

Chapter 4: Carbohydrates, Dietary Fibers and Simple Sugars

Carbohydrates are made up of atoms of carbon, hydrogen and oxygen but no nitrogen, and are broken down into sugars such as glucose and fructose or excreted from the body in undigested form. Those carbohydrates excreted in undigested form or those partially or completely digested by colonic bacteria are referred to as dietary fibers.

The simple sugars are glucose, fructose, lactose and sucrose. These are listed as sugars on food labels, while the so-called complex carbohydrates are not included in this list despite the similarity discussed above. Simple sugars can be directly absorbed across the mucous membranes of the mouth. Short-chain carbohydrates such as maltodextrin or corn sugar made up of 15 glucose units are hydrolyzed in the stomach by enzymes and acid. The digestion of other starches begins in the mouth in the presence of salivary amylase. As with proteins, much of the digestion takes place on the intestinal mucosal villi, which have both digestive enzymes and specific transport systems for sugars.

Lactose and sucrose are combinations of two different sugars linked together. Lactose is made up of up of galactose and glucose while table sugar or sucrose is made up of glucose and fructose. High fructose corn syrup (HFCS) is made from corn by a process that ends up with 55 percent free fructose and 45 percent free glucose, approximately equivalent to table sugar. The tastes of corn sugar, sucrose or table sugar and fructose are different. Fructose is the sweetest tasting sugar and is the one found in fruits such as oranges. Corn sugar tastes like pancake syrup and is the primary sweetener in colas in the U.S. In some countries such as Mexico, sucrose is used to sweeten colas and they taste distinctly different from their U.S. counterparts. The issue with corn syrup is not its chemical character but the huge amount in the diet due to government subsidization of corn, so that it is used in many foods, including soft drinks, in large amounts, adding calories to the diet. Studies suggest that the large amounts of HFCS consumed contributes to the obesity epidemic, along with high-fat foods and a sedentary lifestyle.

Effects of Dietary Fiber

Since dietary fibers are not digested, they do not contribute directly to the nutritive value of foods in terms of calories, but they have many effects on human physiology. Ancient man ate a great deal of fiber, and this fiber resulted in numerous large bulky stools that filled the colon and caused it to contract against a large volume load. Modern man eats a small amount of fiber, approximately 10 to 15 grams per day, compared to 35 grams per day in a healthy plant-based diet and well over 50 grams per day in ancient diets.

One consequence of eating a low-fiber diet is that the colonic muscles contract against a smaller volume of stool and so exert higher pressures. It is generally believed that these higher pressures account

for the common occurrence of diverticulosis (outpouching of mucosa between strands of muscle) in the colons of elderly individuals. Constipation is also very common in modern society, since a low-fiber diet does not stimulate intestinal motility as well as a higher-fiber diet.

This slowing of transit time – the time it takes foods to get through the gastrointestinal tract – also permits greater reabsorption of substances normally excreted through the intestines. For example, estrogen (the female hormone) is excreted in the bile from the liver into the intestine. In the intestine, it is bound to fibers and excreted in the stool. Women with low-fiber diets and constipation reabsorb this estrogen in the distal small intestine, called the ileum, rather than excreting the estrogen. This is not a minor effect, and results in 20 percent higher blood estrogen levels in women on a low-fiber diet compared to a high-fiber diet.

Total dietary fiber is classified as either soluble or insoluble dietary fiber. Insoluble dietary fibers such as cellulose (a structural carbohydrate making up plant cell walls) are not digested in the intestine and pass out in the stool where they can be found intact. Soluble carbohydrates such as pectin, guar and starches are digested by bacteria in the colon. Stool mass is determined by the mass of fibers and the mass of bacteria in stool. A significant portion of stool mass is bacteria. Soluble fibers contribute to stool mass by promoting the growth of the bacteria that digest the soluble fiber and use it as fuel.

Complex Carbohydrate Confusion

The term “complex carbohydrate” usually means a long-chain carbohydrate made up of many glucose or carbohydrate molecules linked together. According to the FDA, maltodextrin, or corn sugar, made up of 15 glucose molecules linked together, is a complex carbohydrate.

In fact, as soon as corn sugar is dissolved in stomach acid it breaks up, giving exactly the same glucose release into the blood as table sugars. The original patent on maltodextrin claimed that it would enable infants to get more calories with less diarrhea since each maltodextrin molecule had 15 times the calories of an equivalent caloric load of glucose with much less osmolality (the physical chemical property of dissolved chemicals that draws fluid into the colon). In fact, this does help, but many infants still have colicky diarrhea as the infant expression of stress and food intolerance. Today maltodextrin also finds application in sports drinks, where the load of molecules is important both to get enough calories and not cause gastrointestinal upset in cyclists, triathletes and runners.

Glycemic Index, Glycemic Load and Calories

Twenty-five years ago, it was enough to talk about refined and complex carbohydrates. The refined carbohydrates were considered to be bad “carbs,” because they caused a rapid rise in blood sugar, which could trigger snacking through effects on brain chemistry.

Then in the 1980s, Dr. David Jenkins of the University of Toronto developed the glycemic index (GI). To determine this number, you compare how much the blood sugar rises over a several hour period by comparison to a fixed dose of pure corn sugar (or dextrose). In practice, a plot is made of the values of blood sugar over a two-hour period, and the dots are connected, creating a curve. The area under the curve of blood sugars after the administration of a fixed portion of carbohydrate (usually 50 grams) of the test food is calculated and compared to the area under the curve following the administration of the same number of grams of carbohydrate from glucose in that person, which is given an arbitrary score of 100. The higher the number, the greater the blood sugar response and the resulting emotional impact on sugar craving. So a low GI food will cause a small rise, while a high GI food will trigger a dramatic spike in blood sugar. Here is a list of common foods with their glycemic indexes.

Food	Glycemic Index
Cornflakes	92
Potatoes	85
Jelly beans	80
Cream of wheat	74
French bread	73
Watermelon	72
White bread	70
Life Savers	70
Rye bread	65
Mars Bar	65
Rice, white	64
Pineapple	59
Banana	52
Whole wheat bread	51
Orange	48
All Bran	42
Peach	42
Apple	40
Ice cream, full fat	38
Milk, skim	32
Yogurt, low fat, fruit	31
Lentils	29
Milk, full fat	27
Soybeans	18

While this was a breakthrough, it was faced with some problems. One problem with the GI is that it only detects carbohydrate quality, not quantity. A GI value tells you only how rapidly a particular carbohydrate turns into sugar. It doesn't tell you how much of that carbohydrate is in a usual serving of a particular food. You need to know both things to understand a food's effect on blood sugar. The best

example of this is the carrot. The form of sugar in the carrot has a high glycemic index, but the total carbohydrate content of the carrot in a usual serving is low, so it doesn't have much effect on blood sugar. That's where glycemic load (GL) comes in: It takes into consideration a food's glycemic index as well as the amount of carbohydrates per serving. A carrot has only 4 grams of carbohydrate. To get 50 grams, you'd have to eat about a pound and a half of them. GL takes the GI value and multiplies it by the actual number of carbohydrates in a serving.

A low glycemic load is set at a value of less than 16, and this has been found to be the most important variable in studies of populations and their risk of chronic disease. So, populations eating a diet that has a high glucose load, such as the U.S. diet of processed grains and few fruits and vegetables, have a higher risk of diabetes and heart disease than those in some Asian countries where they eat lots of fruits and vegetables with few processed foods. This has been documented both in population studies such as those conducted by the Harvard School of Public Health, and in weight loss studies in children conducted at Children's Hospital in Boston where a low GL diet was more effective in promoting weight loss than a high GL diet.

You are not going to be able to eat all low GL foods, but it is important to know both the GL and the calories that the food provides. One problem with GL is that some fatty foods, which carry lots of calories, can still have a lower glycemic index. So the guides below are for your information in selecting or limiting carbohydrate-containing foods and some foods that falsely brag about their low glycemic index and load.

The glycemic index, glycemic load and total calories of foods are listed here. The GI of foods is based on the glycemic index – where glucose is set to equal 100. The glycemic load is the glycemic index divided by 100 multiplied by its available carbohydrate content (i.e., carbohydrates minus fiber) in grams per serving. Most of the GI values shown below are based on the 120 studies in the professional literature referenced in the American Journal of Clinical Nutrition, July 2002.

LOW GI (< 55) AND LOW GL (< 16) FOODS

Lowest Calorie (110 calories per serving or less)

	GI	GL	Serving Size	CALORIES
Most vegetables	< 20	< 5	1 cup, cooked	40
Apple	40	6	1 average	75
Banana	52	12	1 average	90
Cherries	22	3	15 cherries	85
Grapefruit	25	5	1 average fruit	75
Kiwi	53	6	1 average fruit	45

Mango	51	14	1 small fruit	110
Orange	48	5	1 average fruit	65
Peach	42	7	1 average fruit	70
Plums	39	5	2 medium	70
Strawberries	40	1	1 cup	50
Tomato juice	38	4	1 cup	40

HIGH GI (> 55) BUT LOW GL (< 16) FOODS

All Low Calorie (110 or less per serving)

	GI	GL	Serving Size	CALORIES
Apricots	57	6	4 medium	70
Orange juice	57	15	1 cup	110
Papaya	60	9	1 cup cubes	55
Pineapple	59	7	1 cup cubes	75
Pumpkin	75	3	1 cup, mashed	85
Shredded Wheat	75	15	1 cup mini squares	110
Toasted Oats	74	15	1 cup	110
Watermelon	72	7	1 cup cubes	50

MODERATE CALORIE LOW GI, LOW GL FOODS

(110 to 135 calories per serving or less)

	GI	GL	Serving Size	CALORIES
Apple juice	40	12	1 cup	135
Grapefruit juice	48	9	1 cup	115
Pear	33	10	1 medium	125
Peas	48	3	1 cup	135
Pineapple juice	46	15	1 cup	130
Whole-grain bread	51	14	1 slice	80-120

HIGHER CALORIE LOW GI, LOW GL FOODS**(160 to 300 calories per serving)**

	GI	GL	Serving Size	CALORIES
Barley	25	11	1 cup, cooked	190
Black beans	20	8	1 cup, cooked	235
Brown rice	50	16	1 cup	215
Garbanzo beans	28	13	1 cup, cooked	285
Grapes	46	13	40 grapes	160
Kidney beans	23	10	1 cup, cooked	210
Lentils	29	7	1 cup, cooked	230
Soybeans	18	1	1 cup, cooked	300
Yam	37	13	1 cup, cooked	160

LOW GI AND LOW GL, BUT HIGH FAT AND HIGH CALORIE FOODS

	GI	GL	Serving Size	CALORIES
Cashews	22	4	½ cup	395
Premium ice cream	38	10	1 cup	360
Low-fat ice cream	37-50	13	1 cup	220
Peanuts	14	1	½ cup	330
Potato chips	54	15	2 ounces	345
Vanilla pudding	44	16	1 cup	250
Whole milk	27	3	1 cup	150
Fruit yogurt	31	9	1 cup	200+
Soy yogurt	50	13	1 cup	200+

HIGH GI (• 55), HIGH GL (• 16) FOODS**Many Trigger Foods, Many Higher Calorie**

	GI	GL	Serving Size	CALORIES
Baked potato	85	34	1 small	220
Cola	63	33	16-ounce bottle	200
Corn	60	20	1 ear, 1 cup kernels	130
Corn chips	63	21	2 ounces	350

Corn flakes	92	24	1 cup	100
Cream of wheat	74	22	1 cup, cooked	130
Croissant	67	17	1 average	275
French fries	75	25	1 large order	515
Macaroni & cheese	64	46	1 cup	285
Oatmeal	75	17	1 cup, cooked	140
Pizza	60	20	1 large slice	300
Pretzels	83	33	1 ounce	115
Raisin bran	61	29	1 cup	185
Raisins	66	42	½ cup	250
Soda crackers	74	18	12 crackers	155
Waffles	76	18	1 average	150
White bread	73	20	2 small slices	160
White rice	64	23	1 cup, cooked	210

Sugars and Other Carbohydrates

Once absorbed, glucose or fructose travel to the liver via the portal circulation where they enter the hepatocyte for metabolism and storage as glycogen, or for synthesis into other metabolites including fatty acids or amino acids by transamination. The release of glucose into the blood stream versus the use of glucose as building blocks for other metabolic pathways is under hormonal and metabolic control as described in the sections on the adaptation to starvation. Muscle cells also play a key role in the uptake of glucose via specific glucose transporters, and muscles can store glycogen or metabolize glucose for energy. Complex sugars such as raffinoses and stacchioses found in vegetables such as beans and broccoli escape into the colon without being digested. These are then digested by colonic bacteria, often resulting in the formation of gases, which can lead to distension and abdominal discomfort.

Why “Carbs” Have a Bad Reputation

Carbohydrates have gotten a bad reputation, due in part to the recent popularity of so-called high-protein, low-carbohydrate diets for weight loss. Classifying foods as “carbs,” proteins or fats is misleading, since few foods are composed purely of one macronutrient, and the quality of the food can vary significantly. A high-carbohydrate diet could be a plant-based, whole foods diet with phytonutrient-rich fruits and vegetables at the base, with a moderate amount of whole grains and healthy low-fat proteins to balance nutritional needs. But, since sugars, refined flour products (such as white bread and pasta), and

refined grains (such as white rice) are all considered “carbohydrates,” a diet that is based primarily on refined grains, while it could be low in fat, could also be very high in calories due to the fact that these low-fiber grain foods are not particularly filling. Individuals who consume a diet of this type may feel virtuous for avoiding fat, but they could easily gain weight on a diet based on refined grains. The recent popularity of a high-protein, low-carbohydrate diet came on the tails of the high-carbohydrate craze of 20 years ago, because people were finding they were gaining weight on bread, cereal, rice and pasta if they made no distinction between whole grains and refined products. Pasta, which had previously been considered “good” because it is low in fat, is now viewed as “bad” because it is often a refined flour product (there are whole-grain versions available).

Carbohydrates are an important element in the diet, and many of the foods that are rich in carbohydrates are also rich in fiber and phytonutrients. The good carbs are simply fruits, vegetables and some whole grains. Carbohydrate needs should be met first by the intake of five to nine servings per day of diverse and colorful fruits and vegetables, which provide a wealth of beneficial substances. If further carbohydrates are needed to meet needs, these can be supplied by whole grains and legumes (e.g., beans). The low-carbohydrate diet concept restricts carbohydrate grams to such a low level that individuals consuming these diets cannot benefit from the many health benefits of fruits and vegetables.