HOW SWEET IT IS!

Written by Amy Rowley and Jeremy Peacock

Annotation:

In this classroom activity, students will explore the relationship of chemical structure to the functional properties of food ingredients as they compare natural and artificial sweeteners.

Primary Learning Outcomes:

Students will be able to name common sweeteners found in food products.

Students will be able to classify sweeteners as organic compounds.

Students will be able to identify the chemical structures of sucrose, saccharin, and sucralose.

Students will be able to describe the relationship between the chemical structure and functional properties of food ingredients.

Students will be able to explain the role of ingredient selection in the development of food products.

Georgia Performance Standards:

Characteristics of Science

SCSh3. Students will identify and investigate problems scientifically.

Physical Science

SPS2. Students will explore the nature of matter, its classifications, and its system for naming types of matter.

Chemistry Content

SC1. Students will analyze the nature of matter and its classifications.

SC3 Students will use the modern atomic theory to explain the characteristics of atoms.

Related Topics:

Structure and Properties of Matter
Organic Compounds

Duration:

Preparation: 45 minutes
Introduction: 20 minutes
Student Activity: 15 minutes
Conclusion: 15 minutes
Total Class Time: 50 minutes

Materials and Equipment:

<u>For Teacher Preparation</u>:

(Per class of 30 students)

1. ½ Cup sucrose (table sugar)
2. ½ Cup sucralose (Splenda®)
3. ½ Cup saccharin (Sweet'N Low®)
4. 120, 5-oz. Plastic cups
5. 4 Gallons of drinking water
6. Saltine® crackers
7. Napkins

<u>Per Student:</u>

1. *How Sweet It Is!* student handout
2. 5-oz. Cup of Solution A
3. 5-oz. Cup of Solution B
4. 5-oz. Cup of Solution C
5. 5-oz. Cup of water
6. 2 Saltine® crackers
7. Napkin

Safety:

Because students will be allowed to eat during the activity, precautions should be taken to prevent materials from coming into contact with laboratory equipment or surfaces. Materials should remain in cups or on clean napkins at all times.

Technology Connection:

Not applicable

Procedures:

<u>Teacher Preparation:</u>

Use the attached template to prepare the *How Sweet It Is!* student handout for each student. To one gallon of drinking water, add ½ cup of sucrose (table sugar) and mix thoroughly. Label this "Solution A." To a second gallon of drinking water, add ½ cup of sucralose (Splenda®) and mix thoroughly. Label this "Solution B." To a third gallon of drinking water, add ½ cup of saccharin (Sweet'N Low®) and mix thoroughly. Label this "Solution C." For each student, label 4 cups "A," "B," "C," and "water," respectively. Fill each cup with the appropriate sample. *Note: Although this procedure will not provide solutions of equivalent molar concentrations, the relative concentrations are such that students will obtain the desired results. Because saccharin and sucralose are significantly sweeter than sucrose, they are packaged along with filler materials such as dextrose. For example, a one-gram packet of Sweet'N Low® contains only 36 mg of saccharin along with 964 mg of filler and other ingredients. Thus in order to create molar-equivalent solutions of sucrose and saccharin using materials found at the grocery store, it would be necessary to adjust for the presence of filler in the commercially available saccharin product.*

Estimated Time:
45 minutes

Introduction:
Everything we see, touch, smell, and taste is chemical, whether it is the neon lights at your favorite restaurant, the napkin you place in your lap, the aroma of fresh garlic, or the food that you eat.

During the development of a new food product, each ingredient (*i.e.* chemical) is selected because of its specific function within the food. Sugar sweetens. Vanilla flavors. Flour thickens. Potassium sorbate preserves. The specific function of an ingredient is a result of its chemical structure, and therefore, any changes in the chemical structure alter the function of the ingredient. For example, L-carvone and D-carvone are enantiomers, or isomers whose structures are mirror images of one another. In this case, L-carvone exhibits a spearmint aroma; whereas, D-carvone exhibits a caraway, or rye cracker-like, aroma. Structural changes in ingredients can result indirectly from heating, processing, and storage or can result directly from the efforts of food scientists to manipulate specific functional properties of an ingredient. Therefore, knowledge of the relationship between the structure and function of ingredients is critical in food science.
Explain to students that they will be sampling sucrose, saccharin, and sucralose. Each of these is an organic compound that is used as a sweetener in food and beverage products. Organic compounds are often simplified to include those compounds that contain the element carbon. For example, aspirin, $C_9H_8O_4$, is an organic compound. Organic compounds do contain carbon, and most organic compounds also contain hydrogen. Those compounds that consist solely of carbon and hydrogen are called hydrocarbons. Butane, C_4H_{10}, is an example of a hydrocarbon. Other organic compounds may contain oxygen, nitrogen, sulfur, phosphorus, or one of the halogens. These groups of atoms containing elements other than carbon and hydrogen constitute functional groups. Each functional group is important because it provides the compound with unique chemical properties. Furthermore, organic compounds are commonly classified by the functional groups they contain.

As with any ingredient function, it is the chemical structure of sweeteners that allows them to function as such. Food scientists have determined that a specific arrangement of organic functional groups allows a compound to interact with taste bud receptors to register a sweet sensation. A compound must contain an –OH or –NH group, a basic N or C atom, and a hydrophobic group such as $–CH_3$ in a triangle with specific angles and distances in order to act as a sweetener. Among the more than 50 sweeteners known to food scientists, the natural sugars, such as sucrose and fructose, are the best known.

Sucrose (Figure 1), or common table sugar, is a carbohydrate and is a major source of calories and energy in the human diet. Sucrose is actually a disaccharide that is composed of the two monosaccharides glucose and fructose. Table sugar is refined from sugarcane and sugar beets and is considered the standard when measuring the sweetness of compounds.

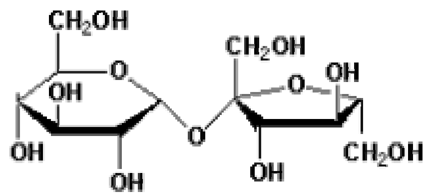


Figure 1: Sucrose

Because of the interest in low-calorie and low-sugar foods that has developed over the last few decades, interest has grown in using low-calorie or no-calorie sweeteners. These sweeteners, such as sucralose, saccharin, cyclamate, and aspartame, are either not metabolized or are so intensely sweet that very small quantities can be used.

Sucralose (Figure 2) is the newest artificial sweetener to enter the market and is known by the trade name Splenda®. Sucralose is made through a process that converts sucrose to a non-caloric, non-carbohydrate sweetener by replacing three –OH groups on the sucrose molecule with three Cl atoms. The result is a stable compound, 600-times sweeter than sucrose, that is not metabolized by the body and is stable at high temperatures. Aside from its use in manufactured products and as a tabletop sweetener, Splenda® is sold as a sucrose-sucralose blend for baking, as sucrose can have important functions in the texture and appearance of baked foods.

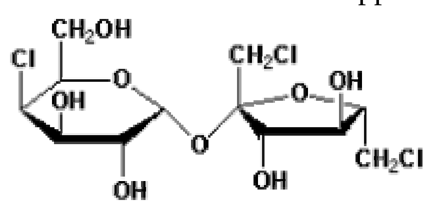


Figure 2: Sucralose

Saccharin (Figure 3), the world's oldest low-calorie sweetener, was discovered accidentally in 1879 when a researcher at Johns Hopkins University spilled the compound on his hand and later noticed his hand to have a sweet taste. Saccharin is a heterocyclic compound that is derived from toluene or methyl anthranilate and is 300-times sweeter than sucrose. It is not metabolized by the body, and although there has been much controversy concerning its health effects, saccharin has been shown to be a safe alternative to sugar. Today, saccharin is sold as a tabletop sweetener under the trade name Sweet'N Low® and is used in such products as baked goods, gum, candy, and salad dressings.

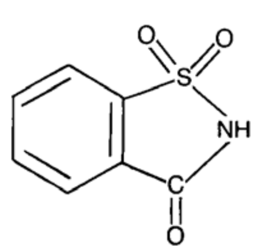


Figure 3: Saccharin

Estimated Time:
20 minutes

<u>Activity:</u>
Provide each student with the materials listed above. Ask students to sample the solutions and rank the relative sweetness intensities according to the instructions given on the *How Sweet It Is!* student handout. Before sampling each solution, students should use the water and crackers to cleanse their palates.

Estimated Time:
15 minutes

<u>Conclusion:</u>
On the board, note the consensus of student rankings. Confirm the correct rankings and discuss any differences observed by the students. Have students individually answer the post-laboratory questions found on the *How Sweet It Is!* student handout.

Estimated Time:
15 minutes

Assessment:
Assessment should be based on completion of the *How Sweet It Is!* student handout.

References:

- Christen, G.L. and J.S. Smith (Eds.). 2000. *Food Chemistry: Principles and Applications*. Science Technology System, West Sacramento, California.
- Emsley, J. 1988. *Artificial Sweeteners*. ChemMatters. February: 4-8.
- Gilman, V. 1988. *Artificial Sweeteners: No-calorie sugar substitutes provide options for enjoying the sweet life.*. Chemical and Engineering News. 82(25): 43.
- http://www.saccharin.org/
- http://www.splenda.com/
- http://www.sweetnlow.com/

HOW SWEET IT IS! *Student Handout*

Introduction:

Sucrose (Figure 1), or common table sugar, is a carbohydrate and is a major source of calories and energy in the human diet. Because of the interest in low-calorie and low-sugar foods that has developed over the last few decades, interest has grown in using low-calorie or no-calorie sweeteners. Sucralose (Figure 2) is the newest artificial sweetener to enter the market and is known by the trade name Splenda®. Sucralose is made through a process that converts sucrose to a non-caloric, non-carbohydrate sweetener by replacing three –OH groups on the sucrose molecule with three Cl atoms. Saccharin (Figure 3), the world's oldest low-calorie sweetener, is known by the trade name Sweet'N Low®. Saccharin is a synthetic compound derived from toluene.

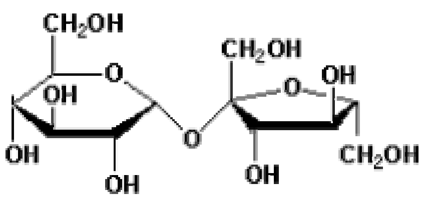


Figure 1: Sucrose

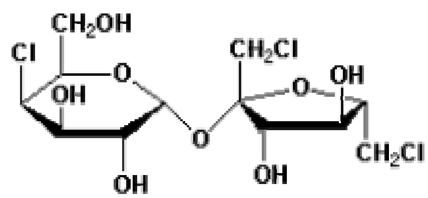


Figure 2: Sucralose

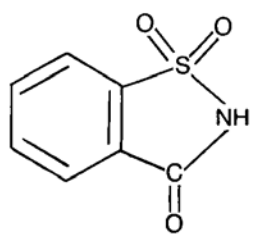


Figure 3: Saccharin

Table sugar is refined from sugarcane and sugar beets and is considered the standard when measuring the sweetness of compounds. Compared to sucrose, artificial sweeteners exhibit much more intense sweetness. Saccharin is 300-times sweeter than sucrose, while sucralose is 600-times sweeter than sucrose.

Purpose:

To identify common food sweeteners, sucrose, saccharin, and sucralose, by comparing sweetness intensity rankings of solutions of each compound.

Materials:

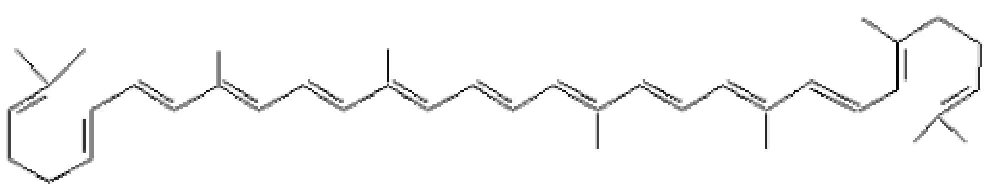
1. 3 Sweetener solutions (A, B and C)
2. Cup of water
3. Saltine® crackers
4. Napkin

Intensity Ranking:
Sample each solution, from A to C. Rank (1 being least intense and 3 being most intense) the sweetness of each solution.

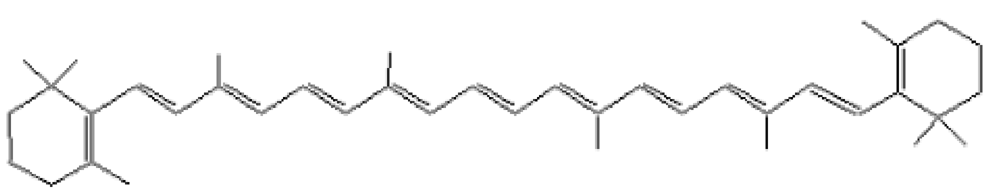
Sample	Sweetness Intensity Ranking	Comments
A	__________	_________________________
B	__________	_________________________
C	__________	_________________________

Post-Laboratory Questions:

1. Identify solutions A, B, and C as sucrose, saccharin, or sucralose based on your sweetness intensity rankings.
2. Other than sweetness intensity, what differences did you detect among the samples?
3. Sucralose is stable at high temperatures. However, for baking applications, Splenda® is sold as a sucrose-sucralose blend. Identify two functions, other than sweetening, that sucrose might have in baked food products that sucralose does not fulfill.
4. Carotenoids are a class of compounds responsible for many of the red, orange, and yellow hues of plant leaves, fruits, and flowers, as well as the colors of some birds, insects, fish, and crustaceans. Examine and compare the chemical structures found below. Lycopene is a carotenoid found in tomatoes. Based on your comparison, would you expect β-carotene to exhibit the properties of a carotenoid? Why or why not?



Lycopene ($C_{40}H_{56}$)



β-carotene ($C_{40}H_{56}$)