Carbohydrates

Sugars, Starches, and Fibers

Chapter 4
Introduction

- Brain
  - Glucose
- Muscles
  - Glucose
  - Glycogen
  - Fat
- Sources of carbohydrates
  - Whole grains, vegetables, legumes, fruits, milk
- “Fattening” – mistaken thinking
Chemist’s View of Carbohydrates

- **Simple Carbohydrates**
  - **Monosaccharides** - single sugars
    - Glucose
    - Fructose
    - Galactose
  - **Disaccharides** - pairs of monosaccharides
    - Maltose
    - Sucrose
    - Lactose
- **Complex Carbohydrates** - chains of monosaccharides
  - **Polysaccharides**
    - Starches and fibers
Chemist’s View of Carbohydrates

Each atom has a characteristic number of bonds it can form with other atoms.

Notice that in this simple molecule of ethyl alcohol, each H has one bond, O has two, and each C has four.
Chemist’s View of Carbohydrates

- **Monosaccharides** are single sugars
- All contain $\text{C}_6\text{H}_{12}\text{O}_6$
  - **Glucose:**
    - Essential energy source
    - Blood sugar
    - Part of every disaccharide
  - **Fructose:**
    - Sweetest
    - Occurs naturally in honey and fruits
    - Added to many foods in the form of high-fructose corn syrup.
  - **Galactose**
    - Occurs naturally as a single sugar rarely
Chemical Structure of Glucose

The lines representing some of the bonds and the carbons at the corners are not shown.

Now the single hydrogens are not shown, but lines still extend upward or downward from the ring to show where they belong.

Another way to look at glucose is to notice that its six carbon atoms are all connected.

In this and other illustrations throughout this book, glucose is represented as a blue hexagon.
The Monosaccharides

Fructose

Glucose

Galactose
Chemist’s View of Carbohydrates

- **Disaccharides:**
  - Pairs of monosaccharides
  - One of which is always glucose

- **Maltose:**
  - consists of two glucose units.

- **Sucrose:**
  - fructose and glucose combined.
  - refined from sugarcane and sugar beets
  - tastes sweet, and is readily available.

- **Lactose**
  - galactose and glucose combined
  - found in milk and milk products.
Simple Carbohydrates

- **Condensation:**
  - Reactions that link monosaccharides together.

- **Hydrolysis:**
  - Reactions that split molecules
  - Commonly occur during digestion.
Condensation and Hydrolysis of a Disaccharide

Condensation

An OH group from one glucose and an H atom from another glucose combine to create a molecule of H₂O.

Hydrolysis

The disaccharide maltose splits into two glucose molecules with H added to one and OH to the other (from the water molecule).

http://nutrition.jbpub.com/animations/animations.cfm?id=6&debug=0

http://nutrition.jbpub.com/animations/animations.cfm?id=7&debug=0
Other Chemical Structures

Galactose

Lactose (alpha form).

Glucose

Sucrose.

Fructose
Chemical Structure of Glucose

Monosaccharides

Glucose

Fructose

Galactose

(found only as a part of lactose)

Disaccharides

Maltose

Sucrose

Lactose
Chemist’s View of Carbohydrates

Polysaccharides -

Glycogen, Starch, Fiber

**Glycogen** -
- Storage form of glucose in the animal body
- Rapid release of energy when needed

**Starches** -
- Storage form of glucose in plants
- Found in grains, tubers and legumes
Complex Carbohydrates
Glycogen and Starch Compared

**Glycogen**
A glycogen molecule contains hundreds of glucose units in highly branched chains. Each new glycogen molecule needs a special protein for the attachment of the first glucose (shown here in red).

**Starch**
A starch molecule contains hundreds of glucose molecules in either occasionally branched chains (amylopectin) or unbranched chains (amylose).
The Complex Carbohydrates

- **Dietary fibers**
  - Provide structure in plants
  - Found in all plant foods
    - Vegetables, fruits, whole grains, legumes
  - Cannot be broken down by human enzymes
Chemist’s View of Carbohydrates

- Polysaccharides
  - Fibers
    - Soluble fibers –
      - Form gels, fermentable
      - Found in oats, barley, legumes, citrus
      - Help lower blood cholesterol and glucose
    - Insoluble fibers –
      - Found in whole grains, vegetables
      - Promote bowel movements, alleviate constipation
  - Functional fibers
  - Resistant starches
  - Phytic acid
    - Binds with minerals (zinc, iron, calcium) and prevents absorption
A Whole Wheat Plant and a Single Kernel
Fibers

- **Cellulose**-  
  - Plant cell walls  
  - Found in fruits, vegetables and legumes

- **Hemicellulose**-  
  - Main constituent of cereal fibers

- **Pectins**-  
  - Found in vegetables, fruits  
  - Used in food industry as a thickener

- **Gums and Mucilages**-  
  - Secreted from plants  
  - Thickened processed foods

- **Lignin**-  
  - Nonpolysaccharide fiber  
  - Woody part of vegetables, carrots, small seeds
Carbohydrate Digestion

- Ultimate goal
  - Glucose for absorption and use
- Hydrolysis via enzymes
- Mouth
  - Amylase
- Stomach
  - Stomach acid & protein-digesting enzymes
  - Role of fiber
Carbohydrate Digestion in the GI Tract

**Starch**
- **Mouth and salivary glands**: The salivary glands secrete saliva into the mouth to moisten the food. The salivary enzyme amylase begins digestion:
  - Starch → Amylase → Small polysaccharides, maltose

**Fiber**
- **Mouth**: The mechanical action of the mouth crushes and tears fiber in food and mixes it with saliva to moisten it for swallowing.

**Stomach**
- **Stomach acid**: Inactivates salivary enzymes, halting starch digestion.
- **Stomach**: Fiber is not digested, and it delays gastric emptying.

**Small intestine and pancreas**
- **The pancreas produces an amylase**: That is released through the pancreatic duct into the small intestine:
  - Starch → Amylase → Small polysaccharides, maltose

**Small intestine**
- **Fiber**: Is not digested, and it delays absorption of other nutrients.

**Large intestine**
- **Most fiber passes intact through the digestive tract to the large intestine.** Here, bacterial enzymes digest fiber:
  - Some fiber → Bacterial enzymes → Short-chain fatty acids, gas
  - Fiber holds water; regulates bowel activity; and binds substances such as bile, cholesterol, and some minerals, carrying them out of the body.

**Intestinal cells absorb these monosaccharides.**
Carbohydrate Digestion

- Small intestine
  - Most carbohydrate digestion
  - Pancreatic amylase
  - Specific disaccharide enzymes
    - Maltase
    - Sucrase
    - Lactase
- Large intestine
  - Fibers
Carbohydrate in Food Becomes Glucose in the Body
Absorption of Monosaccharides

1. Monosaccharides, the end products of carbohydrate digestion, enter the capillaries of the intestinal villi.

2. Monosaccharides travel to the liver via the portal vein.

3. In the liver, galactose and fructose are converted to glucose.

Key:
- Glucose
- Fructose
- Galactose

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Carbohydrate Absorption

- Active transport
  - Glucose
  - Galactose
- Facilitated diffusion
  - Fructose
- Liver
  - Conversion of fructose and galactose
Digestion and Absorption of Carbohydrates

- **Lactose Intolerance**
  - **Symptoms:**
    - include bloating
    - abdominal discomfort
    - and diarrhea
  - **Causes:**
    - Lactase decreases with aging
    - damaged intestinal villi
  - **Prevalence**
    - Lowest in Scandinavians and northern Europeans
    - Highest in Southeast Asians and Native Americans, African Americans, Mediterranean peoples
Digestion and Absorption of Carbohydrates

- Lactose Intolerance - Dietary Changes

- Increase consumption of milk products gradually.
- Mix dairy with other foods.
- Spread dairy intake throughout the day.
- Use of acidophilus milk, yogurt, (fermented products)
- Use of enzymes
- Individualization of diets
- Potential nutrient deficiencies
  - Riboflavin, vitamin D, and calcium
# Lactose in Selected Foods

<table>
<thead>
<tr>
<th>Foods</th>
<th>Lactose (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole-wheat bread, 1 slice</td>
<td>0.5</td>
</tr>
<tr>
<td>Dinner roll, 1</td>
<td>0.5</td>
</tr>
<tr>
<td>Cheese, 1 oz</td>
<td></td>
</tr>
<tr>
<td>Cheddar or American</td>
<td>0.5</td>
</tr>
<tr>
<td>Parmesan or cream</td>
<td>0.8</td>
</tr>
<tr>
<td>Doughnut (cake type), 1</td>
<td>1.2</td>
</tr>
<tr>
<td>Chocolate candy, 1 oz</td>
<td>2.3</td>
</tr>
<tr>
<td>Sherbet, 1 c</td>
<td>4.0</td>
</tr>
<tr>
<td>Cottage cheese (low-fat), 1 c</td>
<td>7.5</td>
</tr>
<tr>
<td>Ice cream, 1 c</td>
<td>9.0</td>
</tr>
<tr>
<td>Milk, 1 c</td>
<td>12.0</td>
</tr>
<tr>
<td>Yogurt (low-fat), 1 c</td>
<td>15.0</td>
</tr>
</tbody>
</table>

NOTE: Yogurt is often enriched with nonfat milk solids, which increase its lactose content to a level higher than milk’s.
How do we store glucose?

Storing glucose as glycogen

- When you have adequate glucose supply-
  - Liver makes glycogen and stores it
  - When needed- Liver breaks glycogen into glucose and releases it into the bloodstream
- Liver stores 1/3 of the body’s total glycogen
- Muscle cells store the rest (2/3), which is used in exercise
Carbohydrate Metabolism

Using glucose for energy

- Fuels most of the body’s cells
- Glucose is converted to energy inside the cell
- Preferred energy source for the brain, nerve cells and developing red blood cells
Carbohydrate Metabolism

What if you don’t eat much carbohydrate?

- **Making glucose from protein**
  - Glucose is the preferred energy for brain cells, nerve cells, and developing red blood cells.
  - Glycogen stores last less than a day.
  - When the glucose supply is inadequate—
    - the body’s protein is broken down to make glucose via gluconeogenesis.

- Having adequate dietary carbohydrate can prevent this process.
Carbohydrate Metabolism

What happens with inadequate carbohydrate?
Making ketone bodies from fat fragments

- With inadequate carbohydrate, fat breakdown increases
- Fat fragments form ketone bodies
  - are then used for energy
- When ketone production exceeds use,
  - ketosis occurs, disturbing the body’s acid-base balance
- 50-100 grams of CHO are needed to prevent ketosis
Carbohydrate Metabolism

What about too much carbohydrate?

Converting Glucose to Fat

- When glycogen stores are full
  - Excess carbohydrate is converted to fat.
- The liver makes triglyceride (fat) from excess glucose, which is then stored in fat cells
Glucose in the Body

- The Constancy of Blood Glucose
- Maintaining Glucose Homeostasis
  - Cells depend on glucose for fuel (from intestines or liver)
  - Low blood glucose
    - may cause dizziness and weakness
  - High blood glucose
    - may cause fatigue.
  - Extreme fluctuations can be fatal.
- Normal blood glucose (fasting): 70-100 mg/dl
- Balanced meals help maintain normal blood glucose - Complex carbohydrates, fiber, protein, and fat
Maintaining Blood Glucose Homeostasis

1. When a person eats, blood glucose rises.

2. High blood glucose stimulates the pancreas to release insulin into the bloodstream.

3. Insulin stimulates the uptake of glucose into cells and storage as glycogen in the liver and muscles. Insulin also stimulates the conversion of excess glucose into fat for storage.

4. As the body’s cells use glucose, blood levels decline.

5. Low blood glucose stimulates the pancreas to release glucagon into the bloodstream.

6. Glucagon stimulates liver cells to break down glycogen and release glucose into the blood.

7. Blood glucose begins to rise.

Key:
- Glucose
- Insulin
- Glucagon
- Glycogen

The stress hormone epinephrine and other hormones also bring glucose out of storage.

High Blood Glucose: [http://nutrition.jbpub.com/animations/animations.cfm?id=8&debug=0](http://nutrition.jbpub.com/animations/animations.cfm?id=8&debug=0)

Low Blood Glucose: [http://nutrition.jbpub.com/animations/animations.cfm?id=9&debug=0](http://nutrition.jbpub.com/animations/animations.cfm?id=9&debug=0)
Glucose in the Body

- The Constancy of Blood Glucose
  - The Regulating Hormones
    - **Insulin**
      - moves glucose into the cells
      - helps to lower blood sugar levels.
    - **Glucagon**
      - brings glucose out of storage
      - raises blood sugar levels.
    - **Epinephrine**
      - acts quickly to bring glucose out of storage during times of stress.
Glucose in the Body

The Constancy of Blood Glucose

**Diabetes** - blood glucose remains high after a meal
- Type 1 diabetes
  - Less common type; pancreas fails to produce insulin
- Type 2 diabetes
  - Common type where cells resist insulin.

**Pre-diabetes**
- Glucose is higher than normal but below the diagnosis of diabetes.

**Hypoglycemia**
- Low blood glucose and can often be controlled by dietary changes.
Glucose in the Body

The Glycemic Response

How quickly the blood glucose rises after a person eats and how quickly it returns to normal

- Glycemic index classifies foods according to their potential for raising blood glucose.
- Glycemic load refers to a food’s glycemic index and the amount of carbohydrate the food contains.
- The benefit of the glycemic index is controversial.
Glycemic Index of Selected Foods

LOW

Peanuts, Soybeans, Cashews, cherries, Barley, Milk, kidney beans, garbanzo beans, Yogurt, Tomato juice, navy beans, apples, pears, Apple juice, Bran cereals, black-eyed peas, peaches, Grapes, Macaroni, carrots, green peas, baked beans, Rye bread, orange juice, Banana, Wheat bread, corn, pound cake, Ice cream, Raisins, white rice, Couscous, Watermelon, popcorn, bagel, Pumpkin, doughnut, Sports drinks, jelly beans, Cornflakes, Baked potato

HIGH

White bread

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Health Effects of Sugars

**Nutrient Deficiencies**

- Foods high in added sugar with few, if any, nutrients
  - Examples: candy, cake, soda
  - Difficult to meet nutrient needs and stay within kcalorie requirement

- Added sugars include:
  - honey, corn syrup, corn syrup solids, dextrose, corn sweetener, molasses, brown sugar, high fructose corn syrup, confectioners sugar, maltose, raw sugar, fructose

- Naturally occurring sugars from fruits, vegetables and milk are acceptable sources
Health Effects of Sugars

- **Obesity and Chronic Disease**
  - Increase in sugary beverages correlates with increase in kcalorie intake, body weight and chronic disease
    - Diabetes, hypertension, heart disease
  - Increase in added sugars in general, particularly fructose, may increase risk of heart disease
  - Role of high fructose corn syrup (HFCS)
The Empty Calories of Sugar

At first glance, honey, jelly, and brown sugar look more nutritious than plain sugar, but when compared with a person’s nutrient needs, none contributes anything to speak of. The cola beverage is clearly an empty-calorie item, too.

<table>
<thead>
<tr>
<th>Food</th>
<th>Energy (cal)</th>
<th>Protein (g)</th>
<th>Fiber (g)</th>
<th>Calcium (mg)</th>
<th>Magnesium (mg)</th>
<th>Potassium (mg)</th>
<th>Vitamin A (re)</th>
<th>Thiamin (mg)</th>
<th>Riboflavin (mg)</th>
<th>Niacin (mg)</th>
<th>Vitamin B6 (mg)</th>
<th>Folate (µg)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar (1 tbs)</td>
<td>45</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Honey (1 tbs)</td>
<td>64</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.1</td>
<td>0</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Molasses (1 tbs)</td>
<td>55</td>
<td>0</td>
<td>0</td>
<td>42</td>
<td>1.0</td>
<td>50</td>
<td>300</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Jelly (1 tbs)</td>
<td>49</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.0</td>
<td>1</td>
<td>12</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Brown sugar (1 tbs)</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0.2</td>
<td>3</td>
<td>31</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Cola beverage (12 fl oz)</td>
<td>152</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>0.1</td>
<td>4</td>
<td>4</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Daily Values</td>
<td>2,000</td>
<td>56</td>
<td>25</td>
<td>1,000</td>
<td>18.0</td>
<td>400</td>
<td>3,500</td>
<td>15.0</td>
<td>1,000</td>
<td>1.5</td>
<td>20.0</td>
<td>2.0</td>
<td>400</td>
</tr>
</tbody>
</table>
# Health Effects of Sugars

## Table 4-1: Sample Nutrients in Sugar and Other Foods

The indicated portion of any of these foods provides approximately 100 kcalories. Notice that for a similar number of kcalories and grams of carbohydrate, milk, legumes, fruits, grains, and vegetables offer more of the other nutrients than do the sugars.

<table>
<thead>
<tr>
<th>Foods</th>
<th>Size of 100 kcal Portion</th>
<th>Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Calcium (mg)</th>
<th>Iron (mg)</th>
<th>Vitamin A (µg)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk, 1% low-fat</td>
<td>1 c</td>
<td>12</td>
<td>8</td>
<td>300</td>
<td>0.1</td>
<td>144</td>
<td>2</td>
</tr>
<tr>
<td>Kidney beans</td>
<td>¾ c</td>
<td>20</td>
<td>7</td>
<td>30</td>
<td>1.6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Apricots</td>
<td>6</td>
<td>24</td>
<td>2</td>
<td>30</td>
<td>1.1</td>
<td>554</td>
<td>22</td>
</tr>
<tr>
<td>Bread, whole-wheat</td>
<td>1½ slices</td>
<td>20</td>
<td>4</td>
<td>30</td>
<td>1.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Broccoli, cooked</td>
<td>2 c</td>
<td>20</td>
<td>12</td>
<td>188</td>
<td>2.2</td>
<td>696</td>
<td>148</td>
</tr>
</tbody>
</table>

## Sugars

<table>
<thead>
<tr>
<th>Sugars</th>
<th>Size of Portion</th>
<th>Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Calcium (mg)</th>
<th>Iron (mg)</th>
<th>Vitamin A (µg)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar, white</td>
<td>2 tbs</td>
<td>24</td>
<td>0</td>
<td>trace</td>
<td>trace</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Molasses, blackstrap</td>
<td>2½ tbs</td>
<td>28</td>
<td>0</td>
<td>343</td>
<td>12.6</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Cola beverage</td>
<td>1 c</td>
<td>26</td>
<td>0</td>
<td>6</td>
<td>trace</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Honey</td>
<td>1½ tbs</td>
<td>26</td>
<td>trace</td>
<td>2</td>
<td>0.2</td>
<td>0</td>
<td>trace</td>
</tr>
</tbody>
</table>
Dental Caries

Bacteria in the mouth ferment sugar and produce acid which dissolves tooth enamel.

Related to:
- How long sugar stays in the mouth
- How often teeth are exposed
- Sticky foods

Bacteria produce acid 20-30 minutes after each exposure.
Health Effects of Sugars

- Prevention of Dental Caries:
  - Eat sugary foods with meals
  - Limit between meal sugary snacks
  - Brush and floss regularly
  - Rinse with water if unable to brush
  - Regular dental check-ups
Recommended Intakes of Sugars

- **Dietary Guidelines**
  - Reduce the intake of kcalories from added sugars

- **DRI**
  - Added sugars
    - No more than 25% of day’s total energy
    - Impact on other food groups

- **WHO and FAO recommendation**
  - Restrict added sugar intake to less than 10% of total kcalories (energy) intake
Naturally occurring sugars from fruits, vegetables and milk are acceptable sources.

An average person in the U.S. consumes about 105 lbs of added sugar per year or about 30 tsp of added sugar per day.
Recommended Intakes of Sugar

1 tsp sugar =
- 1 tsp brown sugar
- 1 tsp candy
- 1 tsp corn sweetener or corn syrup
- 1 tsp honey
- 1 tsp jam or jelly
- 1 tsp maple sugar or maple syrup
- 1 tsp molasses
- 1 ½ tsp carbonated soda
- 1 tbsp catsup
Recommended Intakes of Sugar

- Each of these provide about 500 kcalories
  - 40 oz cola
  - ½ cup honey
  - 125 jelly beans
  - 23 marshmallows
  - 30 teaspoons of sugar
Alternative Sweeteners

- Artificial sweeteners
  - Non-nutritive sweeteners
  - Large doses and adverse effects
- Stevia – an herbal product
  - Generally recognized as safe (GRAS)
- Sugar alcohols
  - Provide kcalories
  - Benefits and side effects
<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Chemical Composition</th>
<th>Body's Response</th>
<th>Relative Sweetness&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Energy (kcal/g)</th>
<th>Acceptable Daily Intake (ADI) and (Estimated Equivalent)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Approval Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acesulfame potassium or Acesulfame K&lt;sup&gt;c&lt;/sup&gt; (AY-sul-fame)</td>
<td>Potassium salt</td>
<td>Not digested or absorbed</td>
<td>200</td>
<td>0</td>
<td>15 mg/kg body weight&lt;sup&gt;a&lt;/sup&gt; (30 cans diet soda)</td>
<td>Approved for use in the United States and Canada</td>
</tr>
<tr>
<td>Aspartame&lt;sup&gt;a&lt;/sup&gt; (ah-SPAR-tame or ASS-par-tame)</td>
<td>Amino acids (phenylalanine and aspartic acid) and a methyl group</td>
<td>Digested and absorbed</td>
<td>200</td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50 mg/kg body weight&lt;sup&gt;a&lt;/sup&gt; (18 cans diet soda)</td>
<td>Approved for use in the United States and Canada; warning for PKU</td>
</tr>
<tr>
<td>Cyclamate (SIGH-kl-a-mate)</td>
<td>Sodium or calcium salt of cyclamic acid</td>
<td>Incompletely absorbed; absorbed cyclamate is excreted unchanged; unabsorbed cyclamate may be metabolized by bacteria in the GI tract</td>
<td>30</td>
<td>0</td>
<td>11 mg/kg body weight&lt;sup&gt;a&lt;/sup&gt; (8 cans of diet soda)</td>
<td>Approval pending in the United States; approved for use in Canada</td>
</tr>
<tr>
<td>Neotame (NEE-oh-tame)</td>
<td>Aspartame with an additional side group attached</td>
<td>Not digested or absorbed</td>
<td>8000</td>
<td>0</td>
<td>18 mg/day</td>
<td>Approved for use in the United States; no warning for PKU</td>
</tr>
<tr>
<td>Saccharin&lt;sup&gt;b&lt;/sup&gt; (SAK-ah-ren)</td>
<td>Benzoic sulfimide</td>
<td>Rapidly absorbed and excreted</td>
<td>450</td>
<td>0</td>
<td>5 mg/kg body weight&lt;sup&gt;a&lt;/sup&gt; (10 packets of sweetener)</td>
<td>Approved for use in the United States; restricted use as a tabletop sweetener in Canada</td>
</tr>
<tr>
<td>Sucralose&lt;sup&gt;1&lt;/sup&gt; (SUE-krä-lose)</td>
<td>Sucrose with Cl atoms instead of OH groups</td>
<td>Not digested or absorbed</td>
<td>600</td>
<td>0</td>
<td>5 mg/kg body weight&lt;sup&gt;a&lt;/sup&gt; (6 cans of diet soda)</td>
<td>Approved for use in the United States and Canada</td>
</tr>
<tr>
<td>Tagatose&lt;sup&gt;1&lt;/sup&gt; (TAG-ah-tose)</td>
<td>Monosaccharide similar in structure to fructose; naturally occurring or derived from lactose</td>
<td>Mostly not absorbed; some short-chain fatty acids absorbed</td>
<td>0.8</td>
<td>1.5</td>
<td>7.5 mg/day</td>
<td>GRAS&lt;sup&gt;a&lt;/sup&gt; approved; does not promote dental caries and may carry a health claim</td>
</tr>
</tbody>
</table>

**Herbal Sweetener**

| Stevia<sup>1</sup> (STEE-vee-ah) | Glycosides found in the leaves of the Stevia rebaudiana herb | Digested and absorbed | 300                          | 0              | 4 mg/kg body weight<sup>a</sup>                                   | GRAS<sup>a</sup> approved                                                   |

---

<sup>a</sup>Relative sweetness is determined by comparing the approximate sweetness of a sugar substitute with the sweetness of pure sucrose, which has been defined as 1.0. Chemical structure, temperature, acidity, and other flavors of the foods in which the substance occurs all influence relative sweetness.

<sup>b</sup>The Acceptable Daily Intake (ADI) is the estimated amount of a sweetener that individuals can safely consume each day over the course of a lifetime without adverse effects. The Estimated Equivalent is based on a person weighing 70 kg (154 lb).

<sup>c</sup>Marketed under the trade names Sunett, Sweet One.

<sup>d</sup>Recommendations from the World Health Organization limit acesulfame-K intake to 9 mg per kilogram of body weight per day.

<sup>e</sup>Marketed under the trade names NutraSweet, Equal, NatraTaste, Canderies.

<sup>f</sup>Aspartame provides 4 kcal per gram, as does protein, but because so little is used, its energy contribution is negligible. In powdered form, it is sometimes mixed with lactose, however, so a 1 g packet may provide 4 kcal.

<sup>g</sup>Marketed under the trade names Sweet'N Low, Necta Sweet.

<sup>h</sup>Marketed under the trade names Splenda, SucraPlus.

<sup>i</sup>Marketed under the trade names Nutrasweet, NutraSweet, Tagatose.

<sup>j</sup>GRAS = food additives that are generally recognized as safe. The GRAS list is subject to revision as new facts become known.

<sup>k</sup>Marketed under the trade names Stevia, Pureva, Truvia, Honey Leaf.
TABLE 4-2  Alternative Sweeteners (continued)

<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Chemical Composition</th>
<th>Body's Response</th>
<th>Relative Sweetness*</th>
<th>Energy (kcal/g)</th>
<th>Acceptable Daily Intake (ADI) and Estimated Equivalentb</th>
<th>Approval Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isomalt</td>
<td>Sugar alcohol</td>
<td>Partially absorbed in small intestine; unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract</td>
<td>0.5</td>
<td>2.0</td>
<td>—m</td>
<td>GRAS approved</td>
</tr>
<tr>
<td>Lactitol</td>
<td>Sugar alcohol</td>
<td>Partially absorbed in small intestine; unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract</td>
<td>0.4</td>
<td>2.0</td>
<td>—m</td>
<td>GRAS approved</td>
</tr>
<tr>
<td>Maltitol</td>
<td>Sugar alcohol</td>
<td>Partially absorbed in small intestine; unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract</td>
<td>0.9</td>
<td>2.1</td>
<td>—m</td>
<td>GRAS approved</td>
</tr>
<tr>
<td>Mannitol</td>
<td>Sugar alcohol</td>
<td>Partially absorbed in small intestine; unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract</td>
<td>0.7</td>
<td>1.6</td>
<td>—m</td>
<td>Approved for use in the United States</td>
</tr>
<tr>
<td>Sorbitol</td>
<td>Sugar alcohol</td>
<td>Partially absorbed in small intestine; unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract</td>
<td>0.5</td>
<td>2.6</td>
<td>—m</td>
<td>GRAS approved</td>
</tr>
<tr>
<td>Xylitol</td>
<td>Sugar alcohol</td>
<td>Partially absorbed in small intestine; unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract</td>
<td>1.0</td>
<td>2.4</td>
<td>—m</td>
<td>Approved for use in the United States</td>
</tr>
</tbody>
</table>

*Relative sweetness is determined by comparing the approximate sweetness of a sugar substitute with the sweetness of pure sucrose, which has been defined as 1.0. Chemical structure, temperature, acidity, and other flavors of the foods in which the substance occurs all influence relative sweetness.

Based on a person weighing 70 kg (154 lb).

Recommended for use in the United States.

Recommended for use in Europe and Canada.

Recommended for use in the United States.

*An ADI is “not specified” for sugar alcohols, indicating the highest safety category. They require a warning label, however, that states “Excess consumption may have a laxative effect.” If reasonable consumption could result in the daily ingestion of 50 g of a sugar alcohol.

Table 4-2b, p. 117
Health Effects and Recommended Intakes of Starch and Fibers

- **Heart Disease**
  - High Fiber Diet may be some protection from heart disease and stroke
    - Whole grains, legumes, vegetables, fruit
    - Soluble fibers (oats, barley, legumes) bind with bile acids (which are made from cholesterol) and thereby lower blood cholesterol levels.
    - Eating 5-10 grams of soluble fiber daily reduces blood cholesterol by 3-5%
Health Effects of Starch and Fiber

- **Diabetes**
  - Reduce the risk of type 2 diabetes by decreasing glucose absorption

- **GI Health**
  - Enhance the health of the GI tract
  - Insoluble fiber increases stool weight and reduces transit time
  - Alleviate constipation
  - Prevent hemorrhoids
  - Prevent diverticula
Health Effects and Recommended Intakes of Starch and Fibers

- **Cancer**
  - Protects against colon cancer
  - Binding and removing potential cancer-causing agents

- **Weight Control**
  - Provide less fat and added sugar
  - Feeling of fullness and delaying hunger
  - Decreased food intake
# Characteristics, Sources, & Health Effects of Fibers

## Table 4-5: Characteristics, Sources, and Health Effects of Fibers

<table>
<thead>
<tr>
<th>Major Food Sources</th>
<th>Types of Fibers</th>
<th>Actions in the Body</th>
<th>Probable Health Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Viscous, Soluble, More Fermentable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley, oats, oat bran, rye, fruits (apples, citrus), legumes (especially young green peas and black-eyed peas), seaweeds, seeds and husks, many vegetables, fibers used as food additives</td>
<td>Gums</td>
<td>Lower blood cholesterol by binding bile</td>
<td>Lower risk of heart disease</td>
</tr>
<tr>
<td></td>
<td>Pectins</td>
<td>Slow glucose absorption</td>
<td>Lower risk of diabetes</td>
</tr>
<tr>
<td></td>
<td>Psyllium&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Slow transit of food through upper GI tract</td>
<td>Lower risk of colon and rectal cancer</td>
</tr>
<tr>
<td></td>
<td>Some hemicellulose</td>
<td>Hold moisture in stools, softening them</td>
<td>Increased satiety, and may help with weight management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yield small fat molecules after fermentation that the colon can use for energy</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase satiety</td>
<td></td>
</tr>
</tbody>
</table>

| **Nonviscous, Insoluble, Less Fermentable** | | | |
| Brown rice, fruits, legumes, seeds, vegetables (cabbage, carrots, brussels sprouts), wheat bran, whole grains, extracted fibers used as food additives | Cellulose | Increase fecal weight and speed fecal passage through colon | Alleviate constipation |
| | Lignins | Provide bulk and feelings of fullness | Lower risk of diverticulosis, hemorrhoids, and appendicitis |
| | Resistant starch | | Lower risk of colon and rectal cancer |
| | Hemicellulose | | |

<sup>a</sup>Psyllium, a soluble fiber derived from seeds, is used as a laxative and food additive.
Health Effects of a High Fiber Diet

- **Excessive Fiber**
  - Abdominal discomfort, gas, diarrhea, obstruction

- **Recommendations:**
  - Increase fiber gradually over several weeks
  - Increase fluids
  - Eat a variety-fruits, vegetables, legumes, whole grain breads and cereals
Recommended Intakes of Starch & Fibers

- DRI for carbohydrates (AMDR)
  - 45 to 65% of energy requirement
- RDA for carbohydrates
  - 130 grams per day
  - DV is 300 grams per day
Health Effects and Recommended Intakes of Starch and Fibers

- **Recommended Intakes of Fiber**
  - FDA sets the Daily Value:
    - 25 grams for a 2,000-kcalorie diet
    - Based on 11.5 grams per 1000-kcalories
  - DRI is 14 g per 1000 kcalorie intake
    - (28 grams for a 2,000 kcalorie diet)
  - No Upper Level
# Fiber in Selected Foods

<table>
<thead>
<tr>
<th>TABLE 4-6 Fiber in Selected Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grains</strong></td>
</tr>
<tr>
<td>Whole-grain products provide about 1 to 2 g (or more) of fiber per serving:</td>
</tr>
<tr>
<td>- 1 slice whole-wheat, pumpernickel, rye bread</td>
</tr>
<tr>
<td>- 1 oz ready-to-eat cereal (100% bran cereals contain 10 g or more)</td>
</tr>
<tr>
<td>- ½ c cooked barley, bulgur, grits, oatmeal</td>
</tr>
</tbody>
</table>

**Vegetables**

Most vegetables contain about 2 to 3 g of fiber per serving:

- 1 c raw bean sprouts
- ½ c cooked broccoli, brussels sprouts, cabbage, carrots, cauliflower, collards, corn, eggplant, green beans, green peas, kale, mushrooms, okra, parsnips, potatoes, pumpkin, spinach, sweet potatoes, swiss chard, winter squash
- ½ c chopped raw carrots, peppers
Fibers in Selected Foods

**Fruit**

Fresh, frozen, and dried fruits have about 2 g of fiber per serving:
- 1 medium apple, banana, kiwi, nectarine, orange, pear
- ½ c applesauce, blackberries, blueberries, raspberries, strawberries
- Fruit juices contain very little fiber

**Legumes**

Many legumes provide about 6 to 8 g of fiber per serving:
- ½ c cooked baked beans, black beans, black-eyed peas, kidney beans, navy beans, pinto beans

Some legumes provide about 5 g of fiber per serving:
- ½ c cooked garbanzo beans, great northern beans, lentils, lima beans, split peas

NOTE: Appendix H provides fiber grams for more than 2000 foods.
### Whole Grain Whole Wheat

**Nutrition Facts**

<table>
<thead>
<tr>
<th>Serving size</th>
<th>Amount per serving</th>
<th>Calories</th>
<th>Calories from Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 slice (30g)</td>
<td></td>
<td>90</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Daily Value*</th>
<th>Total Fat</th>
<th>1.5g</th>
<th>2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans Fat</td>
<td>0g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sodium | 135mg | 6% |
| Total Carbohydrate | 15g | 5% |
| Dietary fiber | 2g | 8% |
| Sugars | 2g | |

**-made from:** Unbromated stone ground 100% whole wheat flour, water, crushed wheat, high fructose corn syrup, partially hydrogenated vegetable shortening (soybean and cottonseed oils), raisin juice concentrate, wheat gluten, yeast, whole wheat flakes, unsulfured molasses, salt, honey, vinegar, enzyme modified soy lecithin, cultured whey, unbleached wheat flour and soy lecithin.

### Natural Wheat Bread

**Nutrition Facts**

<table>
<thead>
<tr>
<th>Serving size</th>
<th>Amount per serving</th>
<th>Calories</th>
<th>Calories from Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 slice (30g)</td>
<td></td>
<td>90</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Daily Value*</th>
<th>Total Fat</th>
<th>1.5g</th>
<th>2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans Fat</td>
<td>0g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sodium | 220mg | 9% |
| Total Carbohydrate | 15g | 5% |
| Dietary fiber less than 1g | 2% |
| Sugars | 2g | |

**-ingredients:** unbleached enriched wheat flour (malted barley flour, niacin, reduced iron, thiamin mononitrate (vitamin b1), riboflavin (vitamin b2), folic acid), water, high fructose corn syrup, molasses, partially hydrogenated soybean oil, yeast, corn flour, salt, ground caraway, wheat gluten, calcium propionate (preservative), monoglycerides, soy lecithin.

### Multi-fiber Low Carbohydrate

**Nutrition Facts**

<table>
<thead>
<tr>
<th>Serving size</th>
<th>Amount per serving</th>
<th>Calories</th>
<th>Calories from Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 slice (30g)</td>
<td></td>
<td>60</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Daily Value*</th>
<th>Total Fat</th>
<th>1.5g</th>
<th>2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans Fat</td>
<td>0g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sodium | 135mg | 6% |
| Total Carbohydrate | 9g | 3% |
| Dietary fiber | 3g | 12% |
| Sugars | 0g | |

**-ingredients:** unbleached enriched wheat flour, water, wheat gluten, cellulose, yeast, soybean oil, cracked wheat, salt, barley, natural flavor preservatives, monocalcium phosphate, millet, corn, oats, soybeans, brown rice, flaxseed, sucralose.
<table>
<thead>
<tr>
<th></th>
<th>Calories</th>
<th>Carbohydrate (g)</th>
<th>Fiber (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 c fresh pineapple chunks</td>
<td>76</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>1 c unsweetened pineapple juice</td>
<td>140</td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>1 c fresh orange segments</td>
<td>85</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>1 c fresh orange juice</td>
<td>111</td>
<td>26</td>
<td>1</td>
</tr>
<tr>
<td>1 c apple (raw, peeled, slices)</td>
<td>65</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>1 c apple juice (clear)</td>
<td>116</td>
<td>29</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
Carbs, kCalories, and Controversies

Highlight 4
Carbohydrates’ kCalorie Contributions

- Obesity and the link to carbohydrates
  - Total daily energy intakes have increased
  - Activity levels have declined
  - Increase in body weight

- Epidemiological studies
  - Inverse relationship between carbs & weight

- Weight loss
  - kCalorie intake
Sugars’ Share in the Problem

- Increase in consumption of added sugars
  - High-fructose corn syrup
  - Body fat stores
- Carbohydrate cravings
  - Self-imposed labeling of foods
- Carbohydrate addictions
  - Not physiological or pharmacological
Energy Nutrients over Time

Key:
- Blue: Carbohydrate
- Yellow: Fat
- Pink: Protein

Graph showing daily intake (% kcal/day) over different years:
- 1977–1978
- 1987–1988
- 1994–1996
- 2005–2006
- 2007–2008

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Daily Energy Intake & Increases in Adult Body Weight over Time

![Graph showing energy intake and body weight changes over time.](image-url)

**Key:**
- **kCalories**
- **Men**
- **Women**
Sugars’ Share in the Problem

- Excess sugar in the diet is associated with increased body fat
- Simple to swallow
  - Sweetened beverages
- Appetite control
  - Fructose and insulin
    - Flaws in plausibility
  - Food form – liquid or solid