PHARMACOGNOSY AND PHYTOCHEMISTRY

Dr. Galvina Pereira

Department of Pharmaceutical Sciences and Technology

Institute of Chemical Technology, Mumbai

Week 3

Lecture15

Week 3: Lecture 15: Soluble and Insoluble fibers

Hello everyone, and welcome to the NPTEL course on pharmacognosy and phytochemistry. In this session, we will be studying different types of carbohydrates, which are soluble and insoluble fibers. So, what are soluble and insoluble fibers? Sometimes, carbohydrate derivatives such as fructooligosaccharides, galactooligosaccharides, or pectins, when soaked in water, form a clear viscous solution. The carbohydrate fibers that are soluble in water but do not degrade are called soluble fibers.

They often result in a very viscous, mucilaginous solution, as we observed in pectin agar. So, most of your gums and mucilages, when hydrated, form a slug-like substance that is viscous, gooey, and thick. A little difficult to digest, though. Such fibers are called soluble fibers. Now, when we move to the second type, insoluble fibers, sometimes you see fibers—take, for example,

your husk, rice bran, or sometimes the polishings or certain vegetable fibers. You must have noticed that when cutting ginger, some fibrous strands protrude out. Even if you put them in water, they will not dissolve. Such fibers are called insoluble fibers. They are generally cellulosic or may comprise hemicellulose or sometimes have lignin deposits. Such fibers are called lignified fibers. A good example of a very herbal remedy used for constipation is isabgol husk. If you examine isabgol husk, you will notice cellulosic matter. When placed in water, the isabgol gradually swells over time, becoming mucilaginous.

So what we have done is we have just taken a little isabgol husk and we have put it on our slide and stained it with a dye called ruthenium red. What ruthenium red does is it stains the mucilaginous matter. And as you can see, when your isabgol swells, this is the mucilage that is swollen and that has taken up your ruthenium red dye. So there are numerous mucilage containing drugs and they form an integral component of your soluble fibers.

But apart from that, you have your pectins, you have your gums, which also are soluble fibers. So what is the difference between your soluble and insoluble fibers? Let's understand them clearly. So soluble fibers, as the name indicates, if you keep them in water, hydrate it or warm it in water, they will form a clear gel like viscous substance. We often refer to a glue like substance and these are the attributes of your soluble fibers.

Whereas when you take your thread, say for example, cellulose or when you take your ginger shreds, when you're doing your cooking, you will see that this fibers or cellulosic fibers or your coir, coconut coir, you will see that this do not dissolve in water. And then they are called insoluble fibers. So there are numerous sources of soluble fibers. This includes your oats, apples.

We saw apples as a source of pectin. Citrus, which is also a source of pectin, as well as barley and legumes, all contain numerous soluble fiber components. Whereas if you see husks, bran, grains, or stiff vegetables—like carrots and celery—when you crush them, you'll see fibrous, string-like things coming out. Those are all sources of insoluble fibers. So sometimes, even in your diet, people say you have to eat fibers.

So which fibers are good? This is something we'll see in the next point. So if you see the digestion. Now, the first part is when you take soluble fibers, they will get into your gut. They will swell.

So they will give you a feeling of satiety—that is, fullness. And they will slow your digestion. Why? Because it's a very viscous solution that has formed or occurred in your stomach. So it slows your digestion.

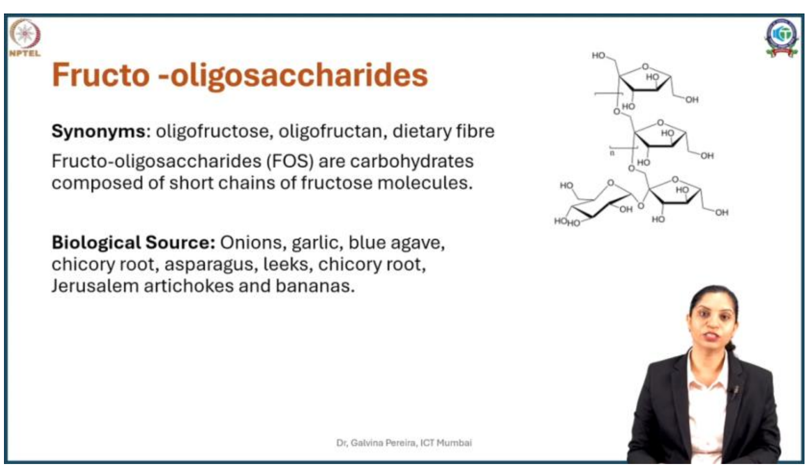
At the same time, it decreases because it's a viscous solution. Nothing can get absorbed very quickly. It forms a barrier-like thing and hence controls the absorption of your blood sugar as well as cholesterol and sadly, some nutrients also. But on the other side, if you see insoluble fibers, imagine something like a rope or coir when you consume it, or bran or husk.

They are not going to swell in your stomach.. They will remain as such. And what happens is they tend to irritate your gut. Now, when they irritate the gut, they do not add bulk, but they increase what is called the peristaltic movement. And as a result, insoluble fibers have a slight laxative effect as well.

Now, in terms of fermentability, soluble fibers, because they are already hydrated, have imbibed water. The microorganisms can get very easy access to them, and hence they can be fermented. Whereas if you see cellulose or lignified fibers, they are pretty stiff. They are not easily digestible. They mostly come out as such in a very undigested or less digested form.

In terms of health benefits, these are definitely the fibers that will help you. The soluble fibers will help prevent a sugar spike. They will decrease the absorption of lipids and hence help with heart conditions. They will help with weight management. They will help with sugar management.

Whereas, if you look at insoluble fibers, they are the ones that trigger peristaltic movement, prevent constipation, and improve gut health. So, let's take an example of a soluble fiber here. And those are your fructooligosaccharides. So, what are fructooligosaccharides? As you can see here, it's a



polymer of fructose, and that's why it's called fructooligosaccharide. So, in this case, you can say that a particular unit of fructose—I'm just putting it here—gets repeated n- number of times. Now, this n can be multiples. So, what happens here is there is a linkage between carbon 1 of fructose and carbon 2.

So this is 1, and this is 2. So there are 1-2 linkages occurring. So this fructose goes on polymerizing to give you an oligosaccharide chain. And if you see your food products—if you see your onions, if you see your garlic, blue agave, chicory (which is often added in conjunction with your coffee), asparagus, leeks, or, you know, Jerusalem artichokes or bananas for that matter.

They are a very rich source of fructooligosaccharides, which are also soluble fibers. Now, let's see what these are as described. This is your carbon number 1; this is your carbon number 2, and the kind of linkage that happens here is a beta. So it's a beta 2,1 glycosidic linkage, and this can easily be represented by the formula GFN. Why GFN? Most of the fructooligosaccharides have their

unit or the end unit as glucose, and the remaining units are all your fructose. So you can see, and plus, if you add a little 'n' here. where 'N' is the number of molecules. Now, this 'N' can range somewhere between 2 to 60, and the molecular weight goes really high—into the thousands units. So, if you see them in terms of their utility as sweeteners, they are polysaccharides.

So, they do not have the ability as a sweetening agent. They are mildly sweet and that is because they get digested by our enzymes into little small sugars but they do take time for the process and that's the reason they are mildly sweet but in terms of its utility as a soluble fiber it is of great help to us. So how are these fructooligosaccharides prepared? Now industry or if you go on the retail or e-commerce sites because of their utility, we just saw how good your soluble fibers work because of their utility in the market.

you will see numerous brands selling your fructooligosaccharides. So they can be obtained in two ways. First, you can obtain them from plant sources like we saw a few of them. That is what you are going to take if you are going to take the plant. For example, you can take your chicory.

extract it in the warm water to dissolve the soluble fiber and then get it to a desired size length by help of an enzyme called enolase. These short chain compounds which are then dissolved in water are filtered and then precipitated with alcohol or any organic solvent which is immiscible in water. So your carbohydrates are not soluble in water and as a result they will precipitate. The other way which industry does it is using your microbial or especially your fungal cultures. Fructooligosaccharide you can take it using sucrose as a source that is a carbohydrate source and use a culture of *aspergillus niger*.

Now this *aspergillus niger* has an enzyme called fructosyl transferase. so this fructosyl transferase takes the molecule of sucrose and to that sucrose goes on adding one by one molecule of fructose. So if you see here, if you remember this was your glucose, this was your fructose. So glucose plus fructose together make your sucrose. So to this sucrose using fructosyl transferase you go on adding your fructose subunits and as a result you are going to get your fructooligosaccharides.

So here also in industry they do it and in this case you get it with much much higher purity. This is also precipitated using water miscible organic solvents and graded as per the size. In terms of utility, you can think of all uses of water soluble fibers that can be applied. So it helps in weight management and it reduces the cholesterol level. This has been even tried in experimental animals and you will see numerous supplements already available in the market.

It's a low calorie sweetener, but its sweetness is half of that of your sugar. Now if you want to prepare something which is fortified or much much more nutritious or fiber loaded definitely fructooligosaccharides have been added and this has been done in your cold drinks, beverages, bakery products and even in dairy products. Now consumption of soluble fibers, especially fructooligosaccharides, improves bowel movements and regularity. Now one more little effect associated with fructooligosaccharides are these are digested by your gut microbiota and then it is converted into what is called as short chain fatty acids. Now this short chain fatty acids if you see the overall pH of your intestine as you move distally towards the colon the pH becomes alkaline and as a result your absorption of minerals do not happen in the colonic area.

But because your gut microbiome is consuming fructooligosaccharides and producing short-chain fatty acids, these acids make the pH slightly more neutral. So they continue to help in the absorption of minerals by creating a slightly acidic pH, and these short-chain fatty acids have also been beneficial in the management of colon cancer. It also helps the growth of prebiotic microorganisms such as bifidobacteria. But there are some effects associated with the overconsumption of fructooligosaccharides. They might be due to the microbiota digesting them.

And this includes diarrhea, gas, bloating, or in some cases, abdominal cramps. So we move to the next one, and the next one is an example of a water-insoluble fiber, and that's your common cellulose. Now, if you see cellulose, cellulose is a polymer of glucose. We discussed another polymer of glucose previously, and that is starch. Now, how does it differ?

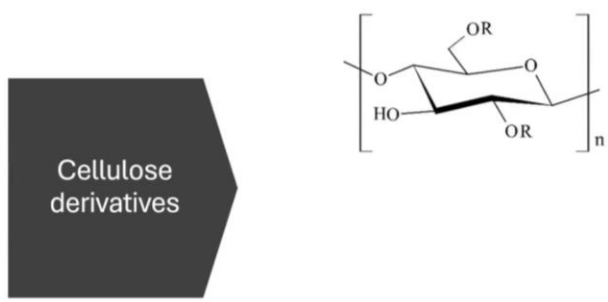
You can see here it only differs by the nature of linkages, and here you will see beta linkages. So cellulose is commonly found in the plant family. Commercial cellulose comes from wood and cotton. If you see wood, it still contains tannins, which are brown and lignified components. But if you see cotton, cotton has almost 95 to 97 percent pure cellulose.

So if you want to obtain cellulose for commercial use, it's generally obtained from wood or cotton fibers. Now, agricultural wastes have also been used to harness cellulose, and this includes rice husk and wheat straw. Apart from that, some microbial sources like *Acetobacter xylinum* have also been used or explored for the production of cellulose. Now, why is cellulose important? Let's see the chemistry first.

Cellulose is a polymer. Similar to starch, it consists of repetitive glucose units, and this time, the enzyme plays a role. Now, what links during biosynthesis? Instead of forming alpha linkages, the enzyme selectively creates beta 1,4 linkages. Now, what is the advantage of creating beta 1,4 linkages? You will see that when you consume starch, it can be easily digested. But because of alpha-amylase.

Now, we don't have beta-amylase, which can, you know, hydrolyze or cleave glucose molecules, and as a result, cellulose remains mostly undigested in humans. Now, as it remains undigested, it becomes what is called insoluble fiber. So cellulose, if you see the polymeric region, depending on its arrangement, has both domains: the crystalline domain and the amorphous domain. Now, because of that, it has good stability and rigidity. Imagine coir fibers—they are very difficult to break, but starch is very pliable. If you swell it, it forms a viscous gel. Cellulose does not. That's the beauty of these beta linkages—they're insoluble in water, even in organic solvents. They are strong and considered biodegradable, making cellulose a very good excipient.

Now the question comes to your mind: how do you apply this as an excipient when it is not going to be soluble in anything? So, in order to make it soluble, numerous derivatives of cellulose have been prepared. Now, I have just put a simple sugar moiety here and imagine for glucose, where this was your H and H out here—I am derivatizing it. For example, let's take this R. In this case, if I put it as a CH3, I make it a methyl derivative. I create what is called methyl cellulose.



Similarly, if I do it, I create what is called ethyl cellulose. So, methyl cellulose and ethyl cellulose have been used as excellent binders, and they have the property to swell and absorb water, unlike cellulose. Now, in addition to that, you have something called hydroxypropyl cellulose. So, this is R, and I'm just starting it from here. So, let's put this as carbon number one, carbon number two, carbon number three.

Let's put a hydroxy here. So, hydroxypropyl cellulose. And then here, if I add an additional methyl, I'll get methyl hydroxypropyl cellulose, which is also called Hypromellose. So, hydroxypropyl cellulose and hypromellose have been used extensively as film-forming agents. So, imagine sometimes when you have dry eyes, a doctor gives you a certain drop.

And those are made up of hypromellose. Sometimes you might be consuming what are called menthol films. We call them orally disintegrating films. So they are very good film producers. And once you dissolve them in a particular solvent and dry it, they create nice, soft, pliable films.

So apart from that, you have acetate derivatives. So you have your cellulose acetate. In addition to cellulose acetate, there is cellulose acetate phthalate. Now, cellulose acetate phthalate gives a very water-resistant, acid-stable film, and that is used for coating your tablets. So numerous derivatives of cellulose can be prepared.

You can even play with the amorphous and crystalline domains of cellulose. Imagine if you hydrolyze the cellulose—only the amorphous domains, because they are very susceptible, get hydrolyzed, and the crystalline domains remain. These crystalline domains precipitate to form what is called microcrystalline cellulose. So you have MCC, which is microcrystalline cellulose, used in the pharmaceutical industry as a good binding agent and disintegrant. You have nanocellulose, which is nowadays used in drug delivery systems.

You also have cross-linked cellulose, which is obtained nowadays for creating what is called bioplastics. So numerous cellulose derivatives have been prepared. But apart from pharmaceuticals, if you see your textile industry, imagine your cellulose, you can dissolve it by using alkalis. So you convert it into a sodium salt and then treat it with something called carbon disulfide. Now this sodium or potassium salt, when treated with carbon disulfide, completely dissolves in a medium.

That is your basic medium. And then when you just put this blend through a needle and put it in acidic pH, you get this regenerated cellulose. So your rayon, or what is referred to as viscose, is actually regenerated cellulose. So this is used to make fabrics. This is used to make paper.

So cellulose has very extensive utility. So if you see in terms of applications, it's used in papers, textiles, especially cellophane, to prepare rayon in pharmaceuticals, binders, fillers, or, you know, dusting agents for your gloves. Nowadays, your HPMC, hydroxypropyl methyl cellulose, is also used in creating your vegan capsule shells, which were earlier made up of gelatin. In the food industry, it is used as a thickener and stabilizer, and nowadays, because of nanocellulose, it's also used in nanoplastics, composites, electronics, and cross-linked cellulose is used to prepare bioplastics. Here's to further reading, and thank you for your attention.