Food Chemistry Experiments
Unit 1. CARBOHYDRATES

Teacher Activity Guide

Expected Outcome

The student will learn about the sources of carbohydrates and their uses in the food industry. The students will be able to use a carbohydrate to modify another food substance and explain how food chemistry was involved.

Activity Objective

Students will use pectin in conjunction with an acid and sugar to form jelly. By varying the sugar concentrations, the students will observe that there is an optimum ratio for the creation of this spreadable gel.

Activity Length

Part 1 - 20 minutes
Part 2 - 20 minutes
Part 3 - 20 minutes

Scientific Principles

Pectin solutions form gels when an acid and sugar are added. As the pH is decreased by the addition of acid, the carbohydrate chains of the pectin molecule join together to form a polymer network, which entraps the aqueous solution. The formation of these junction zones is aided by high concentrations of sugar, which allow the chains to interact with one another by dehydrating (pulling water away from) the pectin molecules. This increases the strength and rigidity of the gel.

Vocabulary

Amylase is an enzyme that hydrolyzes starch polymers to yield glucose and maltose. Salivary amylase begins the chemical breakdown of large starch molecules into smaller sugar molecules.

Carbohydrate is a compound of carbon and water with the basic formula \( \text{C}_n\text{H}_{2n}\text{O}_n \). [Note: condensation products, such as sucrose, have one less \( \text{H}_2\text{O} \) and a formula \( \text{C}_n\text{H}_{2(n-1)}\text{O}_{(n-1)} \)]. Carbohydrates are the most abundant of all carbon-containing compounds, composing nearly three-fourths of the dry mass of all plant life on earth. Examples of carbohydrates include glucose, sucrose (table sugar), starch, and cellulose.
Cellulose is a polymer of glucose, linked by beta-1,4-glycosidic bonds. It is a complex carbohydrate similar in structure to starch. Examples are cotton, wood, and paper. As part of the human diet, cellulose helps prevent constipation and fights colon cancer.

Fructose is a sugar occurring naturally in a large number of fruits and honey. It is the sweetest of all common sugars. It is a simple carbohydrate with the formula C₆H₁₂O₆.

Galactose is a simple sugar having the same chemical formula (C₆H₁₂O₆) as glucose and fructose, but a different arrangement of its atoms. It is an isomer of glucose with a hydroxyl group on carbon 4 reversed in position. Galactose is often found in carbohydrates used in cellular recognition, such as blood types and neural receptors.

Glucose is a simple sugar (C₆H₁₂O₆) and the primary source of energy for all mammals and many plants. It is also known as dextrose, grape sugar, and corn sugar. It is about half as sweet as table sugar.

Hydrolysis is a chemical process whereby a compound is cleaved into two or more simpler compounds with the uptake of the H and OH parts of a water molecule on either side of the chemical bond that is cleaved. During digestion, the intestinal enzyme sucrase hydrolyzes (adds water to) sucrose (C₁₂H₂₂O₁₁) to produce glucose (C₆H₁₂O₆) + fructose (C₆H₁₂O₆) in the intestinal tract.

Hemiacetal is a product of the addition of an alcohol to an aldehyde. An aldehyde is a compound containing the radical CH=O, reducible to an alcohol (CH₂OH) and oxidizable to a carboxylic acid (COOH).

Isomers are two or more molecules with the same number and kind of atoms, but different arrangements of those atoms.

Lactase is an enzyme that hydrolyzes lactose into glucose and galactose, which can be absorbed into the bloodstream.

Lactose is a disaccharide composed of galactose and glucose linked by a beta-1,4-glycosidic bond. Lactose is found in cow’s milk and other dairy products.

Maltose is a disaccharide composed of two molecules of glucose linked by an alpha-1,4-glycosidic bond. It is obtained from the hydrolysis of starch, and is used to flavor some candy. Maltose must be hydrolyzed to glucose before it can be absorbed and taken into the bloodstream.

Polymers contain two or more monomers. Starch is a polymer of the monomer glucose. Protein is a polymer of amino acids.
**Starch** is a polymer of glucose, linked by alpha-1,4-glycosidic bonds. Starch is a complex carbohydrate found in green plants, and an important source of energy for animals and humans. During the day, green plants store energy by converting glucose to starch. At night, plants convert starch back to glucose for growth.

**Stereochemistry** is the branch of chemistry concerned with the spatial three-dimensional relations of atoms in molecules. For example, stereochemistry refers to the relative positions of atoms or groups of atoms in the molecule or compound and the effect of these positions on its properties.

**Sucrose** (C\textsubscript{12}H\textsubscript{22}O\textsubscript{11}) is a disaccharide made up of glucose and fructose. Sucrose is obtained from cane sugar, sorghum, and sugar beets. Sucrose is the name for common table sugar, which can’t be used by the body unless it is broken down by the enzyme sucrase into monosaccharides by the process of digestion. Absorption of glucose and fructose occurs in the small intestine.

**Materials Required**

- *Sure-Jell®*
- Concentrated fruit juice (apple, grape), thawed, if frozen
- Granulated sugar
- Water
- 600-milliliter beakers
- Bunsen burner w/ stands or hot plate
- Heatproof gloves
- Balance or scale
- Graduated cylinder
- Heatproof pad
- Stirring rod/spoon/wooden *Popsicle* stick

**Instructional Strategies and Procedures**

You will be able to complete and observe the entire experiment in one class period, if you divide the class into three groups and each group does one part of the experiment.

**Teaching Tips**

- **The foods produced in these experiments are not to be consumed.**
- Purchase the regular *Sure-Jell*. It contains pectin, acid and dextrose (glucose).
- You can use either frozen juice concentrate or the nonrefrigerated, aseptically processed juice concentrates found in the fruit juice section of the supermarket.
- Caution the students against overheating the jelly. Once the jelly starts to boil, it will bubble up and over the top of the beaker.
SAMPLE DATA TABLE - JELLY CONSISTENCY

<table>
<thead>
<tr>
<th>EXPERIMENT</th>
<th>JELLY</th>
<th>CONSISTENCY *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>Normal</td>
<td>Firm</td>
</tr>
<tr>
<td>Part 2</td>
<td>Half sugar</td>
<td>Runny; viscosity is like glue</td>
</tr>
<tr>
<td>Part 3</td>
<td>Twice sugar</td>
<td>Has some firmness, will not hold a shape</td>
</tr>
</tbody>
</table>

*Jelly results based on the use of Mott’s® In-A-Minute Unfrozen Grape Concentrate.

Key Questions and Answers

1. How did the consistency of the jelly change when you changed the ratio of sugar to pectin?

   When you used half the normal amount of sugar, the jelly was runny; when you used twice the sugar, the jelly was soft and did not hold its shape.

2. Why did the consistency change when you changed the ratio of sugar to pectin?

   There is an optimum ratio for jelly formation. The addition of sugar increases the firmness of the gel by aiding in the formation of polymer junctions. The addition of too much sugar, however, interferes with the gelling process. Although the mechanism for this reaction is not known, it is thought that very high concentrations of sugar dehydrate the pectin molecules to such an extent that some of the entrapped water is pulled out of the gel and back into solution. The result would be a softer gel that would not hold its shape.

Web sites for more information on carbohydrates

www.ag.iastate.edu/departments/agronomy/cornpage.html - Iowa State University. Contains general, technical, and production information on corn.


http://osu.orst.edu/instruct/nfm236/starch/index.htm - Oregon State University. Information on starch, its uses and composition.
Solution for Cryptic Carbohydrates

1. ISOMERS
2. CELLULOSE
3. CARBOHYDRATES
4. LACTOSE
5. SUCROSE
6. PECTIN
7. MONOSACCHARIDE
8. MAILLARD
9. GLYCOSIDIC
10. PHOTOSYNTHESIS

HIDDEN MESSAGE: ICE CREAM
Solution to Cool Carbs

| M | A | I | L | L | A | R | D | S | C | H | O | O | H | P |
| S | E | E | R | A | V | A | A | R | T | G | I | C | E | O |
| T | Y | T | O | E | F | F | O | G | L | N | R | O | D | L |
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| A | C | R | H | F | O | O | C | O | T | S | D | L | G | S |
| R | O | D | U | E | P | O | S | S | + | + | + | + | P | A |
| G | L | Y | C | O | S | I | D | I | C | B | O | N | D | C |

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+ + C + O + O N I T C E P A D
L E G S + P E N E R G Y C L E

(Over, Down, Direction)
CARBOHYDRATE (3, 13, N)  CELLULOSE (13, 14, NW)
ENERGY (7, 14, E)  FRUCTOSE (10, 8, SW)
GEL (3, 14, W)  GLUCOSE (11, 2, SW)
GLYCOSIDIC BOND (1, 7, E)  ISOMER (9, 7, NW)
LACTOSE (14, 14, N)  MAILLARD (1, 1, E)
PECTIN (13, 13, W)  PLANTS (14, 6, NW)
POLYMER (6, 14, NE)  POLYSACCHARIDE (15, 1, S)
STARCH (9, 6, NE)  SUGAR (11, 5, NW)

HIDDEN MESSAGE:
We should choose a variety of foods within each food group.