Glucose: Faster Fuel

Glucose is perhaps the most important of all the carbohydrates, created as a product of photosynthesis in plants and used throughout the biological world as a primary fuel source. Glucose rapidly absorbs into the cells of the body and transforms into ATP, the energy "currency" of all animal life. Carbohydrate in the form of glucose is the body's preferred source of energy during strenuous exercise.[1]

Digestion of Energy Sources

Key points:

- All fuel sources must be transformed into glucose for use by the body, a process that takes time and energy, a detriment to performance
- The body relies heavily on glucose as a fuel source for activity
- When glucose levels decline, the body cannot ignore this and performance is affected

For the most part, all sources of energy (food) regardless of makeup (protein, carbohydrate or fat) must be transformed into glucose prior to entering the cells of the body to provide energy. Fats and proteins are not good sources of immediate energy; they must undergo complicated digestive and metabolic processes prior to supplying the working body with energy. Carbohydrates other than glucose must also undergo prolonged digestive processes prior to entering the bloodstream. For example, complex carbohydrates (vegetables) will release glucose very slowly into the bloodstream, while simple carbohydrates (bread) will release glucose at a much faster rate. Once glucose in its pure form enters the blood, blood sugar levels become elevated and the cells of the body then rapidly absorb it.[2]

Because of the variable effect that different carbohydrates have on blood sugar levels, care must be taken to ensure that an athlete receives the most optimal fuel source for energy needs during activity. This is why consumption of glucose during times of high energy demand is very important; if other foods are consumed, the body must expend time and energy to convert them into the body's preferred energy standard, glucose.

In fact, after drinking glucose, absorption into the blood stream is more than double the rate that the body can produce from its own storage forms. [3] [4] Ingestion of carbohydrate during exercise (in beverage form) leads to enhanced performance during longer, moderate to intense exercise.[5] However, it is important to understand the effect on performance varies dependant on the type of carbohydrate consumed.

Storage Forms of Energy & Replacement

Key Points:

- Mobilization of stored energy (glycogen) takes time & energy
- Depletion of blood sugar (glucose) leads to impaired athletic performance
- Replacement of blood sugar (glucose) enhances performance

Glucose itself cannot be stored in the body; however, in its more complex form, glycogen, it can be stored in certain areas of the body (liver and muscles, mainly). Glycogen must be

metabolized prior to becoming glucose again; a process that also takes time and energy. The amount of glucose supplied through the breakdown of glycogen cannot adequately maintain optimal blood glucose levels by itself during rest or exercise.[6] [7] Once the body's current supply of blood sugar (in the form of glucose) has been utilized, the body must then rely on other stored forms of energy (carbohydrates, fats and proteins) for its energy needs. The breakdown of energy stores takes longer than if the energy is already in the bloodstream to get to working muscles.

Depletion of glucose reserves (in the form of glycogen) is well known to be associated with impaired athletic performance; carbohydrate replacement is suggested at a rate of 30-70 grams per hour to minimize carbohydrate depletion and fatigue. In fact, several studies have shown that replacement and maintenance of blood sugar levels leads to improved performance.[8] [9] [10] [11] [12] [13]

Glucose versus Other Forms of Energy:

Glucose vs. Fructose

Key Points:

1. Fructose is poorly absorbed by humans, and enters the blood stream very slowly
2. Poor absorption of fructose (ex. high fructose corn syrup) can lead to gas, bloating and diarrhea
3. Fructose uses precious energy when metabolized, taxes the body of vitamins and minerals, and raises triglycerides, a form of fat in the blood

Glucose and fructose share the same molecular formula: $C_6H_{12}O_6$; carbon, hydrogen and oxygen, but are arranged differently resulting in stark differences in their metabolism. Seemingly not a big deal, the arrangement of atoms in similar molecules makes a huge difference in how it is used. Glucose is the only immediate source of energy for working cells; it is metabolized in every cell of the body while fructose must be metabolized by the liver, prior to providing energy for working cells.[14] Fructose also robs energy stores in the liver during its metabolism.

Glucose is derived directly from the food we eat, so in this sense it is a naturally occurring sugar. Fructose, on the other hand, is mainly derived from sucrose in a chemical manufacturing process. This process also yields high fructose corn syrup. A common food source of fructose is honey. Although honey is an excellent food source for bees, it is not entirely the best source of energy for humans, especially those desiring optimal performance. Fructose is often found in foods marketed to diabetics because it is metabolized much more slowly than other carbohydrates, and as a result raises blood sugar much more slowly.

This structural difference leads to two different problems: fructose enters the bloodstream much more slowly (recall that foods do not provide energy for the body until they exist the digestive tract, enter the bloodstream, and are absorbed by the cells). Unlike glucose, which is readily absorbed, fructose is slower to leave the GI tract, thereby slowing the availability of energy supply.[15] The second main problem with fructose is that anywhere from 40% to 80% of people are unable to fully absorb fructose when supplied in a solution, and some people can only absorb less than 15 grams of fructose at a given time.[16]

When supplied in amounts approaching 50 grams, gas and diarrhea are common occurrences due to malabsorption. Fructose can also slow digestion in general, leaving an athlete thirsty and running low on fuels. A common misconception regarding the preference of fructose during exercise is that fructose will not stimulate insulin release and consequently inhibit the use of fats for fuel in exercise. This is unfounded, as secretion of insulin does not occur during exercise.[17] Furthermore, fructose taxes the body of its vitamins, minerals and enzymes during assimilation, as it contains none of these nutrients that are necessary for metabolism.[18] Fructose is converted into fats more readily than other simple carbohydrates and raises triglycerides (a type of fat in the blood that causes negative health consequences). [19]

Glucose vs. Sucrose

Key Points:

1. High sucrose intake is associate with cavities, obesity and increased fat in the blood (triglycerides)
2. Sucrose is much sweeter tasting than glucose
3. Sucrose must undergo digestion before assimilation into the bloodstream

Linking a glucose molecule to a fructose molecule creates sucrose, also known as common table sugar. Known as a disaccharide (science-speak for 'two sugars'), sucrose is notorious for its adverse effects on human health. Over consumption of sucrose (found in ALL junk foods and many "sports drinks"), is associated with the development of dental cavities, diabetes, insulin resistance, obesity, and elevated triglycerides, which are a risk factor for the development of atherosclerosis (hardening of the arteries).[20] Sucrose is one of the sweetest tasting sugars known. Sucrose is a larger molecule than glucose, and must be digested prior to entering the bloodstream. This will decrease the speed at which it enters the cells to provide energy. Additionally, sucrose may actually 'hold' on to water in the gut, delaying it's entry into the bloodstream and cells where it is needed most and instead remains in the digestive tract causing bloating, gas and diarrhea.

Glucose vs. Maltodextrin

Key Points:

1. Maltodextrin is synthetically created
2. Maltodextrin must undergo digestion before it can be assimilated for energy

Maltodextrin, or sometimes referred to as "glucose polymers" is a name for groups of dextrose molecules that form a long chain-like structure known as a polysaccharide (many sugars). It is artificially created when acids or other enzymes are applied to cornstarch, which breaks the starch into medium-length chains of dextrose molecules. Maltodextrin is much larger than the previously discussed sugars, requiring digestion. Maltodextrin is technically a complex carbohydrate; while this form of carbohydrate can be beneficial prior to and following exercise, it is large and must be altered by the body prior to direct usage in energy processes.

The Glycemic Index and Insulin Response

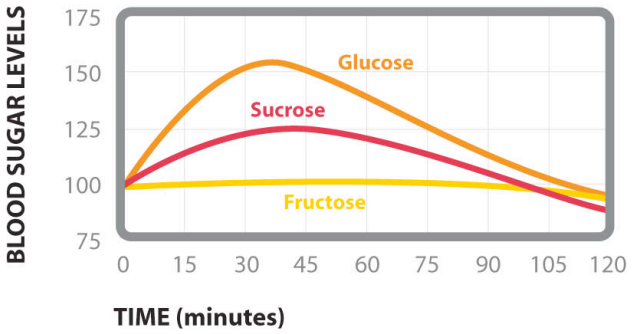
The glycemic index (GI) is a rating system originally developed to assist diabetics in making proper food choices. The speed at which foods are able to increase blood glucose levels is known as the glycemic response. Typically, a carbohydrate is eaten and once it is digested into its simplest form, it enters the blood stream. Carbohydrates are broken down into their respective sugar molecules. This may be glucose, fructose, sucrose, galactose, etc. Once these sugars enter the blood stream, the body senses this and releases the hormone insulin. Insulin is necessary in order for the cells of the body to absorb sugars.

> *Note: one may think of a food as not truly 'in' the body until it has been absorbed into the cells. This means that food in the gastrointestinal tract, or even the bloodstream is not truly in the body. As an example, a diabetic (who is not capable of releasing insulin), can eat a carbohydrate, digest it, and have it in their bloodstream. But because of the absence of insulin, the sugars stay in the blood, and do not enter the cells. This is part of why diabetics have high blood sugars and are typically extremely hungry because they are essentially starving.*

Many factors such as the type of food eaten and how it is processed or prepared influence the glycemic response. The GI ranges from 0 to 100. Glucose is typically assigned the number 100, as it is the most capable of all foods at elevating blood sugar and the respective insulin response. Any other number on the GI scale represents a percentage of how rapidly a food is digested and its sugar components are absorbed into the bloodstream. For example, a food with a GI of 70 is only absorbed at 70% the rate that glucose is. Carbohydrates that are quickly metabolized into simple sugars raise the glycemic index more quickly than foods that are slower to digest. *It must be noted that the GI is indicated only for carbohydrates. Proteins and fats do not directly influence the GI; however if a carbohydrate is mixed with these, it will more than likely slow it's glycemic response and thus it's rating on the GI.*

The glycemic index can be utilized by athletes to determine how rapidly an energy source such as glucose can be absorbed into the bloodstream.

In a recent study of changes in blood sugar concentrations over time, glucose is clearly the best source of energy throughout sport. The high GI of glucose means that it enters the body rapidly providing nearly instantaneous insulin response and entry of the sugar into the cells, providing quick energy. Products with lower GI's (that contain sucrose or fructose, for example) enter the blood more slowly, and are slower to raise insulin, thereby delaying entry of the sugar into the cells and use in the energy cycles.



Changes in Blood Sugar Concentrations Over Time

Blood sugar curves of glucose, sucrose and fructose are representative of the average blood sugar levels that resulted from the ingestion of each type of sugar in a group of subjects. Glucose is the best source of energy before, during & after sport.

Source: Barker J. Glycemic index comparison study of glucose, sucrose and fructose. Gleukos Performance Laboratories, Portland, Oregon. January 2006.

Glycemic Index of Various Carbohydrates[21]

Glucose (Gleukos)	100
Fructose	12
Sucrose	65
Lactose	43
Honey	48
Orange juice	57
Soda	63

Glycemic index of Various Sports Drinks[21]

Gleukos	100
Gatorade	89
XLR8	68
Powerade	65
Cytomax	62
Allsport	53

Glucose: The Facts:

1. Absorption of glucose is so efficient, that the body may be able to absorb 20 pounds of glucose in a 24-hour period.[22]

   Point: This means the body can absorb 6.3 grams of glucose in one minute, or one gram of glucose 9.52 seconds, proving glucose as a highly available energy source.

2. Glucose is the body's preferred source of simple carbohydrate. An active athlete will need roughly 350 to 500 grams of glucose (carbohydrate) per day.

   Point: Supplementation with glucose is absolutely essential if one wants to stay adequately fueled for peak performance.

3. Total amount of blood glucose is roughly 5 grams or 20 calories worth at any time. The liver tries to continually maintain this supply, or it is provided from recent food ingestion. However, as noted earlier, consumption can restore blood glucose levels at more than twice the rate that the body can by itself.

   Point: Because this is such a small amount, it is much more efficient for a person to consume glucose rather than rely on the liver to maintain blood glucose stores-these are needed for later on in the race.

4. Liver glycogen levels (the stored amount of glucose energy in the body) are roughly 75-100 grams, or 300 to 400 calories.

   Point: This is not a lot of stored energy; this will last approximately an hour during exercise. Therefore, energy must be consumed during the course of exercise in order to prevent running out of easily accessed fuel.

5. Muscle glycogen levels total roughly 360 grams or 1440 calories. (Another measurement is 12 grams of glycogen per kilogram of muscle).

   Point: Unless you have huge muscles, this storage form of glycogen is small as well, and will not last long as muscles will rapidly use this up during exercise unless external supplementation with glucose takes place.

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Gleukos Key Points:

1. Once glucose in its pure form enters the blood, blood sugar levels become elevated and the cells of the body then rapidly absorb it.[2]
2. The body relies heavily on glucose as a fuel source for activity
3. When glucose levels decline, the body cannot ignore this and performance is affected