Macronutrients:
Carbohydrate Structure and Biochemistry

Transcript

Now that you have an overview of how carbohydrates are structured and how they function we are going to take a deeper look at the structure and the biochemistry of carbohydrates so you really get a feel for how they work in your body and how to differentiate and how to guide your clients in choosing the best ones.

As usual, just a reminder that this presentation is not intended to replace a one-on-one relationship with a qualified health professional. It is not medical advice. When you are sharing this information with your clients you need to make sure that they are aware that you are educating them and you are giving them what they need to make sound decisions. Always if they are under a care of a practitioner they need to bounce ideas by their practitioner to make sure there aren't any contraindications to whatever medications or treatments that they might be on.

Let's first start with taking a look at the basic core structure of all carbohydrates, which is monosaccharides. There are three main monosaccharides, which we are going to be looking at. We have glucose, fructose, and galactose. Glucose is by far the most common. It is the one that feeds directly into the Krebs cycle to provide us with energy. It is found in not only as part of other sugars, disaccharides which we will be looking at in a little bit, it is also a part of starches.

Fructose is mainly found in fruit but it is also commercially processed from things like corn, high fructose corn syrup. So fructose is found in various places. It has some issues and problems. We will be going into a lot more detail about glucose, fructose, galactose, the various sugars, and how they are processed in the body, in a separate video on sugar.

Finally galactose is milk sugar. It is the single, monosaccharide that is found when we break down lactose, which is the disaccharide milk sugar into its single constituent. So galactose. We will look at the structure of disaccharides in just a moment.

Just to give you a review, each of these sugars is actually a 6-carbon sugars. Glucose is arranged with a ring of six atoms at its core. Five of those are carbons with the sixth carbon being a part of a side chain.

There is also another way that you might see them is with the carbons around the ring not expressed. That is another way that you might see glucose expressed if you are looking at scientific literature. Fructose is arranged in a pentagonal structure meaning five atoms around the ring. Four of those are carbon, one of them is oxygen, and the other two carbons are found in side chains off of some of the other carbons. Again, that is the structure without the carbons around the ring expressed. You might see it that way in various scientific publications.

Galactose, like glucose, is also arranged in a 6-atom ring structure. At first glance it looks very, very similar to glucose. In fact to the naked eye, without someone pointing it out, without having a scientific eye, you probably would not see the difference. If you look more closely you will see that the carbons that are on the sides actually have their hydrogen and OH flipped so they are actually the opposite of the way that the glucose looks. That is it. It is the same, exact numbers of hydrogen, oxygen, and carbon, but it is just a slight difference in the structure that makes a big difference in the function. That is the simplified version.

Let's take a look at disaccharides. Disaccharide as would be implied by the prefix di-, which means two, are two monosaccharides put together. Sucrose is composed of a fructose and a glucose. Lactose is composed of a glucose and galactose. Maltose is two glucose put together. Sucrose is commonly known as table sugar. That is the stuff that is white and crystallized and in the sugar bowl and you pop it on. One glucose, one fructose, and it gets broken down. There is a bond that is holding them together. There are enzymes in the digestive tract that break them down into their monosaccharide constituents. So one fructose, one glucose.

Lactose is the milk sugar. They are bonded together with the galactose and glucose. That bond is significant because it is the enzyme lactase that actually breaks that apart. In lots of folks, in fact the majority of the world over the age of four, have very low levels of the enzyme lactase. You probably heard of lactose intolerance. Lactose intolerance is the inability to make sufficient amounts of lactase to break down the bond between the glucose and the galactose in the lactose molecule.

This is significant. It means that the majority of the adult population throughout the world does not digest milk very well. In fact it makes sense because milk is a species-specific liquid produced by a mom to feed the babies.

Really, in most species, milk is not continued to be ingested into adulthood, specifically milk of another species. So the body is naturally decreasing that function to make room for other functions so that we do not have a wasted function into adulthood. But because of our insistence that milk is good for you ‘got milk?’, the milk ‘mustaches’, all of the things in the dairy industry are pushing to promote milk, that we are learning we have a lot of people that are lactose intolerant. But also there has been some adaptation over time so that you are, by necessity, learning how to digest that.

Finally maltose is two of the glucose for together. Maltose, you will see in fermented products like barley malt and fermented rice syrup. Barley and rice are actually starches to begin with. They have long, long chains of sugar molecules chained together, glucose molecules chained together. Maltose is a sugar, it is a disaccharide form of another starch that gets activated when there is some fermentation happening to create a sweet product from a starch. That is, in summary, disaccharides. Sucrose, again, is glucose plus fructose. Lactose is glucose plus galactose, and maltose is glucose plus glucose. Again, we will go into more detail about the various sugars and how they function in the body in our separate video on sugar.

Let's look at oligosaccharides. Oligosaccharides are actually chains of monosaccharides put together. It is usually anywhere from 3 to 9. You may see different textbooks refer to them as a little bit longer or a little bit shorter but basically they are the shorter chains. They are not quite disaccharides but they are not quite polysaccharides, which are the longer starch chains. The one that you might have heard of most commonly are the fructooligosaccharide.

Fructooligosaccharides are a specific type of oligosaccharide that are found in various vegetables that can actually be used as a prebiotic; meaning that the bacteria in our guts will eat it up and grow as a result. We don't have any ability to break it down so it doesn't really provide any caloric value to us as humans. This does provide some really good food for the probiotics that grow in the gut, which makes it a good way to grow things. There are a lot of controversies over fructooligosaccharides.

Some say that they actually can also feed bad bacteria and bad organisms like candida. The jury is out on that. It is really a matter of testing people and seeing how they respond. There is a particular type of diet called the FODMAPS diet, which we will get into more detail later in the course, and it actually recommends that we remove all fructooligosaccharides from the diet because a lot of people cannot digest them.

It is not a universal principle by any stretch. When you are working with people who are having difficulty digesting, these are all of the stones you do not want to leave unturned and make sure that they are not sensitive to fructooligosaccharides that may be causing bloating and gas, is a good thing to do.

Some of the lovely things you may have heard of are amylose and amylopectin. Pectin is particularly found in citrus. You will see modified citrus pectin used therapeutically. Pectin is actually one of the soluble fibers meaning that it can dissolve in water versus an insoluble fiber which is stuff like wheat bran and cellulose which do not dissolve in water. They provide more coverage and a broom to sweep out and latch onto toxins and eliminate them from the body.

[10:35] Let's look in a little more detail at fructooligosaccharide. Like I said, they actually feed the good gut bacteria. They are not digestible by our pancreatic enzymes. They are also known as prebiotic but the other thing that most people do not realize is fructooligosaccharide can help promote calcium absorption, which can be a good thing if you are working with women who have a tendency towards osteoporosis.

This is what we see as far as the breakdown product of a fructooligosaccharide. If you look at GF, glucose and fructose, that’s a sugar, that's called sucrose. If you add another fructose to it, and another, and another up to nine, you have what is called the fructooligosaccharide. If you add a lot more of the fructose onto it you have a fiber called inulin. Inulin has a sweet flavor but, again, we are not able to break those down. That could be a blessing or that could be a curse. If there is some disruption in gut flora and disruption in the normal way the gut is working, then not being able to absorb those can actually create a fermentation process, a negative fermentation process that happens lower down in the gut which can lead to gas, bloating, and indigestion.

What are some of the other food sources of fructooligosaccharides? We've got Jerusalem artichoke, we've got yacon which is a root that grows in South America, a very common food there, and it is actually used and made into a syrup which is very sweet but generally does not increase blood sugar and generally does not cause issues the same issues that sweeteners do. Again, test, test, test. What are we going to do? We're going to test.
We can ask our client to try yacon, and if they are really looking for a sweetener and see how that works and see if they get bloating and gas because they may have issues with handling the FODMAPs which we will talk about later.

Blue agave, not something that I highly recommend because it also has a lot of fructose in it but blue agave supposedly has more FOS in it than it does fructose. Jury is out.

Bananas have fructooligosaccharides, onions, and chicory root. Chicory root is a new kid on the block in terms of sweeteners. Chicory root contains a fair amount of FOS and as a result it has been recently turned into a syrup that is used as an alternative sweetener. I've tried it. It actually tastes quite sweet and the good news is, it does not raise my blood sugar and I do not get gas from it so, ‘yay’, it is a good one for me.

Again, you are going to have to test, test, test with your clients if they really need something sweet and they are looking for that sweet. Well we are looking for things that do not cost a lot the disruption so it is worth a try. I can say that also Jerusalem artichoke, there is a manufacturer that is making a Jerusalem artichoke syrup which has a slightly sweet, almost maple syrup type of flavor or molasses type of flavor but again does not seem to have the same blood sugar raising effects. Again, fructooligosaccharides, they are eliminated on the diet called the FODMAP diet and we will talk about that in a bit.

Other things that contain fructooligosaccharides are garlic, asparagus, jicama, tomatoes, and leeks: a good source of these foods for the good gut bacteria that our bodies are not able to break down. However if there is a disruption in the lower gut, in the large intestine, in some people, a small percentage of people, do not handle FOS very well and it can cause bloating and gas.

Let's take a look at polysaccharides. What are polysaccharides? Polysaccharides, also known as starch, and starch is a long chain of glucose molecules put together. It repeats and repeats and repeats in various lengths and sundry things depending on what food you are looking at. The other polysaccharide, which is really important for us, is our storage form of sugar: glycogen.

Our body in its infinite wisdom, can take all of these chains and chains and chains of glucose, put them together and store it in the liver and the muscles, so that when we need sugar and there is none to be found in the body, there is a process called glycogenolysis, which causes the breakdown of glycogen into sugar.

Glycogenolysis is typically stimulated by a hormone called glucagon which is secreted by the pancreas. It is the opposite of its cousin, or sister, however you want to call it, insulin. So insulin causes the taking of the sugar that is in the blood and putting it into the cells.

Glucagon goes out to the liver and to the muscles, finds the storage form of the sugar called glycogen, which is basically mammal starch so to speak, which is our storage form, breaks down the bonds between, and increases in blood sugar. This is really important because the folks who get cranky and irritable if they miss meals, there is a disruption in this process because we should be able to go a long time without having food and keep the blood sugar up through the action of glucagon breaking down muscle glycogen.

Not everybody is functioning properly and in some cases there is not a lot of glycogen stored in the muscles, in which case we need to find other forms of glucose to raise the blood sugar, which causes an emergency response from the adrenals to produce cortisol and adrenaline, which will then break down fat stores and the muscle stores. This is a very complicated process. We have a whole module devoted to all of the hormones involved in keeping blood sugar steady, so we will revisit back then.

What is cellulose? Cellulose is fiber. Cellulose is actually fiber. What is it, it is again, a long chain of glucose but it has a particular bond that we do not have enough of the cellulase enzymes to break down which is good. So instead it goes out, basically the way it comes in, and causes a brooming effect of the gut. So cellulose really, the mystery, it really is just a repeated chain of these glucose molecules stuck together, but the bond is tight and we do not have enzymes as humans to break it down. Therefore it acts as a broom and has no caloric value.

The last group of sugars that we are going to look at are sugar alcohols. They are also known as polyols, which is the P in FODMAP. They really do not contain any ethanol in spite of the fact that they are called alcohol.

The reason that they are call sugar alcohol is because they are similar in structure to glucose except they have extra OH, which is alcohol in chemistry terms. So sugar alcohols have a sweetness, which is similar to sucrose and they have fewer calories than sugar. Some have more and some have less.

We will revisit these sugar alcohols in our sugar presentation and go into the various types of sugar alcohols and how many calories each one has and what the relative benefits are of them. The good news is they don't generally raise blood sugar, or they only raise blood sugar a little bit. We will look at that when we look at our sugar module. So that concludes our deep dive into the biochemistry and the structure of our carbohydrates. We will talk more about the clinical applications on the next video.