Macromolecules and fuel

Focus question	How do the processes of fermentation and distillation alter the macromolecule content of the feedstock and fermentation products?
Learning target	Students will be able to explain the effect of fermentation and distillation on the nutrient content of corn.
Vocabulary	Glucose, ethanol, coproducts, dried distillers grains

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

Performance expectation HS-LS1-6	**Classroom connection:** Students will be able to explain the effect of fermentation and distillation on the macromolecule content of corn.

Science and engineering practices

Constructing Explanations and Designing Solutions	**Classroom connection:** Students will construct an explanation for the current use of dent corn in commercial ethanol production and design solutions for the coproducts that are generated from ethanol production.

Disciplinary core ideas

HS-LS1.C: Organization of Matter and energy Flow in Organisms	**Classroom connection:** Students research the macromolecules available in dent corn throughout the process of ethanol production. Students suggest ways the coproducts of ethanol can be used.

Cross-cutting concepts

Energy & Matter	**Classroom connection:** Students will determine how the energy producing molecules change through the process of fermentation and distillation.

Background

Commercial production of fuel ethanol in the United States involves breaking down the starch present in corn into simple sugars **(glucose),** feeding these sugars to yeast **(fermentation),** and then recovering the main product **(ethanol)** and **coproducts** (distillers grains, corn oil, and carbon dioxide). All the remaining nutrients: protein, fat, minerals, and vitamins, are concentrated into **distillers dried grain** (DDGs), a valuable feed for livestock, and carbon dioxide. In this simple experiment, students will determine the nutrient analysis of dent corn before, during, and after ethanol production.

Materials

Provide the following materials to each student group.

- Hot plate
- Funnel
- Filter paper
- Parafilm or vortex for mixing
- Graduated cylinder (10 mL)
- Benedict's solution
- Lugol's iodine solution
- Biuret solution
- Distilled water
- Test tubes and rack
- Cracked corn (ground up)
- Scale or triple beam balance
- Pipette pump
- 10 mL pipettes
- Mortar and pestle
- Test tube holder/hot pads

Teacher preparation

Students should work together in groups of 2–4 to complete the nutrient analysis tests. The tests should be conducted at the beginning on raw product day 1, day 3 after fermentation, and again after the distillation process.

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 in place of the Biuret, or as an assay using a spectrophotometer to compare to a standard curve.

Student handout

Reflection

Reflect on the following questions to create an explanation below:

1. How does the nutrient profile of dent corn change as it undergoes the process of fermentation and distillation?
   a. Is all of the glucose consumed? Provide evidence to support your conclusion.

Possible answers: The majority of sugars are consumed in an efficient commercial ethanol production process. We can tell because the Benedict's test results change showing that less glucose is in later products.

   b. How do the yeast contribute to the nutrient profile of the distillers grains after fermentation?

Possible answers: Yeast consume the sugars to leave a nutrient profile low in carbohydrates, high in protein, and similar in lipid.

   c. How can the yeast contribute to the digestion of the animals consuming the distillers grains?

Possible answers: The yeast left behind in the distillers grains are probiotic and help the animal to more easily digest their diet for a more efficient conversion into energy for the animal's use.

   d. Why are distillers grains considered to be a valuable feed for animals?

Possible answers: Dried distillers grains are easily transportable, store for a long period of time for later use, are economical compared to other feedstocks of similar protein concentration, and are probiotic in nature.

2. Provide a diagram or pie chart showing the percent change of corn composition before/after fermentation.

Possible answer: Students' answers will vary but should incorporate a graphic that provides evidence for the nutrient content change.

3. What are the current industry uses for the coproducts produced in the commercial ethanol production process?

Possible answers: Students' answers will vary. Coproducts listed should include carbon dioxide, corn oil and distillers grains.

4. Create an explanation for the current use of dent corn in commercial ethanol production and why the coproducts generated from ethanol production are used as they are. Suggest additional solutions for the use of these coproducts.

Possible answers: Students' answers will vary.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may investigate the use of corn in pet/animal feed in their local area. Students may choose to interview a farmer, local farmer cooperative, or animal supply store. 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 may research the current use of coproducts in commercial ethanol production. Students may also research additional future uses for ethanol coproducts to make ethanol production more efficient and sustainable. Students may test pet foods to determine the nutrient profile and whether corn is used in those foods.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Construct an explanation for nutrient change of corn as it undergoes the ethanol production process.	Student is able to use the data generated to describe the change in nutrients in corn, but does not explain why the nutrient content changes.	Student is able to use the data generated to describe the change in nutrients in corn as it undergoes the ethanol production process and analyze the reason for the change in to determine the validity of their findings.	Student is able to use the data generated to describe the change in nutrients in corn as it undergoes the ethanol production process, analyze the reason for the change in to determine the validity of their findings and suggest future uses for coproduct usage from commercial ethanol production.

Rubric for self-assessment

Skill	Yes	No	Unsure
I generated data to construct an explanation of nutrient content change for corn as it is transformed into ethanol.			
I constructed a viable explanation for the industrial application of the remaining coproducts produced in the commercial ethanol production and suggested at least one new use.			