4.8: The Food Industry: Functional Attributes of Carbohydrates and the Use of Sugar Substitutes

Skills to Develop

• Discuss the usefulness (or lack thereof) of consuming foods containing sugar substitutes

In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes, including increased sweetness, viscosity, bulk, coating ability, solubility, consistency, texture, body, and browning capacity. The differences in chemical structure between the different carbohydrates confer their varied functional uses in foods. Starches, gums, and pectins are used as thickening agents in making jam, cakes, cookies, noodles, canned products, imitation cheeses, and a variety of other foods. Molecular gastronomists use slow-releasing carbohydrates, such as alginate, to give shape and texture to their fascinating food creations (Video 4.8.1). Adding fiber to foods increases bulk. Simple sugars are used not only for adding sweetness, but also to add texture, consistency, and browning. In ice cream, the combination of sucrose and corn syrup imparts sweetness as well as a glossy appearance and smooth texture. Added sugars include white, brown, and raw sugar, corn syrup, HFCS, malt and maple syrups, liquid fructose, honey, molasses, agave nectar, and crystal dextrose.

Video 4.8.1: Ferran Adrian Demonstrates Alginates

Watch this video to see how molecular gastronomist Ferran Adrian uses the polysaccharide alginate to give shape and texture to olive puree.
Due to the potential health consequences of consuming too many added sugars, sugar substitutes have replaced them in many foods and beverages. Sugar substitutes may be from natural sources or artificially made. Those that are artificially made are called artificial sweeteners and must be approved by the FDA for use in foods and beverages. The artificial sweeteners approved by the FDA are saccharin, aspartame, acesulfame potassium, neotame, and sucralose. Stevia is an example of a naturally derived sugar substitute. It comes from a plant commonly known as sugarleaf and does not require FDA approval. Sugar alcohols, such as xylitol, sorbitol, erythritol, and mannitol, are carbohydrates that occur naturally in some fruits and vegetables. However, they are industrially synthesized with yeast and other microbes for use as food additives.
Pectin (a carbohydrate) is added to jam to give it its consistency. (bottom) This drawing depicts a pectin molecule. These molecules combine to form the network responsible for making jelly. Image used with permission (CC BY-SA 3.0; PatríciaR).

The FDA requires that foods disclose the fact that they contain sugar alcohols, but does not require scientific testing of it. (Though many of them have undergone studies anyway.) In comparison to sucrose, artificial sweeteners are significantly sweeter (in fact, by several hundred times), but sugar alcohols are more often less sweet than sucrose (Table 4.8.1). Artificial sweeteners and Stevia are not digested or absorbed in significant amounts and therefore are not a significant source of calories in the diet. Sugar alcohols are somewhat digested and absorbed and, on average, contribute about half of the calories as sucrose (4 kilocalories/gram). These attributes make sugar substitutes attractive for many people—especially those who want to lose weight and/or better manage their blood-glucose levels.

**Table 4.8.1: Sweetness Comparison of Sugar Substitutes**

<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Trade Names</th>
<th>Times that of Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saccharine</td>
<td>“Sweet-N-Lo”</td>
<td>600.0</td>
</tr>
<tr>
<td>Aspartame</td>
<td>“NutraSweet,” “Equal”</td>
<td>180.0–220.0</td>
</tr>
<tr>
<td>Acesulfame-K</td>
<td>“Sunette”</td>
<td>200.0</td>
</tr>
<tr>
<td>Neotame</td>
<td></td>
<td>7,000.0–13,000.0</td>
</tr>
<tr>
<td>Sucralose</td>
<td>“Splenda”</td>
<td>600.0</td>
</tr>
<tr>
<td>Stevia</td>
<td></td>
<td>250.0–300.0</td>
</tr>
<tr>
<td>Xylitol</td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Sweetener</td>
<td>Trade Names</td>
<td>Times that of Sucrose</td>
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<tr>
<td>-----------</td>
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</tr>
<tr>
<td>Mannitol</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Sorbitol</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>Erythritol</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>


Benefits of Sugar Substitutes

Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. Artificial sweeteners are basically nonnutrients though not all are completely calorie-free. However, because they are so intense in sweetness they are added in very small amounts to foods and beverages. Artificial sweeteners and sugar alcohols are not “fermentable sugars” and therefore they do not cause tooth decay. Chewing gum with artificial sweeteners is the only proven way that artificial sweeteners promote oral health. The American Dental Association (ADA) allows manufacturers of chewing gum to label packages with an ADA seal if they have convincing scientific evidence demonstrating their product either reduces plaque acids, cavities, or gum disease, or promotes tooth remineralization.

There is limited scientific evidence that consuming products with artificial sweeteners decreases weight. In fact, some studies suggest the intense sweetness of these products increases appetite for sweet foods and may lead to increased weight gain. Also, there is very limited evidence that suggests artificial sweeteners lower blood-glucose levels. Additionally, many foods and beverages containing artificial sweeteners and sugar alcohols are still empty-calorie foods (i.e. chewing sugarless gum or drinking diet soda pop) are not going to better your blood-glucose levels or your health.

Health Concerns

The most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion. Since the introduction of sugar substitutes to the food and beverage markets, the public has expressed concern about their safety. The health concerns of sugar substitutes originally stemmed from scientific studies, which were misinterpreted by both scientists and the public.

In the early 1970s scientific studies were published that demonstrated that high doses of saccharine caused bladder tumors in rats. This information fueled the still-ongoing debate of the health consequences of all artificial sweeteners. In actuality, the results from the early studies were completely irrelevant to humans. The large doses (2.5 percent of diet) of saccharine caused a pellet to form in the rat’s bladder. That pellet chronically irritated the bladder wall, eventually resulting in tumor development. Since this study, scientific investigation in rats, monkeys, and humans have not found any relationship between saccharine consumption and bladder cancer. In 2000, saccharin was removed from the US market.

There have been health concerns over other artificial sweeteners, most notably aspartame (sold under the trade names of NutraSweet and Equal). The first misconception regarding aspartame was that it was linked with an increase in the incidence of brain tumors in the United States. It was subsequently discovered that the increase in brain tumors started eight years prior to the introduction of aspartame to the market. Today, aspartame is accused of causing brain damage, autism, emotional disorders, and a myriad of other disorders and diseases. Some even believe aspartame is part of a governmental conspiracy to make people dumber. The reality is there is no good scientific evidence backing any of these accusations, and that aspartame has been the most scientifically tested food additive. It is approved for use as an artificial sweetener in over ninety countries.

Aspartame is made by joining aspartic acid and phenylalanine to amino acids. When digested, it is broken down to aspartic acid, phenylalanine, and methanol. People who have the rare genetic disorder phenylketonuria (PKU) have to avoid products containing aspartame. Individuals who have PKU do not have a functional enzyme that converts phenylalanine to the amino acid tyrosine. This causes a build-up of phenylalanine and its metabolic products in the body. If PKU is not treated, the build-up of phenylalanine causes progressive brain damage and seizures. The FDA requires products that contain aspartame to state on the product label, “Phenylketonurics: Contains Phenylalanine.” For more details on sugar substitutes please refer to Table 4.8.2.

<table>
<thead>
<tr>
<th>Sweeteners with Trade Name</th>
<th>Calories</th>
<th>Source/Origin</th>
<th>Consumer Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspartame</td>
<td>4 kcal/g</td>
<td>Composed of two amino acids (phenylalanine + aspartic acid) + methanol.</td>
<td>FDA set maximum Acceptable Daily Intake: 50 mg/kg body weight = 16 12 oz. diet soft drinks for adults. *Cannot be used in products requiring cooking. People with PKU should not consume aspartame.</td>
</tr>
<tr>
<td>• NutraSweet</td>
<td></td>
<td>Two hundred times sweeter than sucrose.</td>
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<tr>
<td>• Equal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saccharin</td>
<td>0 kcal/g</td>
<td>Discovered in 1878. The basic substance is benzoic sulfinide.</td>
<td>ADI: 5 mg/kg body weight. *Can be used in cooking.</td>
</tr>
<tr>
<td>• Sweet ‘n’ Low</td>
<td></td>
<td>Three hundred times sweeter than sucrose.</td>
<td></td>
</tr>
<tr>
<td>Sweeteners with Trade Name</td>
<td>Calories</td>
<td>Source/Origin</td>
<td>Consumer Recommendations</td>
</tr>
<tr>
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<tr>
<td><strong>Acesulfame K</strong></td>
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<tr>
<td>• Sunnette</td>
<td>0 kcal/g</td>
<td>Discovered in 1967. Composed of an organic salt, potassium (K). Structure is very similar to saccharin’s.</td>
<td>ADI: 15 mg/kg body weight. Body cannot digest it. <em>Can be used in cooking.</em></td>
</tr>
<tr>
<td>• Sweet One</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cyclamates</strong></td>
<td></td>
<td>Thirty times sweeter than sucrose.</td>
<td>No ADI available.</td>
</tr>
<tr>
<td>• Sugar Twin (Canada only)</td>
<td>0 kcal/g</td>
<td>Discovered in 1937.</td>
<td></td>
</tr>
<tr>
<td>Sweeteners with Trade Name</td>
<td>Calories</td>
<td>Source/Origin</td>
<td>Consumer Recommendations</td>
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<tr>
<td>----------------------------</td>
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<tr>
<td>Sucralose</td>
<td></td>
<td></td>
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<tr>
<td>• Splenda</td>
<td>1 Splenda packet contains 3.31 calories = 1g</td>
<td>First discovered in 1976. Approved for use in 1998 in the United States and in 1991 in Canada.</td>
<td>Derived from sucrose in which three of its hydroxyl (OH) groups are replaced by chlorine (Cl(^-)). Six hundred times sweeter than sugar. ADI: 5 mg/kg body weight. <em>Can be used in cooking.</em></td>
</tr>
<tr>
<td>Sweeteners with Trade Name</td>
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<td>Source/Origin</td>
<td>Consumer Recommendations</td>
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<tr>
<td><strong>Stevioside</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Stevia</td>
<td>N/A</td>
<td>Derived from stevia plant found in South America. <em>Stevia rebaudiana</em> leaves.</td>
<td>Classified as GRAS. Considered to be a dietary supplement and approved not as an additive, but as a dietary supplement.</td>
</tr>
<tr>
<td>• Sweet Leaf</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Sucrose</strong></td>
<td>~4 kcal/g</td>
<td>Extracted from either sugar beets or sugar cane, which is then purified and crystallized.</td>
<td>It is illegal to sell true raw sugar in the United States because when raw it contains dirt, insect parts, as well as other byproducts. Raw sugar products sold in the United States have actually gone through more than half of the steps in the refining process as table sugar.</td>
</tr>
<tr>
<td>• Sugar</td>
<td></td>
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</tr>
<tr>
<td><strong>Honey</strong></td>
<td>3 kcal/g</td>
<td>Made from sucrose. Contains nectar of flowering plants. Made by bees. Sucrose is fructose + glucose; however, honey contains more calories than sucrose because honey is denser.</td>
<td><em>Considered safe for baking and cooking.</em> Infants under twelve months old should not be given honey because their digestive tracts cannot handle the bacteria found in honey. Older children and adults are immune to these effects. Honey contains some harmful bacteria that can cause fatal food poisoning in infants.</td>
</tr>
<tr>
<td>Sweeteners with Trade Name</td>
<td>Calories</td>
<td>Source/Origin</td>
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<tr>
<td><strong>HFCS</strong></td>
<td></td>
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<tr>
<td>• high fructose corn syrup</td>
<td>Dry form: 4 kcal/g; Liquid form: 3 kcal/g</td>
<td>Corn is milled to produce corn starch, then the corn starch is further processed to yield corn syrup.</td>
<td></td>
</tr>
<tr>
<td><strong>Sugar Alcohols</strong></td>
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<tr>
<td>• Sorbitol</td>
<td>2–4 kcal/g.</td>
<td>Sugar alcohols.</td>
<td>Less likely to cause tooth decay than sucrose.</td>
</tr>
<tr>
<td>• Xylitol</td>
<td>Not calorie free</td>
<td>Sorbitol is derived from glucose.</td>
<td>Sugar alcohols have a laxative effect.</td>
</tr>
<tr>
<td>• Mannitol</td>
<td></td>
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<td></td>
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</tbody>
</table>

**Regulation**

Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA. The FDA regulates artificial sweeteners along with other food additives, which number in the thousands. The FDA is responsible for determining whether a food additive presents "a reasonable certainty of no harm" to consumers when...
used as proposed. The FDA uses the best scientific evidence available to make the statement of no harm, but it does declare that science has its limits and that the "FDA can never be absolutely certain of the absence of any risk from the use of any substance." US Food and Drug Administration. "Food Ingredients and Colors." Accessed September 30, 2011. http://www.fda.gov/food/foodingredie...ucm094211.htm. The FDA additionally has established ADIs for artificial sweeteners. The ADIs are the maximum amount in milligrams per kilogram of body weight considered safe to consume daily (mg/kg bw/day) and incorporates a large safety factor. The following list contains the artificial sweeteners approved for use in foods and beverages in the United States, and their ADIs:

- Acesulfame potassium (Sunett, Sweet One). ADI = 15 mg/kg bw/day
- Aspartame (Equal, NutraSweet). ADI = 50 mg/kg bw/day
- Neotame. ADI = 18 mg/kg bw/day
- Saccharin (SugarTwin, Sweet'N Low). ADI = 5 mg/kg bw/day
- Sucralose (Splenda). ADI = 5 mg/kg bw/day

**Carbohydrates in a Kernel**

Referring back to the wheat kernel mentioned at the opening of this chapter, recall that all components of the wheat kernel are required in order to build an optimal healthy diet. The endosperm provides the carbohydrates, and the bran and germ contain the majority of protein, vitamins, minerals, and fiber. Eating foods made with whole grains provides a better nutritional punch for your health. Once whole grains are processed and refined, enrichment in only a few of these removed nutrients does not offset the gain from consuming whole-grain products. Other dietary sources of carbohydrates that maximize nutrient uptake are vegetables, fruits, beans, and low-fat dairy products. To avoid compromising your health, do not consume excessive amounts of carbohydrate foods that contain added sugars, or that are high in sodium and saturated fat. Processed foods contain all of these ingredients in an unwelcome nutrient package that negatively impacts health. Sugar substitutes provide one avenue of decreasing the intake of fast-releasing carbohydrates, but there are others. Know that consumer demand for healthy carbohydrate choices is on the rise, so in the future you can expect decreased prices, more variety of whole-grain products, and less added sugars.

**The Bottom Line**

*Choose more slow-releasing carbohydrates, eat more fiber, and reduce consumption of foods high in added sugars.*

**Key Takeaways**

- In the food industry both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes. The differences in chemical structure between the different carbohydrates confer their many different functional uses in foods.
- Due to the health consequences of consuming too many added sugars, sugar substitutes are widely used in many foods and beverages.
- Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. However, the most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion.
• Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA.

Discussion Starters

1. Conduct a taste test of sugar and its substitutes. What do your taste buds tell you? Do you prefer foods with sugar substitutes or the real thing?

2. Have a class discussion on the safety of aspartame. To fuel the debate, read the FDA’s report and watch the reactionary video, “Aspartame, Brain Cancer, and the FDA Approval Process.”

http://www.fda.gov/Food/FoodIngredie.../ucm208580.htm

Aspartame, Brain Cancer, and the FDA Approval Process
(click to see video)