ANIMAL SCIENCE (HS)

Macromolecules in dairy

Focus question	What macromolecules are found in milk? How do these macromolecules differ between various types of milk products? How does milk rate as a complete nutritional food?
Learning target	Students will compare the relative amounts of protein, lipids, sugar, and starch in different samples of milk (whole milk, skim milk, 2% milk, heavy cream, and half and half).
Vocabulary	Monomer, monosaccharide, disaccharide, polysaccharide, starch, amino acids, protein, lipid

HS-LS1-6 From Molecules to Organisms: Structures and Processes

Performance expectation HS-LS1-6	**Classroom connection:** Students are able to explain that the unique structure of carbon atoms allow for unique chemical structures and that the number and arrangement of the atoms in a molecule determine the functions of that molecule when interacting with the indicator.

Science and engineering practices

Constructing Explanations and Designing Solutions	**Classroom connection:** Students are able to explain how the chemical test results of the macromolecules connect to the structure and function of the macromolecules. Students compare the relative amounts of each nutrient to create an explanation of the nutrients contained within each product.

Disciplinary core ideas

LS1.C: Organization for Matter and Energy Flow in Organisms	**Classroom connection:** Students will test for each of three nutrient macromolecules, using various indicators that will react to the specific reagents.

Cross-cutting concepts

Energy and Matter	**Classroom connection:** Students can describe how the molecules in the foods we eat are used differently in the body, depending on the chemical composition of each molecule.

Background

Nutrients occur in varying amounts within all the foods we eat. Dairy products such as milk, yogurt, and cheese all contain lipids, carbohydrates, and proteins. However, different forms of dairy products will contain these nutrients in varying amounts. The varied amounts of nutrients in different dairy products determine how the food fits into a balanced, nutritious diet.

The basic components of the three major classes of macromolecules that we need for food all include the elements carbon, hydrogen and oxygen. These macromolecules are composed of different **monomers,** or building blocks. The differences come from the presence of additional elements, the number of atoms of each present in the molecule, and the arrangement of these atoms. Carbon, hydrogen and oxygen, when arranged in rings, form sugars, or monosaccharides such as glucose. These monosaccharides (monomers of carbohydrates) can be combined to form larger molecules such as disaccharides or even polysaccharides (such as starches). When the same elements are arranged in chains, they form lipids (both saturated and unsaturated fats). Lipids generally do not like water (hydrophobic) and do not dissolve in water. Adding nitrogen to the molecule results in the formation of amino acids, which form complex structures known as proteins.

The indicator solutions used in this lesson react specifically to the chemistry of each molecule.

- Benedict's solution is made of sodium citrate, sodium carbonate, and the pentahydrate of copper(II) sulfate. Simple carbohydrates, such as **monosaccharides** (and a few disaccharides) have free ketones or aldehyde functional groups. Once the indicator and sugar substance are mixed and heat is added, the copper sulfate is reduced to copper oxide and forms a precipitate that ranges from green to brick red.
- Lugol's solution (iodine) selectively binds with glucans found in **polysaccharides,** creating a purple black to black color.
- Biuret solution contains copper ions in an alkaline solution that will form a complex with the peptide bonds in **proteins,** resulting in a change in color from blue to violet. This procedure works well with protein test strips, which are a bit more reliable.
- Sudan III solution is a non-polar, red, fat-soluble dye that stains **lipids,** triglycerides and lipoproteins.

Prior knowledge

In order to successfully complete this activity, students should know or have completed a unit describing the four major classes of macromolecules and should understand the importance of macromolecules in a balanced diet for animals and people.

Suggested timing

2, 50 minute class periods

Materials

- Whole milk
- Skim milk
- 2% milk
- Heavy cream
- Half and half
- Distilled water
- Graduated cylinders/serological (or disposable) pipettes
- Funnel
- 4 test tubes
- Test tube holder
- Hot plate
- Cell well plate
- Large beaker with water for water bath
- Lugol's solution (iodine)
- Benedict's solution (or glucose test strips)
- Protein test strips (or Biuret solution)
- Sudan III solution

Teacher preparation

Set up materials for each lab group to access.

Students should work together in groups of 2–4 to complete the nutrient analysis tests.

*In order to have a positive test for glucose, the disaccharide lactose needs to be broken down into monosaccharides. You can add fast-acting Lactaid to the samples with students or before the lab and explain the process to them. There is an extension lab about enzyme activity and lactose that you can conduct with students.

Note: A Bradford Assay using Coomassie dye may be used to determine the change in protein content, a more sensitive test that can be used with the solution alone, or as an assay using a spectrophotometer to compare to a standard curve.

Procedure

Ask students to create a data table to compare the macromolecules found in each milk sample. Instruct students to follow the protocols for each test found on the student handout. From the data collected, ask students to create an infographic comparing the relative amounts of sugar, carbohydrate, protein and lipids found in various milk products

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students can use the Interstate Milk Shippers information (IMS), found on milk and most dairy products, to discover where the milk samples came from. This is a great opportunity to learn about dairy farms, many of which are local.
  Where did my milk come from? **whereismymilkfrom.com**
- **Students with special needs (language/reading/auditory/visual):** Review macromolecule structure and functions with students before the lesson. Use slides to provide visual instructions for students.
- **Extra support:** Amoeba sisters video: Macromolecules: **youtu.be/1Dx7LDwINLU**
- **Extensions:**
  - Test additional dairy products—cheese, sour cream and cottage cheese—to see how they compare to products tested, or milk alternatives (i.e.almond, oat, or soy beverages).
  - Describe a sandwich or meal that incorporates all three of the macromolecules.
  - Connect the elements found in macromolecules to other agricultural concepts. For example, proteins are made up of carbon, hydrogen, oxygen and nitrogen. In plants, chlorophyll is a plant pigment, which is a protein. The nitrogen in fertilizers helps with photosynthesis and green leaf color because plants need nitrogen to make chlorophyll. Also, legumes are high in protein and able to “fix” or convert nitrogen into forms usable by plants.

Student handout

Reflection

1. Which dairy product contained the most protein?

Potential answers: Generally, milk will contain more protein than half and half or heavy cream.

2. Which dairy product contained the most lipids (or fats)?

Potential answers: Higher fat content milk (whole) will contain more lipids than 2% or skim. Heavy cream and half and half should show more reaction than milk.

3. Did any of the samples contain glucose? Which ones?

Potential answers: Milk contains lactose, which is a disaccharide, so there should be little reaction to Benedict's unless Lactaid is used to break down lactose into glucose.

4. Did any of the samples contain starches? Which ones?

Potential answers: No samples should show starch.

5. Create an infographic about the classes of nutrient macromolecules and examples of which ones are found in dairy products and in what amounts.

Potential answers: These infographics will vary depending on the software used to show them.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Develop an “infographic” or graph to show the differences between relative amounts of sugar, starch, lipid, and protein content in dairy products.	Student has collected data about relative amounts of sugar, starch, lipid, and protein content.	Student has collected data about relative amounts of sugar, starch, lipid, and protein content; and has compared relative amounts in a visual way.	Student has collected data about relative amounts of sugar, starch, lipid, and protein content; has compared relative amounts in a visual way; and displayed in a creative graphic visual.

Rubric for self-assessment

Skill	Yes	No	Unsure
I generated data to compare nutrient content differences between various dairy products.			
I constructed an infographic to show the differences in macromolecule content between dairy products.			
I can explain how milk or other dairy products can be part of a nutritious diet.			