KANSAS CORN STEM

Kansas Corn:
How Sweet It Is!

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KANSAS CORN COMMISSION

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Kansas Corn: How Sweet It Is!
Grade Level: High School

Overview
High fructose corn syrup (HFCS) is a sweetener produced from corn starch. This sweetener is used in many applications and has received much criticism and blame for health problems such as obesity and diabetes. This is attributed to the "high" fructose content indicated in the name. While the use of this sweetener is important to the corn industry, it is equally important to examine any truth to the claims. This lab will look at the sugar make up of HFCS as found in bottled soft drinks and compare it to table sugar (sucrose), dextrose (glucose), light corn syrup and the "natural" sweetener, honey.

Kansas College and Career Ready Standards
Science
- **MS-PS1-2.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
- **HS-LS1-6.** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Language Arts
- **RI.3.1:** Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.
- **RI.3.7:** Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur).
- **W.3.2:** Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
- **SL.3.1:** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.

Math
- **3.MD.A.2:** Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem.

Art
- **Cr2.3.3:** Individually or collaboratively construct representations, diagrams, or maps of places that are a part of everyday life.

Kansas Corn: How Sweet It Is!
Grade Level: High School

Learning Objectives
- The students will relate the amount of glucose in different sweeteners.
- The students will use glucose levels to determine fructose levels in different sweeteners.
- The students will analyze amounts of disaccharides hydrolyzed by enzymes.
- The students will measure and compare the amount of sugar in various drinks.

Materials
- How Sweet It Is PowerPoint (available at kansascornstem.com)
- Glucose meter
- Glucose test strips
- Graduated cylinder
- Pipette's (1 ml and 10 ml)
- Pipette pump
- Distilled water bottle
- 100 ml Graduated cylinder
- Balance
- 2: 250 ml Beakers
- Hot plate or drying oven
- Samples of sweeteners including soft drink sweetened with HFCS, cane sugar, dextrose, honey, agave nectar, sucrose, light corn syrup
- Stirring rods
- Invertase
- Glucoamylase (diluted 2% solution)
- 10: 15 ml centrifuge tubes with caps
- Test tube rack
- 2: 50 ml centrifuge tubes with caps

Safety Considerations
Do not consume or taste anything in a lab setting even if it is labeled as a food product.

Procedures for Instruction
Length of Time for Preparation: 1 hour if teacher is preparing solutions

Length of Time for Classroom Teaching: 2-3 class periods

Kansas Corn: How Sweet It Is!

Grade Level: High School

Background Information

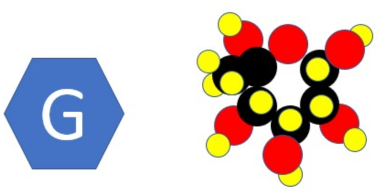
High Fructose Corn Syrup

- High fructose corn syrup has drawn a lot of negative attention in recent years.
- The label "High" fructose concentration is claimed to make it unhealthy.

Chemistry of sugar

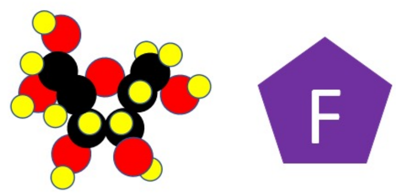
- Simple sugars are called monosaccharides or "single sugars". The two most common monosaccharides are glucose and fructose. They are isomers, having the same formula, C6H12O6, but different structure. This different structure shows in the way we symbolize them. Glucose with a hexagon, fructose with a pentagon. This structure does change how they are metabolized. Glucose can be taken directly from the blood stream into cells for use. Fructose must go to the liver where it is modified into glucose. This difference in metabolism is why many see fructose as being less healthy for consumers.

Glucose



$C_6H_{12}O_6$

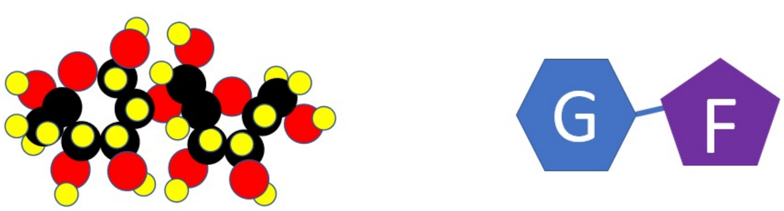
Fructose



$C_6H_{12}O_6$

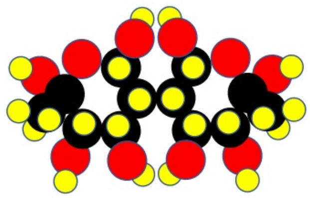
There are also disaccharides, such as sucrose and maltose, in many sweeteners. These are two simple sugars bonded together and are again isomers having the formula, C12H22O11. Sucrose is a glucose bonded to a fructose. These sugars are readily separated by the enzyme sucrase, also known as invertase. This produces an equal amount of glucose and fructose.

Sucrose



Maltose is a combination of two glucose molecules. This may be broken down by the enzyme maltase, or glucoamylase. In this lab we will use a glucoamylase solution. The breakdown of maltose will produce two glucose molecules.

Kansas Corn: How Sweet It Is!
Grade Level: High School



The sweeteners tested in this lab are mostly made up of combinations of these four sugars. The glucose meters only detect individual glucose molecules. Those in disaccharides such as maltose and sucrose will not show up until after the enzymes are added.

Dextrose is another name for glucose and will be used as the reference for a pure glucose sample. The pure fructose solution will be used to demonstrate that it is not detected by the glucose meters. It will read "Lo" which for the meters provided means less than 20 μg/dL of glucose. Because the glucose meter detects glucose and not fructose, this lab compares solutions of different sweeteners with the same concentration with pure glucose. The idea being that the more glucose detected, the less fructose the sweetener can contain. The undigested sweeteners are tested as well to compare how much of the glucose was present in disaccharide form.

Corn syrup initially contains no fructose. High fructose corn syrup is modified using enzymes to produce HFCS 42 and HFCS 55. The 42 and 55 refer to the percentage of fructose they contain with the rest being glucose. Fructose is noticeably sweeter tasting than glucose which is the primary reason HFCS is used instead of pure glucose corn syrup. The published data shows that HFCS used in breakfast cereals and other foods and HFCS 55 used to sweeten soft drinks have a similar or lower fructose to glucose ratio than sucrose, also known as table sugar or cane sugar, honey, agave nectar (90-95% fructose) and many other sweeteners often perceived and promoted as healthier alternatives to HFCS. This lab activity was designed to allow students to test and compare these levels for themselves.

Classroom Discussion

Introduce the topic and assess to students for prior understanding.

- What are simple carbohydrates or sugars primarily used in animals?
  Carbohydrates are primarily an energy source in animals. Providing 4 kcal/g of energy.
- What compound has the formula C6H12O6? This formula represents both glucose and fructose.
  They are Isomers – molecules with the same composition but different arrangement. (Same formula, different structure) Glucose and fructose, both $C_6H_{12}O_6$.

- Does this structural difference really matter? *Fructose tastes sweeter than glucose. Monosaccharides, Fructose and Glucose are similar but are metabolized differently by the body.*
- What does the body produce in response to an increase in blood sugar?
  Insulin is produced in response to glucose. This helps cells pull glucose from the blood to use as fuel. Fructose in the blood does cause the same insulin response. Glucose can be absorbed directly into cells while fructose must be modified in the liver.
- What type of sugar is often marketed as “real sugar”?
  Cane sugar or table sugar that students are familiar with is sucrose. Sucrose is a disaccharide. Disaccharide means “two sugars”. They are sugars composed of two monosaccharides the two main disaccharides in the sweeteners we will test are Sucrose (glucose-fructose) and Maltose (glucose-glucose). These are common in sweeteners and will need to be broken down with enzymes to determine the amounts of glucose and fructose they contain.
- What type of molecules are used to break or build molecules in living organisms?
  Enzymes fit specifically to a molecule and break it, invertase breaks the sucrose into glucose and fructose and glucoamylase breaks the maltose and short chains of glucose into individual glucose molecules.
- Are their sugar types that are healthy, unhealthy?
  Have groups list one healthy and one unhealthy and why they think these are healthy or unhealthy.

Let students discuss their ideas and guide the discussion without telling them if they are right or wrong.

- Predict the order of the sweeteners from lowest glucose to highest glucose. Understanding the base sugars in these sweeteners are primarily glucose and fructose this would be the highest glucose on top and lowest fructose on bottom.
- Have students present their predictions and explain their reasoning.

Sweeteners: Dextrose, HFCS, Corn syrup, Honey, Sucrose, Fructose

Highest Fructose	**Prediction**	**Measured After Digestion**	**% Fructose**
↕			
Lowest Fructose			

Procedure for Lab

Kansas Corn: How Sweet It Is!
Grade Level: High School

Procedure for checking the accuracy of sugar content on a soft drink label (Optional)

Several of the sweeteners being tested contain water. High fructose corn syrup is difficult to purchase in pure form so we will use a soft drink for testing. The concentration, amount of sugar in 100 ml of the soft drinks will be measured by dehydrating the soft drink.

Materials

- 100 ml Graduated cylinder
- Balance
- 250 ml Beakers
- Hot plate or drying oven
- Soft drink containing HFCS

Soft Drink Hydration

1. Find and record the amount of carbohydrates in one serving on the label.
2. Record the volume of a serving as marked on the label in ml.
3. Divide the mass of carbohydrate by serving volume and multiply by 100 ml. Record this as the predicted amount of sugar in 100 ml.
4. Pour approximately 150 ml of the soft drink into a beaker.
5. Pour the sample from one beaker to another and back again several times to reduce carbonation.
6. Rinse and dry the empty beaker.
7. Using a balance, determine mass of the beaker, recording to the nearest centigram.
8. Using a 100 ml graduated cylinder measure exactly 100 ml of soft drink.
9. Pour this sample into the clean beaker.
10. Place beaker on a hotplate on low heat.
11. Let the sample dry.
12. When dry remove from heat and allow to cool.
13. When sample has cooled determine mass of beaker and sample recording to the nearest centigram.
14. Subtract the mass of the clean beaker to determine the mass of the sugar that was dissolved in the soft drink.
15. This mass will be nearly all sugar.
16. Compare this mass with the label mass.

Kansas Corn: How Sweet It Is!
Grade Level: High School

Data Table 1	HFCS Soft Drink
Mass of sugar in 100 ml of soft drink (label calculation)	
Mass of Beaker	
Mass Beaker + Sugar Residue	
Sugar residue	
Difference in claimed and measured values	

Honey/Syrup Dehydration (Optional)

Honey and syrups have a small amount of water in them. Determine the percent water and compare with the published data.

1. Using the balance, determine mass of beaker recording to the nearest centigram.
2. While on the balance add approximately 20g of the sweetener to the beaker.
3. Subtract the mass of the clean beaker to determine the mass of the sweetener to the nearest centigram.
4. Place beaker in a drying oven/incubator at 50 °C.
5. Let the sample dry for several days.
6. When dry remove from heat and allow to cool.
7. When sample has cooled determine mass of beaker and sample recording to the nearest centigram.
8. Subtract the mass of the clean beaker to determine the mass of the dried solute.
9. This mass will be nearly all sugar.
10. Determine the percent of water in the sweetener by dividing (the mass lost by heating)/(the mass of the original sample) multiplying by 100.
11. Compare the calculated value with the published water composition data.

Data Table 2	Honey	Light Corn Syrup
Beaker		
Beaker + Sweetener		
Sweetener (g)		
Beaker + Sugar residue (g)		
Sugar Residue (g)		
Water lost (g)		
Percent water Water lost/syrup mass x 100		
Published Data	17.1 %	22.9%

Kansas Corn: How Sweet It Is!
Grade Level: High School

Comparing sugar composition: Solution preparation

Prepare solutions of equal sugar concentrations of each sweetener for comparison. Each lab group will need a 250 ml beaker, a balance, a type of sweetener, a 100 ml graduated cylinder, and distilled water.

1. Prepare a solution of each sweetener with the same concentration of sugar (carbohydrate).
   a. The HFCS soft drink contained 11.00g of carbohydrate in 100 ml
   b. If you are using a dry sugar (dextrose, sucrose etc.) add mass exactly 11.00g of sugar in a clean, dry 250 ml beaker.
   c. If using honey (17% water) add 13.25 g of honey into a clean dry beaker. This will contain 11.00g of sugar.
   d. Preparing light corn syrup (22.9% water) add 14.26 g of syrup into a clean dry beaker. This will contain 11.00g of sugar and 3.26g of water.
2. Add approximately 75 ml of distilled water to the beaker and stir until dissolved. Solution may be heated gently on the hotplate to speed this process.
3. When the sample has completely dissolved allow to cool if heat was used.
4. Pour sample into the 100ml graduated cylinder.
5. Fill the graduated cylinder to 100 ml.
6. Pour into beaker and cover sample.

Diluting Samples

Most of these sugar solutions have glucose amounts above the range of the blood glucose meter. A serial dilution of 1/10 and 1/100 concentrations will be prepared to produce solutions in the range of the meters.

Day 1

1. Label two 250 ml beakers with sweetener and 1/10 and 1/100 respectively.
2. Using a pipette add exactly 10 ml of the prepared sweetener solution to a 100 ml graduated cylinder.
3. Add distilled water to fill the cylinder to exactly 100 ml.
4. Pour this solution into a beaker labeled 1/10 and stir well.
5. Rinse graduated cylinder well.
6. Using a pipette add exactly 10 ml of the 1/10 sweetener solution prepared in steps 2-4 into the 100 ml graduated cylinder.
7. Add distilled water to fill the cylinder to exactly 100 ml.
8. Pour this into the 1/100 dilution beaker.
9. Repeat steps 5-8 to produce a second 100 ml of 1/100 dilution if samples for more than 5 groups will be needed.
10. Label two 50 ml centrifuge tubes with each type of sweetener and 1/100 no enzymes and 1/100 enzymes.

11. Split the 100 ml sample evenly between the two centrifuge tubes.
12. Replace the cap on the tube labeled no enzymes.
13. To the sample labeled enzymes add 2ml of invertase and 2 ml of glucoamylase.
14. Replace cap and invert gently to mix enzymes thoroughly.
15. Store tubes at room temperature overnight to allow hydrolysis to occur.

Day 2

1. Using a 10 ml pipette, add 10 ml of the 1/100 solution to each of the centrifuge tubes.
2. Rotate to different stations and collect 2 samples of 1/100 solution of each type of sweetener.

Testing free glucose:

The amount of free glucose can be measured in each of the sweeteners. This will only detect glucose monomers and will not detect glucose present in disaccharide forms.

1. Insert a glucose test strip into the meter.
2. Remove the cap from the "No Enzyme" centrifuge tube.
3. Gently tip the tube and touch the test strip to the solution.
4. The meter will read the glucose concentration in μg/dL.
5. Repeat for all sweetener solutions.
6. Record these values in data table 2.
7. If the reading is (Lo) or low, record as Lo which means less than 20μg/dL.

The amount of glucose will now be measured in each of the hydrolyzed sweeteners. These readings may be significantly higher if the sweetener contained disaccharides maltose and sucrose that were broken releasing glucose molecules.

8. Repeat steps 2 through 6 for each of the enzyme hydrolyzed solutions.
9. Calculate and record the percent glucose of the highest reading by dividing it by the reading for the dextrose in data table 2.
10. Calculate the maximum fructose percentage by subtracting the glucose percentage from 100.

Kansas Corn: How Sweet It Is!
Grade Level: High School

Data Table 2	Dextrose (glucose)	High Fruct. Corn Syrup	Honey	Light Corn Syrup	Sucrose	Fructose
No Enzyme						
Hydrolyzed with Enzymes						
% Glucose (glucose reading)/(dextrose) x 100	100%					
Max % Fructose (100 - %Glucose)						

Teacher Tips
For additional resources and tips visit kansascornstem.com.

Lab Analysis
Have students determine and compare glucose and fructose content.

Due to the glucose meters only measuring free glucose. Determine the percentage glucose in the sweetener by dividing the reading by the dextrose (pure glucose) reading.

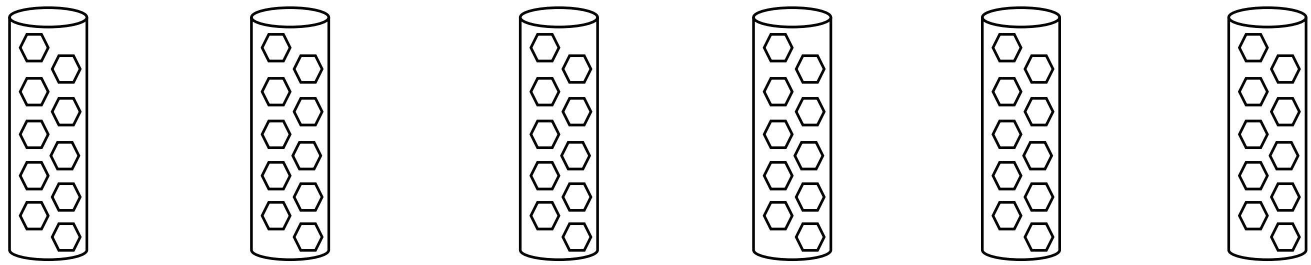
For this lab have students assume the sugars in the sweetener were made up of only glucose and fructose or disaccharides that were hydrolyzed during digestion. Have them subtract the glucose from 100% to determine the maximum amount of fructose in the original sweetener.

Reflection and Conclusion
After calculating fructose levels have students fill out table 1, placing sweeteners in order of most fructose to least fructose including percent calculated.

To visualize the relative amounts of glucose and fructose in each sweetener, round the percentage of glucose to the nearest ten and divide by ten. Color that many hexagons green in the vial. Perform the same calculations for the fructose percentage and color those hexagons red.

Kansas Corn: How Sweet It Is!
Grade Level: High School

Dextrose (glucose)	High Fruct. Corn Syrup	Honey	Light Corn Syrup	Sucrose	Fructose



Assessment
Have students share how the lab results compare with their predictions was there anything that they found surprising?

Extension Activity
Visualizing sugar consumption

Give each group a sweetened beverage that they are likely to consume, sports drinks, energy drinks, fountain drinks, iced coffee, fruit juices, etc. Have students refer to the label and find the amount of sugar in the container. (Make sure they do not use per serving.) Have them mass out the amount of sugar in a graduated cylinder or other container. Have them place each container in a location in the room where they can be observed and compared. Students are shocked at how much sugar is in the drinks that we consume.

Science and Agriculture Careers
To learn more about agriculture careers visit agexplorer.com. You can also find career profiles at kscorn.com.

Sources

Light Corn Syrup water content by mass
https://fdc.nal.usda.gov/fdc-app.html#/food-details/168837/nutrients

Honey water content by mass
https://fdc.nal.usda.gov/fdc-app.html#/food-details/169640/nutrients