Chapter 9

The Complex Carbohydrates: Starches, Cellulose, Gums, and Pectins

This researcher is comparing two varieties of corn. Both are sources of starch, a complex carbohydrate.

Objectives

After studying this chapter, you will be able to

describe characteristics of the four categories of complex carbohydrates.

identify the functions of complex carbohydrates in food preparation.

list five physical properties of starch and liquid mixtures that affect the selection of starches used in food products.

compare the advantages and disadvantages of the three main methods used to add starches to sauces.

analyze the role of starches in a nutritious diet.

Key Terms

polysaccharide
macromolecule
starch
polymer
amylose
amylopectin
granules
cellulose
carbohydrate gum
pectin
gelatinization
gelatinization point
slurry
sol
paste
gel
junction
retrogradation
syneresis
viscosity
stability
opacity
translucency
modified starch
cross-linked starch
cold water paste
buerre manie
roux
ketosis
ketone bodies
Breads, cereals, muffins, cakes, and cookies are well-liked foods in the typical U.S. diet. These foods are rich in carbohydrates. Some of the carbohydrates are simple carbohydrates, which you studied in Chapter 8. However, many of the carbohydrates in baked goods are complex carbohydrates, which are the focus of this chapter. See 9-1.

Complex carbohydrates are called polysaccharides. This is because they are made up of many sugar units, or saccharides. Another term used to describe polysaccharides is macromolecules. Macromolecules are very large molecules that contain hundreds or thousands of atoms each.

The Types of Complex Carbohydrates

Several types of complex carbohydrates are found in foods. These include starches, cellulose, gums, and pectins. These polysaccharides are abundant in grains, seeds, nuts, fruits, vegetables, and seaweed.

Starches

The most abundant complex carbohydrate in the diet is starch. Most starches consist of molecules of 100 to several thousand glucose units linked in chains. Because starches are made up of many sugar units, they are polymers of sugar. A polymer is a large molecule that consists of large numbers of small molecular units, which are linked. Starches are composed of glucose. Other polysaccharides can consist of as many as six or seven types of sugars.

A main source of starch in the diet for most people in the United States is wheat flour. Wheat flour is used to make many types of baked goods and pasta. Starch is also found in rice, corn, potatoes, and oats. Any grain or seed is high in starch. Rye, soy, tapioca, and arrowroot are other less commonly used starch products in the U.S. food supply.

Starches have two basic structures. One is linear, and the other is branched. When the units are linked in a line (linear), they are called amylose. Starches that have a branched structure are called amylopectin. In most foods, starches occur as mixtures of amylose and amylopectin.

Starch is nature’s reserve carbohydrate supply. Plants produce starch in packets called granules. Granules are not soluble in cold water. The size and shape of granules vary from plant to plant. Of the common food starches, rice has the smallest granules and potatoes have the largest. Starch granules are a mixture of amylose and amylopectin molecules. Amylose content can range from 25% to 85%. The varying amylose/amylopectin ratios within the granules cause each type of starch to perform differently in food mixtures.

Starches composed mainly of amylopectin are also called waxy starches. This is because of the appearance of the surface of the seeds from which the starches come. Waxy maize is a starch from corn that has more thickening power than regular cornstarch.

Cellulose

A second group of complex carbohydrates are called cellulose. Cellulose is a polysaccharide made from large amounts of β-D-glucose. Some animals, including cows and sheep, and insects such as termites can use cellulose as a food source. However, humans lack the digestive enzymes needed to break the bonds in cellulose molecules. Cellulose is among the complex carbohydrates that are known as fiber in the diet.

Cellulose forms the rigid structure of plants. The strings in celery and the membranes surrounding kernels of corn are made up largely of cellulose.
Carbohydrate Gums and Pectins

The last group of complex carbohydrates used in food preparation are not generally available to the home cook. These polysaccharides are called carbohydrate gums and pectins. **Carbohydrate gums** are polysaccharides that are soluble in water and extracted from plants. **Pectins** are complex carbohydrates that are found in plant cells and made of chemical derivatives of sugar called sugar acids.

Gums thicken and stabilize mixtures and trap color and flavor. The most common and widely used is gum arabic. It surrounds flavor particles, protecting them from moisture absorption, evaporation, or chemical oxidation. Other gums commonly used in foods include karaya gum, gum tragacanth, gum agar, carageenan, and algin. Gums provide stability and texture to such foods as salad dressings and gummy candies, 9-2.

Pectin is a complex carbohydrate that naturally occurs in fruits. It can produce a strong gel that will remain stable to near 100°C (212°F). In the presence of sugar, pectin molecules will dehydrate. Acid will cause hydrogen bonding to occur between negatively charged molecules, thus creating a thickened structure. These properties make pectin a key component in jams and jellies.

Functions of Complex Carbohydrates in Food Preparation

Complex carbohydrates serve a number of functions in food preparation. They provide structure, bind ingredients together, and act as absorbing agents or thickeners. All complex carbohydrates help stabilize food products by keeping ingredients evenly distributed throughout mixtures.

Provide Structure

Starch is the main component of wheat flour. Flour is the primary ingredient in most baked goods. Flour provides the majority of the bulk or structure of baked goods and many other food products. For instance, most ready-to-eat cereals retain their shape due to their starch content. The pieces are formed in a semiliquid state and remain shaped on drying.

Starch’s ability to thicken when heated and gel when cooled enables foods containing starch to take and hold many shapes. Other complex carbohydrates also provide structure in foods. Cellulose forms the supporting framework or structure for fruits and vegetables. Pectins and gums are responsible for the texture of jams, jellies, ice cream products, and gummy-textured candies.

Bind

Binding agents are substances that tend to hold two other products together. Amylose molecules will work better than amyllopectin molecules at holding batters to vegetables and meats during deep-frying. The binding is increased if batter-dipped foods set for 20 minutes before frying. This allows time for the
chemical reactions needed to bind the batter to the food during cooking. See 9-3.

Carageenan is a gum used as a binding agent. It stabilizes the cocoa in chocolate milk so the cocoa does not settle out of the product. Carageenan is also used to stabilize ice cream and other dairy products.

**Thicken**

Starch can thicken liquids. This function is possible because of starch’s chemical structure, the size of its molecules, and the way it reacts to heat. The molecules of starch are chemically altered as they swell and take up water.

Starches are usually combined with liquids in food preparation. Undamaged starch granules are not readily soluble in water nor do they absorb water. Starch must first be heated to break intermolecular bonds. This allows hydrogen bonds to form between the starch molecules and water.

When starch granules are suspended in water and then heated, gelatinization occurs. Gelatinization is the term food scientists use to describe thickening a liquid with starch. As the temperature increases, so does the swelling of the granule structure. The temperature at which maximum swelling occurs is the gelatinization point. This is the point at which the starch will hold the most water and have the greatest thickening power. The starch used in instant puddings has been pre-gelatinized. This allows it to gel, or set, at the temperature of cold milk. The starch in regular pudding mixes will not gelatinize until it is hot enough to boil. Then it will not gel until it is chilled.

Water is the main component of almost all liquids used in food preparation. Starch molecules are extremely large in comparison to water molecules. Not only are starch molecules large, but they have spaces between their sugar units. Imagine a tumbleweed rolling across a desert. The tumbleweed is a solid that has a ball shape. The ball is made of many branches with air spaces between them. If the tumbleweed rolls across a crumbled up piece of paper, the paper can become stuck between the branches. That piece of paper will now be carried along with the tumbleweed.

That is similar to what happens as large starch granules roll around in water. The very small water molecules will slide between sugar units and be held in place by hydrogen bonding. The more water that “snuggles” into the starch molecule, the thicker the mixture will become. See 9-4.

Applying heat to a starch-water mixture causes it to thicken (gelatinization). As heat is added, starch opens up or stretches. This allows water molecules to slip down between the coils of the large molecule. The addition of heat increases the amount of water the molecule can trap in its coils and branches. The more water the molecule traps, the thicker the mixture will become.

Heat is needed to stretch starch molecules and increase their thickening power. However, too much heat will cause starch molecules to begin to hydrolyze or break apart. This will cause the starch to lose thickening ability and stability. Excess heat can result from using too high a temperature or too long a cooking time.

The presence of salt and sugar affects starch’s thickening ability. Salt and sugar compete for water because they are also polar in nature. If a large amount of salt or sugar is present, it will interfere with the gelling ability of the starch. When sugar is combined with flour or any other starch, it will decrease the strength and viscosity of the gel. It will also increase the translucency of the paste. In most
cases, low concentrations of salt have little effect on gelatinization or the ability to form a gel. Potato starch and some manufactured starches are exceptions. They are salt sensitive. Depending on the starch, salt can increase or decrease swelling.

Pectin is used to thicken jams and jellies. Some fruits, such as crabapples and gooseberries, can provide enough pectin to produce suitably thick jellied products. Other fruits require the addition of commercial pectin. Commercial pectin is made by extracting pectin from its fruit source. It may be dried into a powder or sold in a liquid form for home use. See 9-5.

The basic recipe for jams and jellies is 1% pectin and 60% to 65% sugar. The remaining 34% to 39% is made up mostly of crushed fruit or fruit juice. A little hot water may be added if needed for volume. Jams and jellies must have a pH of 2.0 to 3.5. If the fruit is not very acidic, lemon juice is added to achieve the desired pH level.

Pectin will bond with other pectin molecules and form a gel without sugar if calcium ions are present. This is how dietetic jams and jellies are made. Pectin plus calcium also firms canned tomatoes and pickled cucumbers.

Physical Properties of Starch and Liquid Mixtures

Each starch has different physical properties. Therefore, food scientists must determine which starch source is best for a food product.
and the type of starch-liquid mixture. Scientists do this by examining how the starch works within a food mixture. The most important property to the consumer is usually flavor. For example, cornstarch does not taste the same as rye flour. However, wheat flour, cornstarch, and potato starch all thicken gravies and sauces without adding unpleasant flavors.

There are five properties that food scientists evaluate before selecting a starch. The properties they examine include: retrogradation, viscosity, stability, opacity versus translucency, and texture. Food manufacturers have to carefully evaluate all these characteristics of starches anytime they develop a new starch-thickened product.

**Types of Starch and Liquid Mixtures**

Starch and liquid combinations can be of four types: slurries, sols, pastes, and gels. **Slurries** are uncooked mixtures of water and starch. They are used in the processing and chemical alteration of starches. Acids and/or bases are added to the mixture to chemically alter the structure of the starch molecules. **Sols** are thickened liquids. They are pourable. Examples of sols include pancake, waffle, and muffin batter. Cooked sols include white sauce and gravy. **Pastes** are thickened mixtures of starch and liquid that have very little flow. However, they are thin enough to be spread easily. When making gravy, starch can be combined with water or milk to form a paste. The paste can then be stirred into hot broth without lumping. 9-6. This method works well when thickening soups and stews. **Gels** are starch mixtures that are rigid. In a gel, molecules are bound together in a three-dimensional network. This network keeps molecules from shifting in comparison to one another. When two molecules of hydrogen bond together, a *junction* is formed. Short starch chains tend to form weaker junctions. This makes them unstable in heat. Long starch chains form firmer gels that are more stable in heat. Therefore, linear amylose starches will form more stable gels than branched amylpectins. By controlling the number and location of junctions, food scientists can vary the firmness and stability of gels.

Amylose molecules will set rapidly and form firm gels upon cooling. Amylopectin forms thinner gels or no gels at all. Amylose gels are also elastic, whereas amylpectin gels become rigid. This tendency of amylpectin starches to become rigid is a main cause of breads becoming stale. The rigidity is combined with moisture loss.

**Retrogradation**

*Retrogradation* is the firming of a gel during cooling and standing. It occurs because the starch granules are trying to return to the structure they had before cooking. Amylose will tend to hydrogen bond to other amylose molecules. These overlapping molecules will form crystalline structures that separate out of the gel. This is a problem with starch-thickened pie fillings or gravies that are frozen and then thawed.

Retrogradation is desirable when it causes a gel to thicken during cooling. It is undesirable if it continues to the point that cracks form in the gel. Gravy left uncovered in the refrigerator will develop these cracks after a couple days.

The changes of retrogradation are accompanied by water being squeezed from between the molecules of the gel. *Syneresis* is the term used for water leaking out of a gel in storage. The liquid that separates from many mustards is an example of syneresis. Stable gels will have little or no syneresis.

An important factor related to retrogradation is the serving temperature of a
starch-thickened food product. A sauce will thicken as it cools. If you are planning to serve a sauce immediately, you should cook it to the desired thickness. This is not the case with most sweet sauces. They are often served at room temperature. Because they will thicken as they cool, they must be thinner than desired at the end of the cooking time.

Acids hydrolyze starch. Because acids break down starches, they will also weaken or break down gels. This reduces the thickening power of the starch. This is why lemon pie filling calls for more starch than coconut cream or chocolate cream pie filling. Lemon juice is added after the starch has thickened lemon pie filling. The filling is then cooled rapidly to minimize the thinning effect of the acid in lemon.

Viscosity

Viscosity is the resistance of a mixture to flow. When you spill a glass of water on the table, it spreads out in a large pool. If you spill a bowl of oatmeal, it will only flow a short distance before it stops. The difference between the water and the oatmeal is caused by the starch in the oatmeal.

Solids, including dry starches, hold their shape and stay where they are put. Liquids take the shape of their containers. If there is no container, liquids flow to the lowest point. When you mix solids and liquids, there are some particles trying to stay put and others trying to flow. The more solid that is present, the more resistance there will be to flow. Gels are more viscous than pastes, and pastes are more viscous than sols.

Food scientists run viscosity tests to measure how foods such as ketchup will flow. The scientists use line-spread sheets. A food scientist sets the cylinder in the center of the concentric circles of the line-spread sheet. He or she fills the cylinder with the mixture being measured. The scientist lifts the cylinder, which allows the mixture to flow as far as it will. Substances will rarely flow out in a perfect circle. Therefore, the food scientist takes readings at four equidistant points. He or she then averages the four readings to determine the viscosity. See 9-7.

Viscosity varies with molecular size, shape, and charge. Larger molecules are harder to move, and thus more viscous, than small molecules. Linear molecules are more viscous than branched molecules. This is because linear molecules will not roll over easily unless they are parallel to the direction of flow. Charged macromolecules will have more
resistance to flow than uncharged molecules. This is because of the resistance of opposite charges holding the molecules together. The main functions of starches in food products include providing viscosity, gelatinization, and structure. Therefore, linear starches, such as amylose, are generally more useful in forming gels.

Viscosity could be said to be a measure of a starch’s thickening ability. Food scientists can use viscosity tests to rank the thickening ability of different starches. The scientists can determine the amount of each starch needed to thicken 1 cup of water to the same degree. Listing this information in a starch proportion chart creates a valuable tool for food product developers. They can use the chart to easily see how substituting one starch for another will affect a food product. For instance, changing the type of starch will change the flow of an uncooked batter. Commercial bakers have found they can substitute 30% of the flour in cookies with pure wheat starch. This starch has had protein removed. Protein molecules interact with one another, blocking the flow of a batter. Substituting pure wheat starch for flour will increase the spreading action of the batter. This helps achieve the evenly shaped cookies available in grocery stores.

Stability

*Stability* is the ability of a thickened mixture to remain constant over time and temperature changes. A stable sauce can be frozen and/or reheated. It will look and taste much the same as when it was first prepared. Waxy maize starch is an example of a starch that is stable when frozen or heated. It is a clear, soft paste that is as thick hot as cold.

Cornstarch has more thickening power than flour. It is smoother in texture and more translucent than white flour. However, cornstarch is not as stable in prolonged heat. Cornstarch makes an appetizing mushroom gravy to serve over beef tips. However, suppose you had to prepare the beef tips a day ahead of time. The cornstarch gravy would not thin out into a smooth sauce when reheated. Flour might be a better choice than cornstarch for thickening gravies that must be prepared in advance.

**Opacity Versus Translucency**

*Opacity* refers to how much an object blocks light. *Translucency* is a measure of how much light can pass through an object. An object with maximum opacity allows no light to pass through it. An object with maximum translucency blocks no light. Cornstarch, potato starch, and arrowroot produce gels that are more translucent than gels made with wheat starch. You can see through them to some extent. This makes these starches good choices for fruit sauces, fruit pie fillings, and glazes, which are translucent. Wheat flour is not used for most pie fillings because it becomes yellowish and stringy. However, wheat flour is suitable for use in chowders and white sauce, which are opaque. See 9-8.

**Texture**

The last property a food scientist looks at when choosing a starch is texture. Cornmeal will thicken a gravy, but most people would not like it. The gravy would feel gritty instead of smooth. Likewise, few people make a sauce or gravy from whole wheat flour because of its mouth feel.

**Modified Starches**

Food technologists can alter the structure of starch molecules to achieve special physical
properties. Starches that have been changed structurally by chemical or mechanical means are called modified starches. FDA regulations do not require that labels identify the food product from which a modified starch originates. This can be a problem for those people who are sensitive or allergic to a specific grain product. Some of the most commonly used sources of modified starches are wheat, corn, and soy.

Most modified starches are altered by hydrolysis. They are allowed to set in a mixture or slurry of water and acids or water and enzymes. Starch modification can be controlled to produce various levels of sweetness and particle size. Viscosity, mouth feel, and appearance of starches can also be modified.

Cornstarch that has been modified is used in gum candies and confections as a stabilizer. In the 1970s, it became possible to hydrolyze cornstarch to form a low-cost sweetener. A slurry of cornstarch and acid was heated and combined with enzymes to promote a chemical reaction. The result was corn syrup. Corn syrup has quickly replaced 25% of the 23-billion pounds-per-year sucrose market in the United States. Many manufacturers of processed beverages, syrups, and confections now rely on corn syrup and high-fructose corn syrup. Besides low costs, these sweeteners have relatively reliable supplies.

Cross-linked starches are another type of modified starch. Cross-linked starch is changed chemically so cross-bonding or cross-linking takes place between starch molecules. The resulting molecular network is more resistant to acids and separation in the freezing and thawing process. Potato starch will break down if acid is added, but modified (cross-linked) potato starch will not. Cross-linked starches will not continue to thicken during storage and do not leak water on standing. They are used by food scientists to produce baby foods, salad dressings, cream-style corn, and fruit pie fillings.

Modified food starches can be made to the exact specifications needed for a food product. They have made many new food products possible. Many frozen entrees and instant, quick-mix foods would not be possible without modified food starches. Modified food starches are used to stabilize condiments, sauces, and relishes. They increase the shelf life of many foods thus reducing food costs. These manufactured starches also reduce processor’s dependence on any one grain crop. This helps prevent shortages and keeps food prices more constant.

**Thickening Sauces with Starch**

Starch can be added to liquid to make a thickened sauce in three basic ways. In each method, starch granules are separated to prevent lumping. If starch granules combine into a lump, the outer granules will swell. This prevents water from reaching the granules in the center of the lump. The lump remains dry in the center, the starch loses thickening power, and the sauce becomes lumpy. The method used to prevent lumping depends on the dish, the desired flavor, and personal preference.

**Cold Water Paste**

One method for preventing lumps when thickening a sauce with starch is to form a cold water paste. This involves quickly stirring the starch while adding at least an equal amount of cold water. Continue stirring until a smooth paste is formed. Once the starch granules are evenly distributed, more liquid can be added and the sauce can be heated without lumping. This method can be used to thicken soup stock or milk gravy. It can also be used to make a gravy from broth.

**Starch and Fat**

A second method for preventing lumps in starch-thickened sauces is to separate the starch granules with melted fat. An equal amount of starch is added to heated fat. Once the starch is stirred into the fat, the liquid can be slowly added. Constant stirring is necessary to keep the sauce smooth. This method is used in making white sauce and gravy from meat drippings.

Professional chefs often thicken soups and sauces with prepared beurre manie. Beurre manie is a ball of equal amounts of solid fat and starch mixed together. These balls can be added to hot soups to thicken the broth. The heat of the broth melts the fat. This allows the starch granules to disperse into the broth with little risk of lumping. The French use this
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Technology Tidbit

Modified Corn Starches

To manufacture pregelatinized starch, a starch slurry is heated to above the gelatinization point. The slurry is carried in a trough between two heated horizontal rollers. The heated slurry dries to a thin film on the rollers. The dried starch film is scraped off as the rollers turn. The dried starch is then ground into a powder.

The starch in the powder has already been heated to its gelatinization point. Therefore, it will thicken within minutes of being rehydrated. This thickening without heating is used for instant puddings, pie fillings, and commercial cake frostings.

To manufacture acid-modified starch, a slurry of corn or waxy maize is mixed with HCl or sulfuric acid. The mixture sets for 6 to 24 hours at 25°C to 55°C (77°F to 131°F). The mixture is neutralized with soda ash or dilute NaOH. The mixture is then filtered and dried.

This type of starch is used to make gummy candies. The starch forms hot concentrated pastes that gel firmly on cooling. The cooled pastes are translucent and have a chewy texture that remains stable.


method to make soups and sauces. The balls can be prepared ahead of time. They will keep in the refrigerator for several days or in the freezer for several months. See 9-9.

Cajun cooks who prepare foods from rural Southern Louisiana commonly use a roux to thicken sauces and gravies. A roux is a gravy that has had the starch heated in fat until it turns a rich red-brown. Toasting the flour adds a distinctive flavor to the gravy or sauce. A roux needs low heat and constant stirring during the browning process. This prevents uneven browning and reduces the likelihood of burning the flour. Extended heating will reduce a starch's thickening power. Therefore, a roux can have slightly more starch than fat (75 mL [¾ cup] flour to 50 mL [¼ cup] fat). It will also take more flour per cup of liquid to thicken the mixture. Continuous stirring after thickening will rupture starch cells in any thickened sauce and cause the sauce to become thinner.

9-9 One way to thicken a stew or soup is to add a beurre manie. The ones pictured are made from 2 parts flour and 1 part shortening.
Cooking Tip
If your sauce is too thick, add more liquid. If your sauce is too thin, add one or two beurre manie or add a cold water paste. If your sauce is lumpy, try a whisk to break up the lumps. A gravy stirrer with a spring-like end can also help eliminate lumps.

Starch and Sugar
The third method for avoiding lumps in sauces thickened with starch first requires thoroughly combining the starch and sugar. Then gradually add the liquid. If the liquid is added slowly with constant stirring, lumps will have little chance to form. This is because the sugar helps separate the starch granules and keep them from sticking together. This method of preventing lumping is used in most sweet sauces and puddings. The presence of sugar also helps reduce the viscosity of the liquid. The resulting gel will be tender and smooth rather than rigid.

Nutritional Impact of Complex Carbohydrates
Starches can be divided into two categories: digestible starches and indigestible fiber. Like sugar, digestible starches provide 4 calories of energy per gram. Starch is the most abundant and economical source of calories available to people. Carbohydrates should provide over half of your calories each day. Carbohydrates in the form of glucose are the only energy source the brain can use. The body is very efficient at changing starches and sugar to energy.

Excess carbohydrates are stored as glycogen. Glycogen is larger, heavier, and more branched than most amylopectins. The more branched the glycogen is, the more glucose units the body can release at a time. The body will usually use up glycogen stores in a little less than two hours of vigorous exercise. This is why it is so important to eat carbohydrates every 4 to 6 hours when you are awake. If you skip breakfast, your body will slow brain and organ functions to conserve the available glycogen. Students who skip breakfast will have a harder time concentrating and will remember less of what they hear.

The size of glycogen stores depends on the amount of carbohydrates consumed and how frequently you exercise. Muscles that use up glycogen stores in exercise will increase their future storing ability. The more you exercise, the more energy the muscles will store. The less you exercise, the less glycogen will be available when you need it.

Glycogen is stored in two locations. The liver stores about one-third the total glycogen. It is readily available to the brain and other organs when blood glucose levels drop too low. The muscles store the other two-thirds of the glycogen for times of physical exertion. Suppose your body does not need carbohydrates for immediate energy and your glycogen stores are full. In this case, your body will turn the excess carbohydrates into fat.

If excess starch becomes fat, why not eat a high-fat diet? One reason has to do with the differences in the way the human body uses starches and fats. The body does not need fat to properly use starch. However, carbohydrates must be present to combine with fat fragments for the body to use fat for energy. If carbohydrates are not present, the body goes into ketosis. Ketosis is the process of burning fat without carbohydrates. This process produces ketone bodies as a by-product. High levels of ketones over an extended period will damage the kidneys and interfere with the body's normal acid-base balance. High levels of ketones during pregnancy can cause brain damage and irreversible mental retardation in the fetus.

Fiber, Bran, and Bulk
Much has been written about how people in the United States need to increase the fiber in their diets. Fiber, bran, and bulk are all terms used on labels and in advertising that refer to indigestible carbohydrates. As you read in Chapter 8, the type of glucose determines the digestibility of the starch. A molecule composed of beta-glucose is indigestible and is known as cellulose.

Cellulose provides bulk in the diet. It helps you feel full and aids in digestion and elimination. Many dietary polysaccharides,
mainly from the cellulose components of cell walls, are insoluble and indigestible. The sources of fiber in your diet are vegetables, fruits, and grains, 9-10. Cellulose gives crispness and mouth feel to many foods. Some commercial bakers add cellulose to bread products to improve the water-binding ability of the flour. This slows the staling rate of bread and has been found to improve loaf volume in preparation.

Nutritional Functions of Starches

The main function of carbohydrates is to provide energy for bodily functions. In addition to energy, carbohydrates

- provide bulk for the digestive processes
- tie up bile acids, decreasing their reabsorption
- lower cholesterol levels in the blood, retarding atherosclerosis
- promote the utilization of fat

Carbohydrates are so important that their main food sources represent the largest portion of the USDA’s MyPyramid symbol. The Dietary Guidelines recommend choosing fiber-rich fruits, vegetables, and whole grains often. Six ounce-equivalents of grains, two cups of fruit, and two and one half cups of vegetables per day are recommended for a 2,000-calorie food plan.

Food Feature

The Trouble with Beans

Dried peas and beans, which are called legumes, are excellent sources of many nutrients. However, some people avoid eating these nutritious foods due to concerns about gas. Beans contain the fiber tetrasaccharide stachyose. Like other types of fiber in the diet, tetrasaccharide stachyose is undigested when it reaches the large intestine. Once in the large intestine, multiflora work to attack and break down fiber. (Multiflora are bacteria that naturally live in the intestines.) By-products of this process include acetic and lactic acids. If present in large enough quantities, these acids can have a laxative effect. Another by-product of the multiflora attack is gas. Excess gas produces flatulence, or unwelcome noise and odor.

One way to minimize problems from eating beans is to take a special digestive enzyme. The enzyme product is now available in many grocery stores and pharmacies. It works by breaking up the stachyose in the stomach and small intestine. This prevents the high levels of acids and gas from developing. A drawback to the enzyme product is that it reduces the positive effects of fiber in the body. Use of this product also increases the caloric value of beans.

Another way to avoid problems from eating beans is to maintain a consistent intake of high-fiber foods. This promotes the growth of bacteria that will digest fiber with minimal distress. Eating yogurt also helps promote growth of beneficial bacteria.
A high carbohydrate diet is especially important for cross country runners. Finish eating 3 to 4 hours before competition to keep digestion from interfering with muscle performance.

Eat a high-carbohydrate meal within two hours after exercise to increase glycogen storage by as much as 300%.

During extended periods of exercise, consider consuming a sports drink instead of water. Such drinks are designed to replace electrolytes and fluids while restoring glucose levels for energy.

Types of Energy Foods

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<th>Percent of Calories</th>
<th>Fat and Protein</th>
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<td>55% carbohydrates, 45% fat and protein</td>
<td>83% carbohydrates, 17% fat and protein</td>
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Maximum Endurance Times

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