Biology with Cheese and Yogurt (High School- Post Field Trip)[1]

Background:

Cheese

A lactic-acid producing bacterium is added to milk to begin the cheese making process. This allows the milk to separate into curds and whey. The curds are then cut into smaller pieces allowing the liquid portion, whey, to escape. Whey is the watery portion of milk that separates from the curds when cheese is being made. Heat is applied to the curds to speed up the separation of whey. After the whey has been separated, the curds are drained, stretched, salted, and pressed to form a more concentrated cheese.

To give each cheese its own unique properties, it is then cured ("aged") or ripened to complete the process. Cheese that needs to be cured is not ready for consumption after being prepared.

Depending on the desired characteristics, the cheese is held for a certain amount of time, at a specific temperature, and under certain conditions. Most cheeses we consume are ripened, unless they are fresh, such as fresh mozzarella or ricotta. Fresh cheeses can be consumed right after they are made. Ripening is considered the changes that occur between the formation of curd and the development of the desired characteristics such as aroma (smell), flavor, texture, and composition.

There are many factors that contribute to the cheese making process. The composition of milk is considered the most important factor affecting the curd formation. More specifically, milk's fat and protein concentration impact curd formation because curds are primarily coagulated casein (protein). If whole milk is used, fat globules are also entrapped in the curd.

The type of acid used and temperature of milk during coagulation can also impact curd formation. Coagulation is the breakdown and reformation of proteins by heat. The curd formed at this point is soft. For example, rennet is the general term for any enzyme used

[1] Lesson is adapted from FoodMASTER Middle: Cheese (https://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=572) and Mckillip, John & Drake, MaryAnne. (2000). Fermentation Microbiology: Making Cheese, Yogurt, and Buttermilk as a Lab Exercise. The American Biology Teacher. 62. 65-67.

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to make cheese. Rennet can be found in the lining of a calf's stomach. Scientists have been able to duplicate an artificial version of rennet to be used in larger amounts.

The following factors influence the curdling properties of milk:

- *Bacteria:* Bacteria can be added when making cheese or yogurt, but can also develop as milk begins to sour.
- *Acids:* Acids are found in fruits, fruit juices, and some vegetables (e.g. tomatoes). The addition of an acid will result in the precipitation of casein, the most abundant milk protein. Acid produces a soft and spongy texture due to the decreased pH.
- *Tannins:* Tannins are found in coffee and tea. They will curdle milk in the presence of acid and heat because they readily bond with protein. For example, if you add slightly old (soured) milk to coffee, you may see curdles form. The acidity of the soured milk and heat cause the milk's protein to bond with the tannins (and itself) to form curdles.

Yogurt

Unlike cheese that uses the enzyme rennet to aid the gel formation, yogurt is heated to force the whey proteins to unfold and helps coagulation. Heat is also applied to kill off any harmful bacteria through pasteurization. High temperatures help thicken the product further, but heating the milk for 15 seconds at 171 degrees Fahrenheit is all that's necessary to kill any bacteria. Any cream still left in the mixture will naturally separate from the milk. Manufacturers homogenize the milk to disperse the molecules of cream, creating a consistently smooth texture.

Next comes the most important step in making yogurt taste like yogurt. The manufacturer pours good bacteria in, although the amount and specific type varies greatly from one company to another. The bacteria work together to metabolize the milk sugar, or lactose, to form lactic acid, among other chemicals. After fermentation, which can take three or four hours, the mixture will no longer resemble the milk you started with.

Bacteria required for fermentation in yogurt in the United States are called Lactobacillus (that's the genus) bulgaricus (that's the species) and Streptococcus thermophilus. Manufacturers may also add Lactobacillus acidophilus. Lactobacilli are present in our intestines naturally, before we even eat a spoonful of yogurt. Adding them to yogurt helps replenish our supply.

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Lesson Activity Description: Students will learn about microorganisms and fermentation by making yogurt and cheese.

Part 1: Cheese

Materials:

- Safety goggles
- Apron (optional)
- 2% milk
- 2 small clear plastic cups (labeled “curds” and “whey)
- 1 hot plate or double burner
- 1 cup for massing the milk
- 1 small saucepan
- 1 triple beam balance
- 1 whisk or metal spoon
- 1 black permanent marker
- 1 medium bowl
- 1 small strainer (very thin mesh)
- 4 plastic spoons
- 4 Styrofoam cups
- 1 liquid measuring cup
- 1 small cup containing 1 tbsp. of baking soda
- 1 small cup containing ½ cup of vinegar

Procedure:

1. Distribute lab materials. It is recommended that materials are organized into stations for easier distribution. Students should be arranged in small groups of 4-5. Each group should receive the lab supplies outlined in the *Materials* section.
2. Before beginning the lab investigation:
    a. Require students to wash their hands.
    b. Emphasize the importance of practicing good food safety behaviors by not consuming substances used as part of the lab investigation.

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c. For food safety reasons, DO NOT allow students to taste any casein or whey byproducts.

3. Launch the lab by providing a demonstration for your students. The demonstration will show students how to find the mass of the coagulated protein, while revealing that milk will curdle after exposure to high heat.
    a. Using a triple beam balance, mass 1 cup of 2% milk. Remember to mass the empty cup first. Record the mass in a location visible to the class to help demonstrate conservation of mass.
    b. At high heat, quickly heat the milk to a boil in a small saucepan. Use a whisk or metal spoon to stir the milk as it heats to prevent the milk from burning.
    c. Once the milk has begun boiling, continue to let it boil for 5 minutes. Be careful to continue whisking the milk as it heats. If the milk gets too hot and is not stirred, it will boil over.
    d. To determine the quantity of coagulated proteins you will strain and determine the masses of both the coagulated proteins and the liquid remaining.
    e. Place a clean, clear small cup on your scale. A clear cup is preferred so that students can easily see any coagulated proteins. *Determine the mass of the cup.*
    f. Next, place a strainer over a medium bowl and pour the heated skim milk into the strainer. If present, the strainer will catch any coagulated proteins. Using a plastic spoon, scrape the coagulated proteins out of the strainer with a plastic spoon and place them in the clean cup measured in STEP 1.
    g. Place the clear cup containing the milk proteins that you just scraped from the strainer on your balance. You may need to scrape some coagulated protein from your pot too. The coagulated proteins are called curd proteins. Subtract the mass of the cup from the mass of the cup and curds.
    h. The left over fluid in your bowl is called whey protein. Determine the mass of a second clean, clear cup. Pour the liquid whey protein into a clear cup. Subtract the mass of the cup from the mass of the cup and whey.
4. Begin the student portion of the lab investigation by asking students to observe and make a prediction about treatments that may cause milk to curdle . Based on the teacher demonstration completed in the previous step, students should already know that heat would cause milk to curdle.

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5. Have students repeat the experiment again removing the heat and adding vinegar to the milk instead. What do they notice?
    a. *Vinegar:* Students should observe clear curdling. When an acid is added to milk it causes the normal pH (6.5 – 6.7) to fall. A lower pH causes the milk proteins to destabilize. Curd proteins will precipitate and be observable. Whey proteins are not as sensitive to acid as curd proteins and will remain in a colloidal suspension (fluid state).
6. Have students repeat the experiment again removing adding baking soda to the milk instead. What do they notice?
    a. *Baking Soda:* No curdling should be observed. The addition of baking soda will result in an increase in pH. Milk proteins will remain stable.
7. Bring students back together and discuss the cheese making process. What would be the most effective way to separate the curds and whey?

Part 2: Yogurt

Materials:

- 1/2 gallon milk
- Powdered yogurt cultures
- 3 quart or larger Dutch oven or heavy saucepan with a lid
- Spatula
- Instant-read or candy thermometer
- Small measuring cup or small bowl
- Whisk

Procedure:

1. Heat the milk to 180 degrees fahrenheit. When you create an environment for bacteria to multiply, you only want the good bacteria (which you introduce to the milk) to multiply. Heating the milk also creates a thicker yogurt by changing the protein structure.

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2. Cool the milk to 112-115 degrees fahrenheit. Use the same instant read thermometer you used when heating your milk, to know when it's cooled to 112-115 degrees. An ice bath is helpful for cooling the milk down.

3. Add your yogurt starter. Pour out one cup of warm milk and stir in a yogurt starter
4. Stir the yogurt starter with the rest of the milk. This spreads the bacteria throughout all the milk.
5. Pour the milk into jars and incubate for 7-9 hours. After about 8 hours, you'll have thick and creamy yogurt.
6. Place the jars in the fridge to cool and set. Cool the yogurt in the refrigerator for a couple of hours before eating.

Relevant Standards:

- Science
  - HS-LS4-4. Research and communicate information about key features of viruses and bacteria to explain their ability to adapt and reproduce in a wide variety of environments.
  - HS-PS1-6. Design ways to control the extent of a reaction at equilibrium (relative amount of products to reactants) by altering various conditions using Le Chatelier's principle.
  - HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.*
  - HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance, as well as social, cultural, and environmental impacts.

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