ANIMAL SCIENCE (MS)

Milk as a mixture

Focus question	What are the components of milk? How might we discover the different types of substances and make a model to explain them?
Learning target	Students analyze milk as a mixture to identify its components; classify the mixture as a solution, colloid, or other type of mixture; and develop a model to explain how milk's structure relates to its physical and chemical properties.
Vocabulary	Colloid, casein, lactose, mixture, solution, homogenization

MS-PS1 Matter and its Interactions

Performance expectation MS-PS1–2	**Classroom connection:** Students will analyze milk as a mixture by investigating its components (e.g., water, fats, proteins like casein, and sugars like lactose). They will compare various mixtures to determine their properties.
Performance expectation MS-PS1–1	**Classroom connection:** Students will explore the atomic composition of milk components in dairy products and model how homogenization and other processes affect milk as a mixture.

Science and engineering practices

Analyzing and Interpreting Data	**Classroom connection:** Students will investigate milk components through experiments and interpret results to classify components.
Develop a Model	**Classroom connection:** Students will create models of milk's molecular composition, illustrating its status as a mixture, solution, or colloid.

Disciplinary core ideas

PS1.A: Structure and Properties of Matter	**Classroom connection:** Students will understand how milk's composition (proteins, fats, sugars) defines its physical and chemical properties.
PS1.B: Chemical Reactions	**Classroom connection:** Students will investigate changes while making emulsions to differentiate physical changes from chemical reactions.

Cross-cutting concepts

Scale, Proportion, and Quantity	**Classroom connection:** Students draw the structures of the components of milk.
Structure and Function	**Classroom connection:** Students will relate milk's physical composition to its functions in food science.

Background

Milk is a biological product that contains water, fat globules, casein (milk protein that gives milk its white color), lactose (milk sugar), and vitamins/minerals. It is produced from a lactating mammal (an animal that has recently given birth). Most milk consumed by humans is from dairy cows, usually part of a herd cared for by dairy farmers. These cows have given birth to a calf, and are milked for a limited period of time afterwards to collect the milk. The milk is transported to a milk processing plant to be made into various dairy products such as cream, cheese, and milk of varying fat content (skim, 2%, and whole milk), and bottled to be sold in a grocery store for consumption. (Watch **floridamilk.com/on-the-farm/from-the-farm-to-the-fridge.stml** for more details about milk processing). In this lesson, students have the opportunity to examine milk and identify its components and discover how milk is processed before it reaches the consumer.

A glass of milk is an example of a **colloid,** a mixture in which fat globules and proteins are dispersed or suspended throughout a mixture we call milk. A glass of milk is an example of both a colloid and an emulsion. A colloid is a broader term referring to a mixture where tiny particles are dispersed in a continuous medium, while an emulsion is a specific type of colloid where a liquid is dispersed into another liquid, typically, two immiscible liquids like oil and water. The milk fat globules are too small to be seen with the naked eye or even through an optical microscope, but (unlike a solution) are large enough to scatter light and create the Tyndall effect. Colloids are visually homogeneous (uniform throughout), but microscopically heterogeneous (lumpy/grainy—in this case, the globules of milk fat remain separate from the rest of the milk). Generally, colloids cannot easily be filtered nor settle at the bottom of the beaker. (**sciencenotes.org/tyndall-effect-definition-and-examples**)

Homogenization keeps milk fat from separating from the rest of the mixture. Milk is forced through small holes under high pressure to break fat globules into tiny, uniform particles. This changes the milk's texture and prevents the cream from rising. Watch this video: "Milk Movements in the factory Homogenisation and Pasteurisation" (**youtu.be/r0rCEBPgo5Q**) or "The basic steps of milk production" (**youtu.be/7TMtA8Eh9uE**).

Prior knowledge

Students should be able to use a microscope and should know that all matter is made up of atoms and molecules.

Materials

- Glass beakers (200–250 mL)
- Paper or white boards
- Microscopes
- Slides and coverslips
- Disposable pipettes
- Sudan III
- LED flashlight
- Milk
- Heavy cream
- Water
- Food coloring (McCormick green recommended)
- Test tubes or jars with lids
- Sugar
- Salt
- Soy lecithin
- pH strips
- Yogurt culture

Suggested timing

2–3 days

Teacher preparation

Day 1

1. Pour water into one clear glass beaker and milk into another clear glass beaker. Prepare a demonstration space where students can see the demonstration (a document camera may be helpful to project onto a whiteboard).
2. Prepare microscope stations: provide disposable pipettes and slides with coverslips for students to use to observe milk, added water, and stain under the microscope.

Day 2

3. Prepare for emulsions: gather test tube racks to hold capped tubes or small glass jars with lids for groups of students to use when they create their emulsions.
4. Create a station for students to obtain small amounts of salt, sugar, and soy lecithin to add to their emulsions.

Day 3

5. Prepare milk by heating one sample and then refrigerating again, and leaving one at room temperature. If desired, add one teaspoon of yogurt to the room temperature sample.

Procedure

Day 1: Class discussion and diagrams

Pour a beaker of 100–150 mL milk for each lab group. Discuss milk as a mixture and ask students to draw a diagram to include the different components of milk (water, fat globules, sugar, and protein).

1. Introduce particle diagrams: Explain that milk is composed of different types of substances. The diagram they are making should include the particles contained in milk. Create a diagram to show the components and structure of milk.
   - On paper or whiteboards, have students draw diagrams of milk components.
   - Tell them to include labels for each of the components.
   - Have them guess the relative amounts of each substance within milk. (This could be shown as a pie chart.)
2. Demonstrate that milk is a colloid as it shows the Tyndall effect. Shine a flashlight through a beaker of water, then a beaker of milk. Have students try to explain what is happening.
   - Explain the concept of a mixture: where different components coexist without chemical bonding.
3. Show the components of milk using the accompanying deck.
   - Have students record their observations, noting that components may not be visible. How might we make these components visible?
   - After showing the deck, ask students to revise their drawings.
4. Have students examine milk under a microscope to observe the dispersed fat globules, or show them digital microscope images. Discuss the natural tendency of fat molecules to clump together without external processing (homogenization). The milk you use will be homogenized, so fat globules will look uniform. Use Sudan III to show the fat globules more readily.

Day 2: Creating emulsions

Emulsions are mixtures where tiny droplets of one liquid are dispersed in another liquid without dissolving. In milk, fat droplets are suspended in water. Use milk as a control to show that homogenization is used to keep the fat from clumping together.

1. Have students add food coloring to water, then add the colored water to cream. Before shaking, have students observe the mixture. They should see distinct layers, as fat (cream) doesn't naturally mix with water.
2. Have students shake the jar vigorously for 30 seconds, creating an emulsion where the fat globules disperse throughout the water. (Be sure the lids are capped tightly.)
3. Ask students to observe the mixture again. They should see that after shaking, the mixture appears more uniform. This is a temporary emulsion, which will eventually separate.
4. Once students have finished shaking, have them record the time and check the mixture every 5–10 minutes. Record their observations.
5. Ask students to repeat steps 1–4 again and this time add a pinch of "stabilizer." Students may choose from salt, sugar, or soy lecithin.
6. Ask students to hypothesize whether the "stabilizer" will help the emulsion stay mixed for a longer period.
7. After shaking, students observe and time how long it takes for separation to begin.
8. Show students how to make a table to record their observations.

Day 3: Discussion of emulsions and pasteurization

1. Have students discuss their observations. They may notice that emulsions with added salt or sugar took slightly longer to separate, suggesting that these additives help stabilize emulsions by increasing the water's surface tension. Soy lecithin is used in many foods as an emulsifier.
2. Explain that milk also contains natural emulsifiers like casein that help stabilize the mixture by reducing surface tension and preventing fat molecules from clumping together.
3. Provide two samples of milk: one that's been heated and cooled (representing pasteurization) and one left at room temperature (with added yogurt).
4. Have students measure the pH using pH strips or Universal Indicator to see the difference, demonstrating that bacteria activity can spoil milk.
5. Discuss how heating the milk kills potential microbial activity.

Student handout

Day 1 reflection

1. What particles did you include in your drawing?

Potential answers: Answers will vary

2. Explain the Tyndall effect.

Potential answers: The different components in milk scatter light as it enters the milk.

3. Draw what you saw under the microscope.

Potential answers: Drawings will vary in quality.

Day 2 reflection

1. How did shaking affect the mixture?

Potential answers: The mixture has bubbles on the top and there are no visible layers between the cream and the water.

2. Did salt, sugar, or soy lecithin make a difference in stability?

Potential answers: Soy lecithin made the largest difference in adding stability; salt and sugar had little effect on the stability.

Day 3 reflection

1. What might account for the difference in pH?

Potential answers: Bacteria or other microorganisms may create changes in pH.

2. Why are emulsions important in foods like milk?

Potential answers: They keep the mixture from separating. Stabilizers also extend shelf life.

3. How do additives help stabilize emulsions in processed foods? (Think about chocolate or salad dressings.)

Potential answers: They keep the mixture from separating. Stabilizers also extend shelf life.

4. How does this experiment relate to milk homogenization?

Potential answers: Shaking the mixture allowed the cream and water to mix. However, fat likes to clump together and is less dense than water. Making the fat globules all the same size can keep the milk mixed longer.

5. What is the purpose of pasteurization?

Potential answers: To keep bacteria or other microorganisms from growing and spoiling milk.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** If there are nearby farms or farmers' markets that carry the commodities that you plan to use for the lesson, reach out to see if a farmer would be willing to come to your class to speak on the topic of all the uses for their commodity and how they cultivate the product. If there are no farms in your local area, reach out to your local extension office to see if an agent or a farmer would virtually visit your classroom.
- **Students with special needs (language/reading/auditory/visual):** Students with special needs can be placed in lab groups to work collaboratively with other students. If they struggle with reading, the group will work together. A stronger reader will be made the director of the group to read the lab sheet aloud to the rest of the group. After this, the group will discuss how to proceed or what answers they will then put down on the paper. ESL students may need to utilize their translation devices with the group in order to fully communicate with their peers.
- **Extra support:**
  - Dairy Process modules: **dairyprocessinghandbook.tetrapak.com/chapter/chemistry-milk**
  - Florida Dairy Farmers website: **floridamilk.com/in-the-schools/dairy-curriculum/science-on-the-farm.stml**
- **Extensions:**
  - Model-making: Ask students to create a physical model of milk using materials provided:
    - Tapioca beads or water beads (fats)
    - Legos (proteins)
    - Small pieces of fuzzy sticks (sugar)
  - Research assignment: Have students research other types of emulsions in food (e.g., mayonnaise) and present how they are stabilized chemically.
  - Experiment: Test pH levels of different dairy products like yogurt or sour cream to explore how acidity affects stability and bacterial growth

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Analyze and interpret data	Identifies some components of milk but struggles to classify them or interpret results of separation processes.	Accurately separates milk components and classifies them as solutions, colloids, or other mixtures based on observed data.	Analyzes milk components with precision, explains their properties, and provides detailed interpretations of the separation process.
Develop a model	Creates a basic or incomplete model of milk's composition, lacking clear connections to its mixture types.	Develops a clear and accurate model of milk's molecular composition, illustrating its classification as a mixture.	Designs a comprehensive model that explains milk's molecular structure and its physical/chemical properties in the context of its composition.
Understand structure and properties	Describes basic components of milk but does not relate their structure to function or processing behaviors.	Explains how milk's components (e.g., casein, lactose) define its physical and chemical properties.	Provides an in-depth explanation of how the structure of milk's components is impacted during processes like homogenization.
Relate scale, proportion, and quantity	Recognizes some relationships but struggles to connect the molecular scale to observable properties of milk.	Relates molecular structures and interactions of milk components to their macroscopic behaviors.	Demonstrates advanced understanding of how molecular interactions affect milk's properties at different scales.

Rubric for self-assessment

Skill	Yes	No	Unsure
I can identify and classify the components of milk, such as water, fats, proteins, and sugars.			
I can analyze and interpret data from experiments that separate milk components.			
I can develop a clear model to show milk's molecular composition as a mixture, solution, or colloid.			
I can explain the difference between physical changes (e.g., homogenization) and biological changes (microbial growth) in milk.			
I can draw connections between the molecular scale of milk's components and their observable properties.			
I can use evidence from my experiments to explain how milk behaves during processing, like homogenization or separation.			
I can connect the scientific concepts I've learned about milk to real-world applications in dairy science and industry.			