Lesson 5: Ethanol: Corn Mash and Distillation

Essential Question: *How is ethanol produced? What are the steps in ethanol production?*

Investigation

How can we modify dent corn to make glucose available for **fermentation**? What role does **anaerobic respiration** play as yeast consume glucose to create ethanol and carbon dioxide? What change does glucose undergo to become ethanol and carbon dioxide? Students will create a corn mash and break down starch into glucose that will undergo the fermentation process into ethanol. Students will then separate the **distillers grains** from the **filtrate** for distillation and distill ethanol from the filtrate. Students will then construct and revise their explanations as they determine how anaerobic respiration plays a role in the fermentation process that is necessary for ethanol production. Students will continue to research ethanol production and propose future solutions to improve the efficiency of ethanol production.

Instructions

Day 1: Preparation of corn mash

1. Weigh out 100 g of hammered dent corn and add to a 1000 mL beaker.

2. Add 300 mL of distilled water. Record observations in Data section. Stir well. Place the beaker on a hot plate and set the temperature to high to get it to boil, boil gently and stir constantly for 15 minutes. **Be careful not to let it burn.** (If the mixture becomes too dry, more water may be added).

3. After boiling is completed, remove the beaker from the hot plate and allow it to cool to touch (49–55° C). Record observations on consistency, color and smell in Data section.
    a. Measure 100 mL of distilled water and pour into a 250 mL beaker.
    b. Shake the amylase solution well.
    c. Measure 10 mL of the amylase solution into a small graduated cylinder and add to the 250 mL beaker of water and stir.
    d. Add the mixture to the corn mash and stir to evenly incorporate.
    e. Stir the mixture occasionally with a glass rod during the next 10 minutes.

4. At the end of the 10-minute period:
    a. Shake the buffer and glucoamylase solutions well
    b. In a 100 mL beaker, mix 35 mL of the buffer solution (to maintain a slightly acidic pH), 10 mL of glucoamylase solution, and 10 mL of the yeast solution together.
    c. Pour the mixture into the corn mash. Stir the entire mixture well.

5. Place a piece of plastic wrap over the mouth of beaker and label (fermentation will occur so do not secure it too tightly).

6. Place your beaker in an incubator on the counter and allow it to sit for 3 days so that the enzymes have time to work. Stir the corn mash each day to maximize fermentation.
Optional: Place corn mash in an incubator set at 37ºC/*98.6°F (optimal temperature for yeast metabolism).*

Day 3: Distillation of ethanol from corn mash

1. Set up the distillation apparatus as demonstrated by your instructor. (Before you use your distillation apparatus, have your lab instructor inspect it).
    a. Make sure to either grease or wet the ground glass joints before connecting them. This helps to prevent any vapor from escaping the joints and to keep the joints from freezing together.
    b. Filter out your distillers grains by using cheesecloth or coffee filters. Be sure to press on the mash to filter out all of the liquid. Pour about 50–75 mL of your solution in the distilling flask so that it is a little more than half full.
        - *If you are using a large distillation flask (1000 mL), put the entire classes' solution into the flask.*

- *If necessary, add enough distilled water to the flask to reach the halfway point of the flask to ensure even heating of distillate.*

c. You will use a heating mantle to provide the heat necessary for the distillation. * *Do not use a bunsen burner!* The inside of the mantle will eventually become extremely hot. In order to control the heat, you can raise or lower the temperature of the heating mantle. Make sure the distillation flask and condenser tube are properly supported! The outside of the mantle is relatively cool to touch.

2. The best separation of alcohol will occur if the distillation is done slowly. Ethanol's boiling point is 173.1°F/78.37°C and water's is 212°F/100°C, please keep the temperature between these two boiling points. Collect the ethanol distillate samples into a small beaker to be used for the alcohol flame test (we recommend that you collect them in 4 dram vials). Pour the distillate samples into a capped vial for storage until ready to do the flame test.

3. When you are no longer able to distill your product, turn the heating mantle off and allow the distillation apparatus to cool before disconnecting and cleaning.

Data

Day 1	**Consistency**	**Color**	**Smell**
Before boiling (step 2)			
After boiling (step 3)			
After enzyme addition (step 4)			
Day 3			
Before distillation (step 1)			
First distillate sample (step 3)			
Second distillate sample (step 4)			

Flame Test	**Time**	**Flame Properties**
Sample 1		
Sample 2		

Alcohol flame test

1. *This test should only be done in a fume hood after the ethanol distillation is complete and there is no vapor in the air.* You will be testing the ethanol distillate for alcohol concentration by lighting it on fire. The longer the flame burns, the greater the alcohol concentration. If the distillate does not burn, the water concentration is too high (over 50%).

2. Place a watch glass in the fume hood and pour 2 mL of your ethanol distillate on it.

3. Turn the fume hood on and lower the window, light your distillate, record the time the flame burns and observe.

4. Measure the amount of remaining water on the watch glass and calculate the alcohol percentage of your product.

Salt wash (optional)
Students can separate remaining water from the ethanol distillate by adding potassium carbonate, K_2CO_3, which is soluble in water but not in ethanol. The K_2CO_3 and water will form an alkaline solution and separate from the ethanol to form a dense, bottom layer with the ethanol remaining in the top layer.

Reflection
Construct an explanation for the process of commercial ethanol production based on evidence from student investigations and design logical solutions for the coproducts that are produced. Reflect on the following questions while creating your explanation.

1. What effect does the physical heating have on the corn mash?

2. Explain how each enzyme (amylase and glucoamylase) change the corn mash mixture in preparation for fermentation.

3. What is the function of the yeast during the fermentation process? How did the consistency of the corn mash change during the 3 day fermentation process?

4. What are other ways you can experiment to make the fermentation process more efficient?

5. Describe the physical changes that your corn went through during its transformation into ethanol.

6. What byproducts result from ethanol production?

7. What are efficient and economical uses for the coproducts (carbon dioxide and distillers grains) that are generated during ethanol production?

Constructing Explanations and Designing Solutions:
Construct an explanation for the process of commercial ethanol production based on evidence from student investigations and design logical solutions for the coproducts that are produced.

Self-Assessment Rubric: Ethanol: Nutrient Testing

	Yes	No	Maybe/Unsure
Did we generate data and construct an explanation for the process of commercial ethanol production?			
Did we construct viable solutions for the industrial application of the remaining coproducts produced in the commercial ethanol production?			