Chapter 4

The Carbohydrates - Sugar, Starch, Glycogen, and Fiber

PowerPoint Lectures for
Nutrition: Concepts and Controversies, eleventh edition
Frances Sizer and Ellie Whitney

Lectures by Judy Kaufman, Ph.D.

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What do you think of when you hear the word “carbohydrates”? 
Introduction

Carbohydrates

- Name means “carbon and water (hydrate)”
- Chemical short hand CHO
Carbohydrates

- ideal nutrients to meet your body’s needs
- feeds your brain and nervous system
- keeps digestive system fit
- helps to keep your body **LEAN** *(w/in calorie limits)*
What are the 2 types of carbs?
2 Types of Carbs

1. **simple carbs** - sugars, “bad carbs” :

2. **complex carbs** (polysaccharides) – starch or fiber, “good carbs”
Where do carbohydrates come from?

**Photosynthesis:** process by which green plants make carbs.

**You need:**

1. **chlorophyll** (green pigment)
2. **sunlight**

**Process**

1. H2O (water) absorbed by roots gives hydrogen & oxygen
2. CO2 (carbon dioxide gas) absorbed by leaves gives carbon & oxygen

**Result**

Sun + water + carbon dioxide = glucose (single sugar)
What happens to the glucose (sugar) that the plant made?
Answer

1. Used for energy by the plant itself
   • Work done by the cells of the stem, roots, flowers, fruits,

2. Stored in a fruit or vegetable or seed for use by animals or people.
6 sugar molecules are important in nutrition

- **Monosaccharides** – single sugars (3 in each)
- **Disaccharides** – double sugars (3 in each)

Three types of monosaccharides ...

- Fructose
- Glucose
- Galactose

... join together to make three types of disaccharides.

- Sucrose (fructose—glucose)
- Maltose (glucose—glucose)
- Lactose (glucose—galactose)

A note on the glucose symbol:
The glucose molecule is really a ring of 5 carbons and 1 oxygen plus a carbon “flag.”

For convenience, glucose is symbolized as

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*a* Galactose does not occur in foods singly but only as part of lactose.

*b* The chemical bond that joins the monosaccharides of lactose differs from those of other sugars and makes lactose hard for some people to digest—lactose intolerance (see later section).
Fructose - fruit sugar  (monosaccharide)

- Really sweet sugar of fruit
- Rearranged atoms in glucose molecule
- Fruits, honey, part of table sugar
- Soft drinks, ready to eat cereals
- Products that have high fructose corn syrup

Three types of monosaccharides ... Fructose  Glucose  Galactose

- Sucrose (fructose—glucose)
- Maltose (glucose—glucose)
- Lactose (glucose—galactose)

A note on the glucose symbol:
The glucose molecule is really a ring of 5 carbons and 1 oxygen plus a carbon “flag.”

For convenience, glucose is symbolized as or

\(^a\)Galactose does not occur in foods singly but only as part of lactose.
\(^b\)The chemical bond that joins the monosaccharides of lactose differs from those of other sugars and makes lactose hard for some people to digest — lactose intolerance (see later section).
Galactose (monosaccharide)

- Same # and kind of atoms as glucose and fructose but different arrangement
- Makes up the sugar in milk

Three types of monosaccharides ...

- Fructose
- Glucose
- Galactose\(^a\)

... join together to make three types of disaccharides.

- Sucrose (fructose—glucose)
- Maltose (glucose—glucose)
- Lactose\(^b\) (glucose—galactose)

\(^a\)Galactose does not occur in foods singly but only as part of lactose.
\(^b\)The chemical bond that joins the monosaccharides of lactose differs from those of other sugars and makes lactose hard for some people to digest—lactose intolerance (see later section).
Lactose (Disaccharides)

- glucose + galactose
- Sugar found in milk

Maltose

- glucose + glucose
- Starch is being broken down like in germinating seeds or starch digestion in the human body.

Three types of monosaccharides ...

Fructose
- Sucrose (fructose—glucose)
- Maltose (glucose—glucose)
- Lactose (glucose—galactose)

A note on the glucose symbol:
The glucose molecule is really a ring of 5 carbons and 1 oxygen plus a carbon “flag.”

For convenience, glucose is symbolized as

Galactose
- Galactose does not occur in foods singly but only as part of lactose.
- The chemical bond that joins the monosaccharides of lactose differs from those of other sugars and makes lactose hard for some people to digest—lactose intolerance (see later section).
Sucrose- beet, cane, table sugar
(disaccharide)

- fructose + glucose
- Comes from refining beets or sugar cane
- It also occurs naturally in fruits and vegetables
- Monosaccharides are absorbed into blood directly
- Disaccharides must be broken down then digested.

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**A note on the glucose symbol:**
The glucose molecule is really a ring of 5 carbons and 1 oxygen plus a carbon “flag.”

For convenience, glucose is symbolized as

---

*a* Galactose does not occur in foods singly but only as part of lactose.

*b* The chemical bond that joins the monosaccharides of lactose differs from those of other sugars and makes lactose hard for some people to digest—lactose intolerance (see later section).
Polysaccharides aka complex carbs (good carbs)

- Poly = many

**Starch**  Glucose units are linked in long, occasionally branched chains to make starch. Human digestive enzymes can digest these bonds, retrieving glucose. Real glucose units are so tiny that you can’t see them, even with the highest-power light microscope.

**Glycogen**  Glycogen resembles starch in that the bonds between its glucose units can be broken by human enzymes, but the chains of glycogen are more highly branched.

**Cellulose (fiber)** The bonds that link glucose units together in cellulose are different from the bonds in starch or glycogen. Human enzymes cannot digest them.
Starch (Polysaccharides = complex carbs = good carbs)

- Starch is a plant’s storage form of glucose
- Found in seeds
- Nutritive for humans b/c they can digest the starch into glucose.

The sugars in these fruits are diluted with water and packaged with vitamins, minerals etc.
Storage form of glucose in animals and human beings.

Undetectable in meats because glycogen breaks down rapidly when the animal is slaughtered.
Fiber  polysaccharide

- Structural form of glucose in plant leaves, stems, and seeds.

- Other fibers retain water and protect the seeds from drying out.

- Human digestive enzymes cannot break the chemical bonds holding the sugar units together, i.e. indigestible in human beings.
• What are the 2 types of fibers?
Soluble fibers

- Dissolve in water
- Easily digested by bacteria in human colon
- Are **viscous:** sticky, gummy, gel like consistency. Flows slowly
- Lowers blood cholesterol, help control blood sugar
- Protects us from heart disease & diabetes
- Found in: barley, legumes, citrus fruits, oats, vegetables
Insoluble fibers

• Don't dissolve in water
• Retain their structure and texture after cooking
• Ease bowel movements
• Found in: outer layers of whole grain, corn, celery strings,
Glucose is a critical energy source for the nervous system, including the brain.

Fat is not normally used by the nervous system and brain.

Protein-rich foods are usually expensive and offer no advantage over carbohydrates.

Sugars that hang on protein molecules are responsible for: slipperiness of mucus, affects cell to cell communication, nerve and brain cell function...
If I Want to Lose Weight and Stay Healthy, Should I Avoid Carbohydrate?

Are carbohydrates “fattening”? 

- NO!! They have 4 calories per gram.
- People who wish to lose fat, maintain lean tissue, and stay healthy should
  - Pay attention to portion size
  - Control total calories
  - Design a diet around whole foods that supply carbohydrates in balance with other nutrients
If I Want to Lose Weight and Stay Healthy, Should I Avoid Carbohydrate?

- 130 grams of carbs for adults and children
- 38 grams of total fiber for men up to 50 yrs
- 25 grams of total fiber for women up to age 50 years
Carbohydrate rich foods provide:

- Vitamins, minerals, phytochemicals, fiber and little fat
- Promotes normal blood cholesterol
- Controls blood pressure
- Adjusts blood glucose concentration
- Maintains healthy bowel function
- Promotes healthy body weight!!!
High-fiber foods – especially whole grains – play a key role in reducing the risk of type 2 diabetes

How can they do this?

- Soluble fibers trap nutrients and delay glucose absorption
How does fiber play a role in maintaining proper colon function?

- Cellulose enlarges and softens the stools
- Speeds up transit time
- Prevents constipation
- Lower risk of hemorrhoids (swelling of rectal veins)
- Lower risk of appendicitis (infected appendices)
- Lower risk of diverticula (infected pockets in colon)
Some studies support a role for fiber in defending against cancers of the colon and rectum

- Fiber attracts water, so may dilute potential cancer-causing agents and speed their removal from the colon.
- Fiber-rich foods supply folate which may be protective.
- Resident bacteria multiply rapidly in fiber-rich intestinal contents and may bind nitrogen, a possible cancer causer.
- A colon well supplied with butyrate from a diet high in soluble fibers may resist chemical injury that could otherwise lead to cancer formation.
How can fiber help maintain a healthy weight?

- Whole foods rich in complex carbohydrates tend to be low in fats and added sugars and therefore promote weight loss by delivering less energy per bite.

- Fiber provides a feeling of fullness.

- Fiber delays hunger because fibers swell as they absorb water.
Dietary Guidelines for Americans

consume between 45% to 65% of calories from carbohydrates

Most adults need between

- Men, age 19-50  38g/day
- Men, age 51& up  30g/day
- Women, age 19-50  25g/day
- Women, age 51& up  21g/day
Too much fiber and too little liquids can overwhelm the digestive system.

Too much purified fiber may displace nutrients from the diet or cause them to be lost by binding the nutrients and speeding up transit.

Get your fiber from whole foods
The U.S. Enrichment Act of 1942 was passed by Congress to prevent deficiencies that developed when people turned to refined breads.

- Required iron, niacin, thiamin and riboflavin be added to all refined grain products

- Amended in 1996 to include the vitamin folate (folic acid on food labels)
Body must have **glucose** available for its cells at a steady rate all day.

Body cannot use polysaccharides or disaccharides or even fructose or galactose.

Glucose is needed.
Figure 4-11 p131

1. Some starch is partially broken down by an enzyme from the salivary glands of the mouth.

2. Fiber, starch, monosaccharides, and disaccharides enter the stomach and pass into the small intestine.

3. An enzyme from the pancreas digests most of the starch to disaccharides.

4. Enzymes on the surface of cells that line the intestine split disaccharides to monosaccharides.

5. Monosaccharides enter capillaries and are then delivered to the liver via the portal vein.

6. The liver can convert galactose and fructose to glucose.

7. Fiber and resistant starch travel unchanged to the colon.

Key:
- glucose
- galactose
- lactose
- sucrose
- fiber
- maltose
- starch
Starch digestion begins in the mouth.

Enzyme (made of protein) in saliva mixes with food.

Starch is split into maltose.

Once in the stomach, starch digestion stops because stomach acid digests protein. Salivary enzymes (made of protein) are deactivated by stomach's protein digesting enzyme.

Continues in the small intestine breaks down starch into di- and small polysaccharides.

Other enzymes free the monosaccharides for absorption.
Disaccharides are split to monosaccharides

Monosaccharides are absorbed

Galactose, fructose, and glucose travel to liver which converts galactose and fructose to glucose or related products
Circulatory system transports glucose and other products to cells
Liver may store some glucose as glycogen
All body cells may split glucose for energy
Fiber is not digested by human digestive enzymes.

Fiber is digested (fermented) by colon bacteria producing odorous gases.

Don't give up on fiber foods that cause gas.

Start with small servings and increase later.
Why Do Some People Have Trouble Digesting Milk?

- As people age, upward of 75% of the world’s people lose the ability to produce the enzyme lactase which digests lactose.
- Almost all mammals lose some of their ability to produce lactase as they age.
Symptoms of lactose intolerance after consuming lactose-containing products:

- Nausea
- Pain
- Diarrhea
- Excessive gas

Milk allergy is due to the immune system’s reaction to milk protein.
Milk Tolerance and Strategies

Many people can tolerate as much as 1-2 cups of milk a day

Alternatives include

- Cheese
- Yogurt
- Lactose-free milk
- Over-the-counter lactase pills and drops
- Calcium-fortified juices, soymilk, canned sardines or salmon with the bones
The Body’s Use of Glucose

Glucose is the basic carbohydrate that each cell of the body uses for energy.
When a cell splits glucose for energy, it performs a series of chemical reactions.

1. glucose can be put back together to make glucose again.

2. broken further they can't be put back together.
   - carbs CAN be made into building blocks of protein.
   - hitched together into units of body fat.
When there is inadequate carbohydrate in the diet, the body has two problems:

1. Having no glucose, the body turns to protein and fat to make some glucose.
   - Called the **protein-sparing action** of carbohydrate
   - Protein is needed for maintaining immune system and other critical functions.
   - Fat cannot regenerate enough glucose to feed the brain and prevent ketosis
2. Without carbohydrate in the diet, fat cannot be used correctly for energy, and the body converts its fats into **ketone bodies**.

- fat + glucose compounds = energy supplies

Instead

- fat + fat = ketone bodies =ketosis

- Disturbs acid base balance in body

- vitamin & mineral deficiencies, loss of bone minerals, bad moods, + of kidney stones ...
Ketosis results when an undesirable high concentration of ketone bodies accumulate in the blood.

Minimum amount of digestible carbohydrate set by the DRI committee to adequately feed the brain and reduce ketosis has been set at 130 grams a day for an average-sized person.
After a meal, as blood glucose rises, the pancreas releases **insulin**, which signals the body’s tissues to take up the surplus glucose.

- Muscle and liver cells can convert the excess glucose to glycogen
- Muscle store 2/3 of total glycogen for its own use
- Brain stores a little glycogen
- Liver stores the rest for the brain or other tissue when body is low in glucose
Storing Glucose as Glycogen

- When blood glucose concentrations drop, a pancreatic hormone, **glucagon**, is released.
- Glucagon liberates stored glucose from liver glycogen.
Healthy body keeps blood glucose concentrations from becoming too low or too high.

Too much glucose = confusion, difficulty breathing

Too little = dizziness and weakness
Regulating blood sugar depends on two pancreatic hormones:

- **Insulin** – removes excess glucose from blood to become glycogen or fat *(when too much)*

- **Glucagon** – triggers the breakdown of liver glycogen to free glucose. *(when too little)*

* Epinephrine also breaks down liver glycogen during emergencies (“fight or flight” reaction)
**High blood glucose**

1. After a meal, blood glucose rises, signaling the pancreas to release insulin into the bloodstream.

2. Insulin signals fat (adipose) tissue and skeletal muscles to take up glucose from the blood. It also stimulates glycogen storage by the liver.

3. Blood glucose falls to its normal concentration.

4. In response to normal blood glucose, the pancreas slows its insulin output.

**Low blood glucose**

5. As body cells use up glucose, blood glucose declines, signaling the pancreas to release glucagon into the bloodstream.

6. Glucagon signals the liver to break apart its stored glycogen, releasing glucose into the bloodstream.

7. Blood glucose rises to its normal concentration.

8. In response to normal blood glucose, the pancreas slows its glucagon output.

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Figure 4-13 p135
Handling Excess Glucose

Excess dietary glucose is converted in the liver to:

- **Glycogen** – (liver and muscles hold a limited amount, 4 to 6 hours worth)
  
  if you are consuming more glucose

- Body energy shifts to burning more glucose than fat

- So more fat is left circulating in the blood which is picked up by fatty tissue and stored there

  still more glucose coming

- Liver breaks glucose into smaller fragments and makes fats which is released into the blood stream and taken to fat tissues and deposited there
Handling Excess Glucose

• Fat cells can also directly take glucose and convert them into fat
• Fat cells can store unlimited amounts of fat
• When you eat foods that have too much glucose and fat your body will use the glucose first (b/c it takes less energy) and store the fat.

Be careful of how much sugar and fat you consume throughout the day
Diabetes and Hypoglycemia

- Abnormal use of carbohydrates
The Perils of Diabetes

- Diabetes ranks 7th among killers in U.S.
- Doubles the risk of heart disease and stroke.
- Leading cause of permanent blindness and fatal kidney failure.
Harm to the Body

Chronically elevated blood glucose alters metabolism in every cell in the body

- Blindness
- Kidney disease
- Heart disease
- Nerve damage
- Increased infections
- Amputations of limbs
Type 1 Diabetes

- Type 1 causes 5 to 10 percent of diabetes
- **Autoimmune disorder** where person’s immune system attacks insulin-producing pancreas cells
- External sources of insulin needed to assist cells to take up glucose
Type 2 Diabetes

- Type 2 causes 90 to 95 percent of diabetes

- Muscle, adipose, and liver cells lose their sensitivity to insulin, i.e. **insulin resistance**

- Resulting in high levels of glucose in the body
Obesity-related in young and older people

Genetic factors also involved
Preventing Type 2 Diabetes

- Maintain healthy body weight
- Choose a diet high in vegetables, fruits, poultry, fish, and whole grains
- Exercise regularly
- Restrict alcohol
- Abstain from smoking
Management of Diabetes

- The tighter the control over blood glucose, the milder the effects of diabetes can be.

- **Lifestyle changes**

- Eat a healthy diet that delivers the same amount of carbohydrate each day, spaced evenly throughout the day.

- Not too much protein

- Adequate in fiber

- Low in fat
If I Feel Dizzy Between Meals, Do I Have Hypoglycemia?

- Hypoglycemia is abnormally low blood glucose
- Requires a blood test to diagnose
- Two types
  - Postprandial – low blood glucose after a meal; uncommon. Fatigue, weakness, dizziness, sweating...
  - Fasting – 8-14 hours. Headaches, mental dullness, fatigue, confusion, amnesia...
For a 2,000-calorie diet

- Carbohydrates should provide 45% to 65% of calories
- 225 to 325 grams each day
<table>
<thead>
<tr>
<th>Food</th>
<th>Fiber (g)</th>
<th>Food</th>
<th>Fiber (g)</th>
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</thead>
<tbody>
<tr>
<td>Pear, raw, 1 medium</td>
<td>5</td>
<td>Other berries, raw, 1/2 c</td>
<td>2</td>
</tr>
<tr>
<td>Blackberries/raspberries,</td>
<td>4</td>
<td>Peach, raw, 1 medium</td>
<td>2</td>
</tr>
<tr>
<td>raw, 1/2 c</td>
<td></td>
<td>Strawberries, sliced, 1/2 c</td>
<td>2</td>
</tr>
<tr>
<td>Figs, dried, 3</td>
<td>3</td>
<td>Cantaloupe, raw, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Apple, 1 medium</td>
<td>3</td>
<td>Cherries, raw, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Apricots, raw, 4 each</td>
<td>3</td>
<td>Fruit cocktail, canned, 1/2 c</td>
<td>1</td>
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<tr>
<td>Banana, raw, 1</td>
<td>3</td>
<td>Peach half, canned</td>
<td>1</td>
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<tr>
<td>Orange, 1 medium</td>
<td>3</td>
<td>Raisins, dry, 1/4 c</td>
<td>1</td>
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<tr>
<td></td>
<td></td>
<td>Orange juice, 3/4 c</td>
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### Vegetables

<table>
<thead>
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<tbody>
<tr>
<td>Baked potato with skin, 1</td>
<td>4</td>
<td>Mashed potatoes, home recipe, 1/2 c</td>
<td>2</td>
</tr>
<tr>
<td>Broccoli, chopped, 1/2 c</td>
<td>3</td>
<td>Bell peppers, 1/2 c</td>
<td>1</td>
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<tr>
<td>Brussel sprouts, 1/2 c</td>
<td>3</td>
<td>Broccoli, raw, chopped, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Spinach, 1/2 c</td>
<td>3</td>
<td>Carrot juice, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Asparagus, 1/2 c</td>
<td>2</td>
<td>Celery, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Baked potato, no skin, 1</td>
<td>2</td>
<td>Dill pickle, 1 whole</td>
<td>1</td>
</tr>
<tr>
<td>Cabbage, red, 1/2 c</td>
<td>2</td>
<td>Eggplant, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Carrots, 1/2 c</td>
<td>2</td>
<td>Lettuce, romaine, 1 c</td>
<td>1</td>
</tr>
<tr>
<td>Cauliflower, 1/2 c</td>
<td>2</td>
<td>Onions, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Corn, 1/2 c</td>
<td>2</td>
<td>Tomato, raw, 1 medium</td>
<td>1</td>
</tr>
<tr>
<td>Green beans, 1/2 c</td>
<td>2</td>
<td>Tomato juice, canned, 3/4 c</td>
<td>1</td>
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</table>

### Grains

<table>
<thead>
<tr>
<th>Food</th>
<th>Fiber (g)</th>
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<tbody>
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<td>100% bran cereal, 1 oz</td>
<td>10</td>
<td>Pumpernickel bread, 1 slice</td>
<td>2</td>
</tr>
<tr>
<td>Barley, pearled, 1/2 c</td>
<td>3</td>
<td>Shredded wheat, 1 large biscuit</td>
<td>2</td>
</tr>
<tr>
<td>Cheerios, 1 oz</td>
<td>3</td>
<td>Corn flakes, 1 oz</td>
<td>1</td>
</tr>
<tr>
<td>Whole-wheat bread, 1 slice</td>
<td>3</td>
<td>Muffin, blueberry, 1</td>
<td>1</td>
</tr>
<tr>
<td>Wheat flakes, 1 oz</td>
<td>3</td>
<td>Puffed wheat, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Brown rice, 1/2 c</td>
<td>2</td>
<td>White pasta, 1/2 c</td>
<td>1</td>
</tr>
<tr>
<td>Light rye bread, 1 slice</td>
<td>2</td>
<td>Cream of wheat, 1/2 c</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Muffin, bran, 1 small</td>
<td>2</td>
<td>White bread, 1 slice</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Oatmeal, 1/2 c</td>
<td>2</td>
<td>White rice, 1/2 c</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

### Meat, Poultry, Fish, Dry Peas and Beans, Eggs, and Nuts

<table>
<thead>
<tr>
<th>Food</th>
<th>Fiber (g)</th>
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<th>Fiber (g)</th>
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</thead>
<tbody>
<tr>
<td>Lentils, 1/2 c</td>
<td>8</td>
<td>Soybeans, 1/2 c</td>
<td>5</td>
</tr>
<tr>
<td>Kidney beans, 1/2 c</td>
<td>8</td>
<td>Almonds or mixed nuts, 1/4 c</td>
<td>4</td>
</tr>
<tr>
<td>Pinto beans, 1/2 c</td>
<td>8</td>
<td>Peanuts, 1/4 c</td>
<td>3</td>
</tr>
<tr>
<td>Black beans, 1/2 c</td>
<td>7</td>
<td>Peanut butter, 2 lbs</td>
<td>2</td>
</tr>
<tr>
<td>Black-eyed peas, 1/2 c</td>
<td>6</td>
<td>Cashew nuts, 1/4 c</td>
<td>1</td>
</tr>
<tr>
<td>Lima beans, 1/2 c</td>
<td>5</td>
<td>Meat, poultry, fish, and eggs</td>
<td>0</td>
</tr>
</tbody>
</table>

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*All values are for ready-to-eat or cooked foods unless otherwise noted. Fruit values include edible skins. All values are rounded values.

*Pasta includes spaghetti noodles, lasagna, and other noodles.
Note: The term *sugars* here refers to all of the monosaccharides and disaccharides. On a label’s ingredients list, the term *sugar* means sucrose. See Controversy 4 for terms related to *artificial sweeteners* and *sugar alcohols*.

- **added sugars** sugars and syrups added to a food for any purpose, such as to add sweetness or bulk or to aid in browning (baked goods). Also called *carbohydrate sweeteners*, they include glucose, fructose, corn syrup, concentrated fruit juice, and other sweet carbohydrates.
- **brown sugar** white sugar with molasses added, 95% pure sucrose.
- **concentrated fruit juice sweetener** a concentrated sugar syrup made from dehydrated, deflavored fruit juice, commonly grape juice; used to sweeten products that can then claim to be “all fruit.”
- **confectioner’s sugar** finely powdered sucrose, 99.9% pure.
- **corn sweeteners** corn syrup and sugar solutions derived from corn.
- **corn syrup** a syrup, mostly glucose, partly maltose, produced by the action of enzymes on cornstarch.
- **dextrose** an older name for glucose.
- **evaporated cane juice** raw sugar from which impurities have been removed.
- **fructose, galactose, glucose** the monosaccharides.
- **granulated sugar** common table sugar, crystalline sucrose, 99.9% pure.
- **high fructose corn syrup** a commercial sweetener used in many foods, including soft drinks. Composed almost entirely of the monosaccharides fructose and glucose, its sweetness and caloric value are similar to sucrose.
- **honey** a concentrated solution primarily composed of glucose and fructose, produced by enzymatic digestion of the sucrose in nectar by bees.
- **invert sugar** a mixture of glucose and fructose formed by the splitting of sucrose in an industrial process. Sold only in liquid form and sweeter than sucrose, invert sugar forms during certain cooking procedures and works to prevent crystallization of sucrose in soft candies and sweets.
- **lactose, maltose, sucrose** the disaccharides.
- **levulose** an older name for fructose.
- **maple sugar** a concentrated solution of sucrose derived from the sap of the sugar maple tree, mostly sucrose. This sugar was once common but is now usually replaced by sucrose and artificial maple flavoring.
- **molasses** a syrup left over from the refining of sucrose from sugarcane; a thick, brown syrup. The major nutrient in molasses is iron, a contaminant from the machinery used in processing it.
- **naturally occurring sugars** sugars that are not added to a food but are present as its original constituents, such as the sugars of fruit or milk.
- **raw sugar** the first crop of crystals harvested during sugar processing. Raw sugar cannot be sold in the United States because it contains too much filth (dirt, insect fragments, and the like). Sugar sold as “raw sugar” is actually evaporated cane juice.
- **turbinado** (ter-bih-NOD-oh) *sugar* raw sugar from which the filth has been washed; legal to sell in the United States.
- **white sugar** pure sucrose, produced by dissolving, concentrating, and recrystallizing raw sugar.
### Strawberry Jam Nutrition Facts

**Serving size:** 1 Tbsp (20g)  
**Servings Per Container:** About 14

<table>
<thead>
<tr>
<th>Amount per serving</th>
<th>% Daily Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories 40</td>
<td>0%</td>
</tr>
<tr>
<td>Total Fat 0g</td>
<td>0%</td>
</tr>
<tr>
<td>Sodium 1mg</td>
<td>1%</td>
</tr>
<tr>
<td>Total Carbohydrate 10g</td>
<td>4%</td>
</tr>
<tr>
<td>Sugars 7g</td>
<td></td>
</tr>
<tr>
<td>Protein 0g</td>
<td></td>
</tr>
</tbody>
</table>

*Percent Daily Values are based on a 2,000 calorie diet.

**INGREDIENTS:** Strawberries, Corn Syrup, Sugar, High Fructose Corn Syrup, Citric Acid, Fruit Pectin.

### Strawberry 100% Fruit Spread Nutrition Facts

**Serving size:** 1 Tbsp (18g)  
**Servings Per Container:** About 16

<table>
<thead>
<tr>
<th>Amount per serving</th>
<th>% Daily Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories 40</td>
<td>0%</td>
</tr>
<tr>
<td>Total Fat 0g</td>
<td>0%</td>
</tr>
<tr>
<td>Sodium 0mg</td>
<td>0%</td>
</tr>
<tr>
<td>Total Carbohydrate 10g</td>
<td>3%</td>
</tr>
<tr>
<td>Sugars 8g</td>
<td></td>
</tr>
<tr>
<td>Protein 0g</td>
<td></td>
</tr>
</tbody>
</table>

*Percent Daily Values are based on a 2,000 calorie diet.

**INGREDIENTS:** Clarified Grape Juice Concentrate, Strawberries, Clarified Pear Juice Concentrate, Pectin, Natural Flavor, Citric Acid.
Food Feature: Finding the Carbohydrates in Foods
Honey is more nutritious than sugar.

1. Agree
2. Disagree
Food Feature: Finding the Carbohydrates in Foods

Table 4-10 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>IRON (mg)</th>
<th>MAGNESIUM (mg)</th>
<th>POTASSIUM (mg)</th>
<th>ZINC (mg)</th>
<th>THIAMIN (mg)</th>
<th>RIBOFLAVIN (mg)</th>
<th>NIACIN (mg)</th>
<th>VITAMIN A (μg)</th>
<th>VITAMIN B₆ (mg)</th>
<th>VITAMIN C (mg)</th>
<th>FOLATE (μg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar (1 tbs)</td>
<td>46</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>
<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</td>
<td>0</td>
<td>&lt;1</td>
<td>0</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>0.2</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Concentrated grape or fruit juice sweetener (1 tbs)</td>
<td>30</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>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</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</td>
<td>1</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>&lt;1</td>
<td>0</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</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>Cola beverage (12 fl oz)</td>
<td>153</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>0.1</td>
<td>4</td>
<td>4</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>Daily Values</td>
<td>2,000</td>
<td>56</td>
<td>25</td>
<td>1,000</td>
<td>18</td>
<td>400</td>
<td>3,500</td>
<td>15</td>
<td>1,000</td>
<td>1.5</td>
<td>1.7</td>
<td>20</td>
<td>2</td>
<td>400</td>
<td>60</td>
</tr>
</tbody>
</table>
Controversy: Sugar and Alternative Sweeteners: Are They Bad For You?

*Sugary soft drinks are the leading source of added sugars in the US*
Controversy: Sugar and Alternative Sweeteners: Are They Bad For You?

![Graph showing the increase in daily teaspoons of sugars from 1890 to today. The suggested upper daily limit is indicated.]

- Daily teaspoons of sugars
- Suggested upper daily limit
- 1890
- 1970
- 1980
- 1990
- Today
Evidence Concerning Sugar

Sugar has been accused of

- Promoting and maintaining obesity
- Causing and aggravating diabetes
- Increasing the risk of heart disease
- Disrupting behavior in children and adults
- Causing dental decay and gum disease
Any weight gain associated with sugars may result not so much with the chemistry of the carbohydrate itself, but with how it is used in the diet.

Most people choose far too may servings of sweet foods and beverages (juices/sodas), while ignoring the whole carbohydrate sources, such as fruits, vegetables, and whole grains.
Added sugars alone are not culpable in type 2 diabetes causation.

Added sugars can easily provide excess calories, however, and type 2 diabetes risk rises with body weight.
Throughout many years of research, no evidence has come to light linking an average intake of sugar with heart disease.
Research results do not suggest that sugar itself negatively affects behavior in either normal or hyperactive children.

In fact, in several well-controlled studies, sugar administered to normal children calmed them down, a finding consistent with biochemical evidence. In adults, carbohydrate-rich foods seem to improve memory and mood.
Total sugar does play a major role in the prevalence of dental caries.

Caries begin when acid dissolves the enamel that covers the tooth. If not repaired, the decay may penetrate the dentin and spread into the pulp of the tooth, causing inflammation and an abscess.

**Table C4-1: Dental Terms**

- **dental caries** decay of the teeth (caries means “rottenness”).
- **plaque** (PLACK) a mass of microorganisms and their deposits on the crowns and roots of the teeth, a forerunner of dental caries and gum disease. (The term plaque is also used in another connection—arterial plaque in atherosclerosis. See Chapter 11.)
Based on research, no guilty verdict can yet be issued for any of the first four accusations against sugar, but of the fifth, it is guilty as charged - sugar causes dental caries.
Dietary Guidelines suggest *limiting* sugar

Sugar can safely contribute up to 10 percent of the total calorie intake

- 2000-calorie diet can have up to 200 calories of sugar (13 teaspoons)

To lower sugar intake, many choose *alternative sweeteners*
# Evidence Concerning Sugar Alcohols

## Table C4-2: Sugar Alcohols

<table>
<thead>
<tr>
<th>Sugar Alcohols</th>
<th>Relative Sweetness*</th>
<th>Energy (cal/g)</th>
<th>Approved Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythritol</td>
<td>1.0</td>
<td>0.0</td>
<td>Beverages, flavored milk, yogurt, and pudding, frozen dairy desserts, bakery products, chewing gum, candies, table sweetener</td>
</tr>
<tr>
<td>Isomalt</td>
<td>0.5</td>
<td>2.0</td>
<td>Candies, chewing gum, ice cream, jams and jellies, frostings, beverages, baked goods</td>
</tr>
<tr>
<td>Lactitol</td>
<td>0.4</td>
<td>2.0</td>
<td>Candies, chewing gum, frozen dairy desserts, jams and jellies, frostings, baked goods</td>
</tr>
<tr>
<td>Maltitol</td>
<td>0.9</td>
<td>2.1</td>
<td>Particularly good for candy coating</td>
</tr>
<tr>
<td>Mannitol</td>
<td>0.7</td>
<td>1.6</td>
<td>Bulking agent, chewing gum</td>
</tr>
<tr>
<td>Sorbitol</td>
<td>0.5</td>
<td>2.6</td>
<td>Special dietary foods, candies, gums</td>
</tr>
<tr>
<td>Xylitol</td>
<td>1.0</td>
<td>2.4</td>
<td>Chewing gum, candies, pharmaceutical and oral health products</td>
</tr>
</tbody>
</table>

*a The relative sweetness depends on the temperature, acidity, and other flavors of the foods in which the substance occurs. The sweetness of pure sucrose is the standard with which the approximate sweetness of sugar substitutes is compared.
Evidence Concerning Sugar Alcohols

- Do not contribute to dental caries because not metabolized by oral bacteria
- Low glycemic index so useful for diabetics
- Side effects from ingesting large amounts
  - Gas
  - Abdominal discomfort
  - Diarrhea
Evidence Concerning Artificial Sweeteners

<table>
<thead>
<tr>
<th>Table C4-3</th>
<th>Sugar Substitute Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ acceptable daily intake (ADI) the estimated amount of sweetener that can be consumed daily over a person's lifetime without any adverse effects.</td>
<td></td>
</tr>
<tr>
<td>■ acesulfame (AY-sul-fame) potassium, also called acesulfame-K a zero-calorie sweetener approved by the FDA and Health Canada.</td>
<td></td>
</tr>
<tr>
<td>■ alitame a noncaloric sweetener formed from the amino acids L-aspartic acid and L-alanine. In the United States, the FDA is considering its approval.</td>
<td></td>
</tr>
<tr>
<td>■ aspartame a compound of phenylalanine and aspartic acid that tastes like the sugar sucrose but is much sweeter. It is used in both the United States and Canada.</td>
<td></td>
</tr>
<tr>
<td>■ cyclamate a zero-calorie sweetener under consideration for use in the United States and used with restrictions in Canada.</td>
<td></td>
</tr>
<tr>
<td>■ isomalt, lactitol, maltitol, mannitol, sorbitol, xylitol sugar alcohols that can be derived from fruits or commercially produced from a sugar; absorbed more slowly and metabolized differently than other sugars in the human body and not readily used by ordinary mouth bacteria.</td>
<td></td>
</tr>
<tr>
<td>■ neotame (NEE-oh-tame) an artificial sweetener composed of two amino acids (phenylalanine and aspartic acid) linked in such a way as to make them indigestible by human enzymes.</td>
<td></td>
</tr>
<tr>
<td>■ saccharin a zero-calorie sweetener used freely in the United States but restricted in Canada.</td>
<td></td>
</tr>
<tr>
<td>■ stevia (STEEV-ee-uh) the sweet-tasting leaves of a shrub sold as a dietary supplement, but lacking FDA approval as a sweetener.</td>
<td></td>
</tr>
<tr>
<td>■ sucralose a noncaloric sweetener derived from a chlorinated form of sugar that travels through the digestive tract unabsorbed. Approved for use in the United States and Canada.</td>
<td></td>
</tr>
<tr>
<td>■ tagatose an incompletely absorbed monosaccharide sweetener derived from lactose with a caloric value of 1.5 calories per gram. About 80% of the ingested tagatose travels to the large intestine where bacterial colonies ferment it. Tagatose is not readily used by mouth bacteria and so does not promote dental caries.</td>
<td></td>
</tr>
</tbody>
</table>
## Evidence Concerning Artificial Sweeteners

<table>
<thead>
<tr>
<th>ARTIFICIAL SWEETENERS</th>
<th>ENERGY (cal/g)</th>
<th>ACCEPTABLE DAILY INTAKE (ADI)</th>
<th>AVERAGE AMOUNT TO REPLACE 1 TSP SUCROSE*</th>
<th>APPROVED USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saccharin (SugarTwin, Sweet N’ Low, others)</td>
<td>0</td>
<td>5 mg/kg body weight (341 mg for a 150 lb person)</td>
<td>12 mg</td>
<td>Tabletop sweeteners, wide range of foods, beverages, cosmetics, and pharmaceutical products</td>
</tr>
<tr>
<td>Aspartame (Nutra-Sweet, Equal, others)</td>
<td>4</td>
<td>50 mg/kg body weight(^b) (3,409 mg for a 150 lb person)</td>
<td>18 mg</td>
<td>General-purpose sweetener in all foods and beverages. Warning to population with PKU</td>
</tr>
<tr>
<td>Acesulfame-potassium (Sunette, Sweet One)</td>
<td>0</td>
<td>15 mg/kg body weight (1,023 mg for a 150 lb person)</td>
<td>25 mg</td>
<td>Alcoholic beverages, baked goods, candies, chewing gum, desserts, gelatins, puddings, tabletop sweeteners</td>
</tr>
<tr>
<td>Sucralose (Splenda)</td>
<td>0</td>
<td>5 mg/kg body weight (341 mg for a 150 lb person)</td>
<td>6 mg</td>
<td>Baked goods, carbonated beverages, chewing gum, coffee and tea, dairy products, frozen desserts, fruit spreads, salad dressing, syrups, tabletop sweeteners</td>
</tr>
<tr>
<td>Neotame</td>
<td>0</td>
<td>18 mg/day</td>
<td>0.5 μg</td>
<td>Baked goods, beverages (nonalcoholic), candies, chewing gum, frostings, frozen desserts, gelatins, puddings, jams and jellies, syrups</td>
</tr>
<tr>
<td>Tagatose</td>
<td></td>
<td>7.5 g/day</td>
<td>1 tsp</td>
<td>Bakery products, beverages, cereals, chewing gum, confections, dairy products, dietary supplements, health bars, tabletop sweeteners</td>
</tr>
</tbody>
</table>

\(^a\)Rounded values
\(^b\)In Canada, the acceptable level is 40 mg/kg.
Do Artificial Sweeteners Help With Weight Control?

Can Artificial Sweeteners Help With Weight Control?
A recent study reports sizable weight losses when artificial sweeteners replace sizable amounts of sugar in the diet.

Some studies report no weight loss differences between people fed sugar and those fed artificial sweeteners.
Current evidence indicates that moderate intakes of artificial sweeteners pose no health risks.

Artificial sweeteners may not be a magic bullet in fighting overweight, but they probably do not hinder weight-loss efforts either, and they are safer for teeth than carbohydrate sweeteners.