

The Carbohydrates: Sugars, Starches, and Fibers

I. The Chemist's View of **Carbohydrates**

Carbohydrates are made of carbon, hydrogen and oxygen atoms. These atoms form chemical bonds that follow the laws of nature.

II. The **Simple Carbohydrates**

The six simple carbohydrates include the monosaccharides (glucose, fructose and galactose) and the disaccharides (sucrose, maltose and lactose). Monosaccharides are similar in numbers and kinds of atoms but differ in their arrangement and sweetness. Disaccharides are formed by condensation reactions and are broken down by hydrolysis reactions.

A. **Monosaccharides** are single sugars (most are **hexoses**).

1. **Glucose** serves as the essential energy source, and is commonly known as blood sugar or **dextrose**.
2. **Fructose** is the sweetest, occurs naturally in honey and fruits, and is added to many foods in the form of high-fructose corn syrup.
3. **Galactose** rarely occurs naturally as a single sugar.

B. **Disaccharides** are pairs of monosaccharides, one of which is always glucose

1. Condensation reactions link monosaccharides together.
2. Hydrolysis reactions split molecules and commonly occur during digestion.
3. **Maltose** consists of two glucose units. It is produced during the germination of seeds and fermentation.
4. **Sucrose** is fructose and glucose combined. It is refined from sugarcane and sugar beets, tastes sweet, and is readily available.
5. **Lactose** is galactose and glucose combined. It is found in milk and milk products.

III. The **Complex Carbohydrates** are few (**oligosaccharides**) or many (**polysaccharides**) glucose units bound/linked together in straight or branched chains.

A. **Glycogen**

1. Storage form of glucose in the body

2. Provides a rapid release of energy when needed

B. Starches

1. Storage form of glucose in plants
2. Found in grains, tubers, and legumes

C. **Dietary fibers** provide structure in plants, are very diverse, and cannot be broken down by human enzymes.

1. **Soluble fibers** are **viscous** and can be digested by intestinal bacteria (this property is also known as **fermentability**). These fibers are found in fruits and vegetables.
2. **Insoluble fibers** are nonviscous and are not digested by intestinal bacteria. These fibers are found in grains and vegetables.
3. Fiber Sources
 - a. Dietary fibers are found in plant foods.
 - b. *Functional fibers* are health-benefiting fibers that are added to foods or supplements.
 - c. *Total fiber* considers both dietary and functional fibers.
4. **Resistant starches** escape digestion and are found in legumes, raw potatoes and unripe bananas.
5. **Phytic acid** or **phytate** has a close association with fiber and binds some minerals.

IV. Digestion and Absorption of Carbohydrates

The body breaks down starches and sugars to short glucose chains called **dextrins**. They are then broken down into monosaccharides and the glucose is used for energy. Fiber slows glucose absorption and regulates the passage of food through the GI tract.

A. Carbohydrate Digestion

1. In the mouth, the salivary enzyme **amylase** begins to hydrolyze starch into short polysaccharides and maltose.
2. In the stomach, acid continues to hydrolyze starch while fiber delays gastric emptying and provides a feeling of fullness (**satiety**).
3. In the small intestine, pancreatic amylase among other enzymes (**maltase, sucrase, and lactase**) hydrolyzes starches to disaccharides and monosaccharides.
4. In the large intestine, fibers remain and attract water, soften stools and ferment.

B. Carbohydrate Absorption

1. Primarily takes place in the small intestine
 2. Glucose and galactose are absorbed by active transport.
 3. Fructose is absorbed by facilitated diffusion.

C. Lactose Intolerance

1. Symptoms include bloating, abdominal discomfort, and diarrhea.
2. Causes include **lactase deficiency** due to a natural decrease that occurs with aging or damaged intestinal villi.
3. Prevalence
 - a. Lowest in Scandinavians and northern Europeans
 - b. Highest in Southeast Asians and native North Americans
4. Dietary Changes
 - a. Increase consumption of milk products gradually.
 - b. Mix dairy with other foods.
 - c. Spread dairy intake throughout the day.
 - d. Use of acidophilus milk, yogurt, and **kefir** (fermented products)
 - e. Use of enzymes
 - f. Individualization of diets
 - g. Must be careful that vitamin and mineral deficiencies do not develop

V. Glucose in the Body

Through the study of sugars, known as **glycobiology**, researchers are uncovering many roles that glucose has in the body. These include glucose's interaction with protein, lipid, and cancer cells.

A. A Preview of Carbohydrate Metabolism

1. The body stores glucose as glycogen in liver and muscle cells.
2. The body uses glucose for energy if glycogen stores are available.
3. If glycogen stores are depleted, the body makes glucose from protein.
 - a. **Gluconeogenesis** is the conversion of protein to glucose.
 - b. **Protein-sparing action** is having adequate carbohydrate in the diet to prevent the breakdown of protein for energy.
4. Making **ketone bodies** from fat fragments
 - a. The accumulation of ketone bodies in the blood is called **ketosis**.
 - b. Ketosis upsets the **acid-base balance** in the body.
5. The body can use glucose to make body fat when carbohydrates are consumed excessively.

B. The Constancy of Blood Glucose

1. Maintaining Glucose Homeostasis
 - a. Low blood glucose may cause dizziness and weakness.
 - b. High blood glucose may cause fatigue.
 - c. Extreme fluctuations can be fatal.
2. The Regulating Hormones
 - a. **Insulin** moves glucose into the cells and helps to lower blood sugar levels.
 - b. **Glucagon** brings glucose out of storage and raises blood sugar levels.
 - c. **Epinephrine** acts quickly to bring glucose out of storage during times of stress.
3. Balance glucose within the normal range by eating balanced meals regularly with adequate complex carbohydrates.
4. Blood glucose can fall outside the normal range with hypoglycemia or diabetes.
5. **Diabetes**
 - a. **Type 1 diabetes** is the less common type with no insulin produced by the body.
 - b. **Type 2 diabetes** is the more common type where fat cells resist insulin.
 - c. **Prediabetes** is blood glucose that is higher than normal but below the diagnosis of diabetes.
6. **Hypoglycemia** is low blood glucose and can often be controlled by dietary changes.
7. **Glycemic response** is how quickly the blood glucose rises and elicits an insulin response.
 - a. **Glycemic index** classifies foods according to their potential for raising blood glucose
 - b. **Glycemic load** refers to a food's glycemic index and the amount of carbohydrate the food contains.
 - c. The benefit of the glycemic index is controversial.

VI. Health Effects and Recommended Intakes of Sugars

Sugar poses no major health problem except dental caries. Excessive intakes may displace nutrients and contribute to obesity. Consuming foods with **added sugars** should be limited. Naturally occurring sugars from fruits, vegetables and milk are acceptable sources.

A. Health Effects of Sugars – Foods with added sugars have sugars listed as a first ingredient. Sugars may include **brown sugar, confectioners' sugar, corn sweeteners, corn syrup, dextrose, granulated sugar, high-fructose corn syrup, honey, invert sugar, levulose, maple sugar, molasses, raw sugar, turbinado sugar and white sugar.**

1. Nutrient deficiencies may develop from the intake of empty calories.
 - a. Just because a substance is natural does not mean it is nutritious. (Example: honey)
2. **Dental caries** may be caused by bacteria residing in **dental plaque** and the length of time sugars have contact with the teeth.

B. Controversies Surrounding Sugars

1. Excessive sugar intake can contribute to the development of body fat.
2. Sugar may be able to alter blood lipid levels and contribute to heart disease in some.
3. There is no scientific evidence that sugar causes misbehavior in children and criminal behavior in adults.
4. There is a theory that sugar increases **serotonin** levels, which can lead to cravings and addictions.

C. Recommended Intakes of Sugars

1. The USDA Food Guide states that added sugars can be included in the diet as part of discretionary calories.
2. *Dietary Guidelines* state to limit intake of foods and beverages that are high in added sugars.
3. DRI suggest added sugars should contribute no more than 25% of a day's total energy intake.

VII. Health Effects and Recommended Intakes of Starch and Fibers

A diet rich in complex carbohydrate may help to control body weight and prevent heart disease, cancer, diabetes and GI disorders. It is recommended that people consume 45-65% of the daily total energy intake from carbohydrate.

A. Health Effects of Starch and Fibers

1. May be some protection from heart disease and stroke
 - a. Soluble fibers bind with bile and thereby lower blood cholesterol levels.
 - b. Fiber may also displace fat in the diet.
2. Reduce the risk of type 2 diabetes by decreasing glucose absorption

3. Enhance the health of the GI tract which can then block the absorption of unwanted particles
4. May protect against colon cancer by removing potential cancer-causing agents from the body
5. Promote weight control because complex carbohydrates provide less fat and added sugar.
6. Harmful effects of excessive fiber intake
 - a. Displaces energy and nutrient-dense foods
 - b. Abdominal discomfort and distention
 - c. May interfere with nutrient absorption

B. Recommended Intakes of Starch and Fibers

1. RDA for carbohydrate is 130 g per day, or 45-65% of energy intake.
2. Daily Values is 300 grams per day.
3. *Dietary Guidelines* encourage a variety of whole grains, vegetables, fruits and legumes daily.
4. *Healthy People 2010* recommends six servings of grains and five servings of fruits and vegetables.
5. Fiber
 - a. FDA recommends 25 grams for a 2,000-kcalorie diet.
 - b. DRI at 14 g per 1000 kcalorie intake (28 grams for a 2,000 kcalorie diet)
 - c. American Dietetic Association recommends 20-35 g per day.
 - d. World Health Organization suggests no more than 40 g per day.

C. From Guidelines to Groceries

1. Grains – encourage whole grains
2. Vegetables – starchy and nonstarchy vegetables differ in carbohydrate content
3. Fruits – vary in water, fiber and sugar content
4. Milks and Milk Products – contain carbohydrate; cheese is low
5. Meat and Meat Alternates – meats are low but nuts and legumes have some carbohydrate
6. Food labels list grams of carbohydrate, fiber and sugar; starch grams can be calculated.

VIII. Highlight: Alternatives to Sugar

People may find it pleasing to replace sugar with **artificial sweeteners** or **sugar replacers**. This may help to control calories and limit sugar.

A. Artificial Sweeteners (also called **nonnutritive sweeteners**)

1. **Saccharin**

- a. Used primarily in soft drinks and as a tabletop sweetener
- b. Rapidly excreted in the urine
- c. Does not accumulate in the body
- d. Has been removed from list of cancer-causing substances

2. **Aspartame**

- a. General purpose sweetener
- b. Warning about phenylalanine for those with PKU
- c. Controversial finding that aspartame may have caused cancer in rats
- d. Excessive intake should be avoided by those with epilepsy.

3. **Acesulfame-K (acesulfame potassium)**

- a. Research confirms safety

4. **Sucralose**

- a. Made from sugar
- b. Passes through digestive tract

5. **Neotame**

- a. Most recent on the market
- b. Very sweet
- c. Phenylalanine not an issue

6. **Tagatose**

- a. Used for foods and beverages
- b. Provides less calories than sugar
- c. High doses can cause flatulence and loose stools.

7. **Alitame and Cyclamate**

- a. Pending FDA approval
- b. Approved in other countries

8. **Acceptable Daily Intake (ADI)** is the level of consumption, maintained every day and still safe by a wide margin. Moderation and variety are still recommended.

9. Artificial Sweeteners and Weight Control

- a. Much research still being done
- b. Using artificial sweeteners will not automatically reduce energy intake.

B. **Stevia** – An Herbal Alternative

1. Lacks research

2. Classified as a dietary supplement
3. Not required to have testing and FDA approval

C. **Sugar Replacers**

1. Also called **nutritive sweeteners**, sugar alcohols, and polyols
2. Maltitol, mannitol, sorbitol, xylitol, isomalt, and lactitol
3. Absorbed more slowly and metabolized differently in the body
4. Low glycemic response
5. Side effects include GI discomfort