW7Xss "How to Melt and Pour Agar Plates" by Carolina Biological.

The following can be purchased from Ward's Science (www.wardscience.com). Prices as of November 2024.

-Ward's Student Bacterial Culture Kit. Item #470030-200. $42.39.
(It includes 20 sterile mini-Petri dishes, 20 sterile applicator swabs, 2 bottles nutrient agar)

-Ward's High School Bacteria Culture Set. Item #470176-502. $158.95.

Additionally you can buy the following from Carolina (www.carolina). Prices as of November 2024.

-Applicator sticks, sterile, plain tip, box of 200. Item #703034. $35.00

-Nutrient Agar, prepared media bottle, 500 mL, plastic bottle. Item #776366. $28.60.

Bibliography

Kim, S.-h. (n.d.). *Kimchi: Traditional Korean Food.* Ewha Womans University Press.

Koo, S. (2021). *K Food: Secrets of Korean Flavors. Part Three.* Kong & Park.

Patra, J. K., Das, G., Paramithiotis, S., & Shin, H.-S. (2016). Kimchi and Other Widely Consumed Traditional Fermented Foods of Korea: A Review. *Frontiers in Microbiology*, Article 1493.

Read, J. (2024). *Of Cabbages & Kimchi.* Particular Books.

Thomas, K. (2023). What to know about kimchi. *Medical News Today*.

Videos

How To Make Kimchi At Home… Easy Mode. Joshua Weissman. https://www.youtube.com/watch?v=aXhJcdXPyYI accessed on October 2024.

Kimchi: A Story of Love and Patience. Great Big Story. https://www.youtube.com/watch?app=desktop&v=Bou9l7XlDwc accessed on October 2024.

The Science Behind Kimchi: fermentation & cellular respiration. Bite Scized Education. https://www.youtube.com/watch?app=desktop&v=yDQLQA2pm3U accessed on October 2024.

What Makes Kimchi So Delicious. PBS Digital Studios. https://www.youtube.com/watch?app=desktop&v=DG4afs7C1XI accessed on October 2024.