ANIMAL SCIENCE (HS)

Enzyme action in ruminants

Focus question	How does the pH and temperature of an environment affect enzyme activity?
Learning target	Students will be able to explain how the pH of an environment affects enzyme activity.
Vocabulary	Ruminants, enzymes, fermentation, starch, polysaccharide, monosaccharide

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

Performance expectation HS-LS1-6	**Classroom connection:** Students are able to explain that the structure of carbon atoms allow for unique chemical structures through the interaction of enzymes on carbohydrates and that the arrangement of the atoms in a molecule determine the functions of that molecule.

Science and engineering practices

Constructing Explanations and Designing Solutions	**Classroom connection:** Students demonstrate how amylase is able to break down complex carbohydrates into simpler sugars under certain conditions.

Disciplinary core ideas

LS1.C: Organization for Matter and Energy Flow in Organisms	**Classroom connection:** When enzymes catalyze a chemical reaction, the substrate is chemically transformed into a new product or products. When enzymes react with biological macromolecules, they are speeding up the breakdown and assembly of these carbon-based molecules.

Cross-cutting concepts

Energy and Matter	**Classroom connection:** Students see how enzymes rearrange molecules to affect their function within a digestive system.

Background

Dairy cattle belong to a class of mammals known as ruminants. One distinctive characteristic of ruminants is their multi-chambered stomach that helps break down the insoluble complex carbohydrates found in hay, grass and cattle feed. As the complex carbohydrates make their way through the cow's digestive tract, they are broken down through the process of fermentation. The cow can then absorb them, turning the feed into energy for daily activities and milk production.

Enzymes are a type of protein that catalyze, or speed up, chemical reactions. Digestion enzymes help break down large molecules (polymers) into smaller molecules (monomers). Enzymes are highly specialized molecules. In general, each enzyme can only perform one specific reaction, due to their specific shape. Enzymes work best within specific temperature and pH ranges. When an enzyme is in an environment outside of its optimum range, its shape changes and it becomes denatured. This means that it will no longer work as well.

Amylase speeds up the breakdown of starches into disaccharides and simpler sugars. Since amylase is not found in the saliva of ruminants, it can be added as a supplement to feed to help facilitate the breakdown of starches for the primary source of energy for cells.This lesson uses iodine as a control test to show when the enzyme is ineffective.

Prior knowledge

- Students should be able to describe enzymes and be able to identify the primary characteristics of enzymes.
- Students should be familiar with how to measure pH.

Suggested timing

Two 45-minute class periods

Materials

- 3 disposable pipettes
- Iodine solution in a dropper bottle (or with another pipette)
- Test tube rack
- 3 test tubes (labeled as pH 4, pH 7, pH 10)
- Well plate
- Stopwatch (or phone)
- Sharpie
- For the class (set up ahead of the lab):
  - Amylase solution
  - Starch solution (corn potato or bean)
  - pH buffer solutions (4, 7, 10)

Teacher preparation

1. Make the buffer solutions ahead of time for students or have students prepare the solutions and test the pH of each.
2. Prepare the starch solution by mixing 5 grams of cornstarch, potato starch, or bean starch with 500 mL of cold water. Boil the solution until it is clear.
3. Prepare the amylase solution: 12 grams/100 mL water.
4. Copy the student handout.

Student handout

Reflection

1. What is the name of the enzyme in this lab?

Amylase

2. What is the optimum pH for amylase, based on your lab results?

pH 7

3. Based on your results, at what pH is amylase denatured?

Amylase should be denatured at a pH of 10. The student should be able to observe that the starch does not break down, turning the iodine blackish–purple.

4. Why is it important to add the buffer to the enzyme before adding the starch?

Possible answer: the enzyme will begin acting on the starch if it is not exposed to the differing pH level before being added to the starch.

5. How might adding amylase as a supplement for cows increase the efficiency of a starch-based feed?

Possible answer: It will begin to break down the starch so that it is easier to digest by the ruminant.

Procedure

Ask students to follow the procedure on their handout.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students can research other enzymes that are valuable in the dairy industry (for example chymosin/ rennet for cheesemaking).
- **Students with special needs (language/reading/auditory/visual):**
  - Create slides with instructions for students to make directions easier to follow.
  - Have students sketch the enzyme-subtraction complex before conducting the lab.
- **Extra support:** Video tutorials about enzymes (i.e., Amoeba Sisters: `youtu.be/qgVFkRn8f10` or this enzyme tutorial: `youtu.be/6FPN-pP_PAs`).
- **Extensions:**
  - Students can also use Benedict's on the starch samples before and after they are added to the amylase/buffer solutions. Since the starch should be broken down from a polysaccharide to simpler sugars, Benedict's test may show a positive result where the enzyme is active.
  - Research additional enzymes that aid in digestion.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Construct an explanation based on evidence for the changes observed.	Student observed the point at which the enzyme was ineffective, but was unable to explain why.	Student observed the point at which the enzyme was ineffective and explained why using data.	Student observed the point at which the enzyme was ineffective and explained why, using data; students can explain what change in the enzyme occurred.

Rubric for self-assessment

Skill	Yes	No	Unsure
I can tell that a chemical change took place through the action of the enzyme.			
I can explain how the iodine shows that a chemical change did not take place.			
I can determine when an enzyme is ineffective or denatured.			