Biomass to sugars

Focus questions	Which feedstock will provide the most simple sugars for yeast consumption?
Learning target	Students will analyze the capacity of various carbohydrates to provide simple sugars for fermentation.
Vocabulary	Polysaccharide, disaccharide, monosaccharide

HS-LS1C: Organization for Matter and Energy Flow in Organisms

Performance expectation HS-LS1-6	**Classroom connection:** Students investigate the glucose content of both sweet and dent corn over a 3-day period.

Science and engineering practices

Constructing Explanations and Designing Solutions	**Classroom connection:** Students will construct and revise an explanation to determine which feedstock will provide the most glucose for fermentation over time and design a solution for the most logical feedstock in the United States.

Disciplinary core ideas

HS-LS1.C: Organization of Matter and energy Flow in Organisms	**Classroom connection:** Students investigate how Carbon, Hydrogen, and Oxygen in starch are broken down to create smaller glucose molecules.

Cross-cutting concepts

Energy & Matter	**Classroom connection:** Students observe and research the availability of energy in feedstocks that are used in ethanol production.

This lesson is designed to follow Lesson 1, Fermentation Factories, and Lesson 2, Ticketase, where students utilize different components (enzymes, yeast, feedstocks, and water) to produce ethanol and carbon dioxide through the process of fermentation and model enzyme action on starch to produce simple sugars. This lesson focuses on Constructing Explanations and Designing Solutions to explain the current feedstock choice for commercial ethanol production in the United States. Students will generate data in order to construct explanations for the current feedstock choice and explain the glucose availability from each feedstock.

Students will investigate the glucose content in both sweet and dent corn over a 3-day period. During this process they will compare data and analyze the treatment methods employed to extract glucose from the feedstocks. Students will then construct and revise their explanations as they determine which feedstock will provide the most glucose for fermentation over time. Students will continue to research ethanol production and propose future solutions to improve the efficiency of ethanol production.

Background

Commercial production of fuel ethanol in the United States involves breaking down the polysaccharides (starch) present in dent corn into monosaccharides (glucose), feeding these sugars to yeast (fermentation), and then recovering the main product (ethanol) and coproducts (animal feed and carbon dioxide). Ethanol is an alcohol produced through the process of alcoholic fermentation of sugars by yeast.

$$\underset{\text{glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{2 ethanol}}{2CH_3CH_2OH} + \underset{\text{2 carbon dioxide}}{2CO_2}$$

The complex carbohydrates (starch) found in corn must be broken down into monosaccharides for fermentation to be successful. Heating the feedstock can help to break apart carbohydrate bonds but is not 100% successful. Enzymes are used to efficiently cut carbohydrates into simple sugars. For example, amylase breaks down complex carbohydrates into disaccharide molecules: maltose, and glucoamylase breaks down maltose into a monosaccharide molecule: glucose. Glucose is the simple sugar used during fermentation for industrial ethanol production.

Materials

- Glucose, ground up (3.0 g per station)
- Sweet corn, fresh or frozen, ground up (3.0 g per station)
- Cracked kernel corn or corn flour, ground up (3.0 g per station)
- Test tube holder/hot pads
- 500 ml beakers
- Amylase enzyme solution (1 tsp amylase / 100 ml water)
- Glucoamylase enzyme solution (1 tsp glucoamylase / 100 ml water)
- Mortar and pestle
- Hot plates
- Safety goggles
- Hot gloves
- Stirring rods
- Water
- 15 ml centrifuge tubes (10 per group)
- Test tube racks
- Glucose test strips
- Optional: Glucose monitor and test strips
- Scale and weigh boats
- .5 ml disposable pipettes
- Marker/tape
- Scale
- Optional: stopwatch, ice bath, pipette pump with 10 ml serological pipettes

Prior knowledge

Students should be able to use a dip strip to match colors to a standard. Students must be able to use glucose monitors to test glucose content.

Teacher preparation

1. Gather materials for students to use.
2. Prepare amylase and glucoamylase solutions.
3. Students should work together in groups of 4 for the investigation.
4. Students set up the investigation and test for three days.
5. Students must analyze their results to determine which conditions led to the most glucose production based on measurements using glucose test strips or glucose monitors.

Student handout

Reflection

Reflect on the following questions while creating your explanation for which feedstock will provide the most glucose for fermentation over time and design a solution to use the most logical feedstock(s) in the United States.

1. Where does the glucose come from in sweet corn or dent corn?

Possible answers: Starch (polysaccharide) and maltose (disaccharide) are cut into glucose molecules by the enzymes amylase and glucoamylase.

2. How much glucose is present in each feedstock for ethanol production?

Possible answers: The students' numbers will vary based upon lab technique and measuring ability. Starch should contain the most glucose over time.

3. Which type(s) of pretreatment were most effective at liberating glucose? How does each pretreatment manipulate the feedstock?

Possible answers: Heat treatment and enzyme treatment combined. Heat treatment helps to break some bonds, but the enzymes lower the activation energy required to break bonds to allow the starch molecules to be broken down into smaller molecules.

4. What additional pretreatments for dent corn can be employed to improve the efficiency of ethanol production?

Possible answers: The students will need to research ethanol production for more advanced techniques. Building on information from this lesson storyline, students should make suggestions such as heat treatment, grinding, temperature control, aeration, enzyme addition, etc.

5. What other feedstocks can be used in ethanol production?

Possible answers: Students should conduct research to determine what other feedstocks are available for ethanol production, such as tulip trees, switchgrass, corn stover, algae, etc.

6. What possible alternative feedstock options are available that can help to make ethanol production more efficient and sustainable in the future?

Possible answers: The students will need to research ethanol production for more advanced techniques. Answers should include feedstock varieties, farming methods used, enzyme additions specific to feedstock varieties, technologies used to distill ethanol, co-product distribution, etc.

7. Construct and revise an explanation to determine which feedstock will provide the most glucose for fermentation over time and design a solution to use the most logical feedstock(s) in the United States.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may investigate the production and availability of feedstocks in their community. Students can communicate with their findings with their classmates and their local community.
- **Students with special needs (auditory/visual/language/reading):** See the extra support below.
- **Extra Support:** Video: How ethanol is made (youtu.be/59R-NqykoXs). This video helps demonstrate relationships between the components of the ethanol fermentation ecosystem.
  Infographic: vitalbypoet.com/infographics/ethanol-process-2
  This infographic represents the process of corn flour breakdown into glucose for fermentation.
- **Extensions:** Students might investigate the presence of contaminants in the tubes. Students may research the current use of feedstocks in commercial ethanol production. Students may also research additional future feedstocks for ethanol, such as cellulosic switchgrass, and the enzymes that would be necessary for carbohydrate breakdown.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Constructing explanations and designing solutions	The student is able to use the data generated to create an explanation for the current feedstock used in commercial ethanol production.	The student is able to use the data generated to create an explanation for the current feedstock used in commercial ethanol production and analyze the data to create explanations of glucose availability in each of the feedstocks to determine the validity of their findings.	The student is able to use the data generated to create an explanation for the current feedstock used in commercial ethanol production; analyze the data to create explanations of glucose availability in each of the feedstocks to determine the validity of their findings; and design future solutions for viable feedstock choices for commercial ethanol production.

Rubric for self-assessment

Skill	Yes	No	Unsure
I can explain the difference in glucose content between sweet corn and dent corn for ethanol production.			
I can use reasoning to connect the evidence of glucose availability in starch and construct an explanation to demonstrate why dent corn is used in commercial ethanol production.			
I designed possible future solutions to feedstock choice options in commercial ethanol production.			