

Food Packaging Technology
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Lecture – 19
Testing of Packaging Materials P4

Hello everyone. Welcome back to the third module of the Food Packaging Technology course. This week we have already discussed on the designing of packaging materials and I have already gone through the testing of packaging materials in three parts. We have come to the last part, fourth part, a revision of what we have done. We talked about testing of packaging materials, paper, paper boards and on plastics. That was the first and the second part.

The third part we talked about permeability, especially water vapour transmission rate and gas transmission rate along with the overall migration. Coming to the last part which is on the identification of plastics and the access to storage life. I thought it would be a good addition as part of the testing of packaging materials. Though it is the other tests that we have studied in part one, two and three that are generally done in the food packaging laboratories.

Now this picture here might look a little confusing but you can go step by step and see what are the different tests that can be done to identify a plastic. Now we have plastics everywhere from foods to cosmetics to pharmaceuticals, even daily use, buckets, chairs, everything is made of plastics. But how do you identify what plastic it is? You have already gone through the different kinds of plastics, LDPE, HDPE, the polystyrene, polypropylene, but how would you identify how they are? The first thing we need to do is we need to find out the form. Now there are three things in this diagram here in maroon, the film, foam or bottle. You have certain plastics which are in films which is used for wrapping and for packaging.

You have certain plastics in the foam material and certain plastics come as bottles or rigid materials. Now let's start with bottles or rigid plastics. When you get a plastic bottle, the first thing you would look is visible identification code. You would have noticed in most of the bottles, underneath these bottles or containers, you would have seen codes like these. Number one will be your PET, polyethylene terephthalate.

If you see this number two, it will be high density polyethylene, HDPE, you have

already learned the properties in the other modules. Now this symbol here shows that these are recyclable too. Now number three is PVC, polyvinyl chloride. Number four is LDPE, low density polyethylene. Number five will be polypropylene PP.

Number six polystyrene and you have the other numbers which are unallocated references which number seven which is the highest number. Now if you have this code there, this is yes, this is the first one here, number two which is visible identification code. So, does your plastic bottle or your container have visible identification codes? If this is yes, you can directly identify but if it is no, you do not have any code under your plastic, what is the next thing you would do? You would see what happens when silver is cut in the plastic. What that means is if you take your plastic material and you cut it with a blunt edge, certain materials will give you certain powdery forms. Now if you get these powdery forms, they are supposed to be the thermoset plastics.

I hope you recall what are thermoset plastics and thermoplastics. Thermoset plastics are plastics that are usually seen in switchboards that once formed, you cannot heat and remold them again. If you take a blunt material and cut it, you see those powdery materials which is known as silvers, then you can identify them as your thermoset plastics. Now these thermoset plastics which you can see in these pictures, they can be also used in your switchboards like semiconductors and your integrated circuits. Now if it is not, suppose you do not get these powdery materials, if it is no, then if it is smooth, you can cut it smoothly, then it is supposed to be some of your thermoplastics.

Thermoplastics is a wide range of plastics that we have studied in detail. Now the next thing you do is you take these plastics which you confirm that is not thermoset, you allow them to float in water. Now those floats, suppose they float in water, then they are supposed to be your polyolefins. What are these polyolefins? Polyolefins are your P, polyethylene which consists of HDPE, LDPE and the polypropylene. So, if you see that your material floats in water, then it can be your polyolefins, one of these three.

One of the next tests you can do is, you put this plastic into, now you have confirmed that it is polyolefins, you put it into alcohol. You notice that HDPE sinks, if the plastic sinks, it is HDPE which is high density polyethylene and if it floats, it can be your PP, polypropylene or your LDPE. So now you have different HDPE from the other two polyolefins. You take the material, suppose it does float, you take that material and put it in vegetable oil. If the material floats, then it is supposed to be polypropylene.

Now polypropylene is another material which has got excellent chemical resistance, high melting point and it is hard but fairly flexible. Plastic chairs you see, any flexible containers that you have, those are generally your polypropylene. They have good

printability also. That has a waxy surface and it has a translucent finish. You can find them in most of your products like I told you, the pancake syrup bottles, the yogurt and margarine containers, potato crisp bags, plant pots can also be made of polypropylene, heavy gauge, your woven bags and tubs, these are also made of polypropylene.

So if it floats, it is your polypropylene. So, you put it in, once you have your polyolefins, you first put it in alcohol, differentiate your HDPE and those that float, you put it into vegetable oil. If it floats again, it is polypropylene. What if it sinks? If it sinks, if it does not float, that is what I have written here, no. If it doesn't float, then it is supposed to be your polyethylene, most likely LDP.

Now polyethylene itself like we already know, there are two types, HDPE, high density polyethylene and LDPE, low density polyethylene. HDPE, excellent barrier properties, chemical resistance, strong, semi flexible and permeable to gas. On the other hand, your LDP is predominantly used in most of your plastic bags and it is used in manufacture of many films like garment and produce bags, your agricultural films, refuse sacks, anything more, it is very versatile one. So, if it floats in vegetable oil, you can guarantee it is LDPE. With all simple tests, you can identify some of the plastics.

Now coming back, now that we have identified our polyolefins, we look at the ones that suppose it does not float in water. The ones that float, they are polyolefin. If it doesn't float in water, it can be some of the others. Then one of the most important tests they do to identify the other plastic, PVC, PET, polystyrene, those tests will go in for the flame test. You will burn it and you will find out what is the color of the flame.

Now if you do get a green color flame, it is supposed to be PVC, polyvinyl chloride. Now polyvinyl chloride has excellent transparency, good chemical resistance and its long-term stability. You must have seen PVC in most of your bags because it is impervious to the attack of bacteria or organisms. It is also corrosion resistant, good strength. It is also used in food contact applications, it is also used in carpet backings, windows, shampoo bottles, vegetable oil bottles, anything.

PVC is also versatile and if your flame is green in color, you can guarantee it is PVC, polyvinyl chloride. Now suppose you get a blue flame. The blue flame indicates that your plastic is some other plastic not identified with the 6 most common plastics. The most common ones in this category under blue can be your nylon which is polyamide, ABS which is acetonitrile butadiene styrene or your polycarbonates which is for burning bottles, polycarbonates or PC. Now these items that are layered or have a mix of polymers can also fall into this category and give you a blue flame.

Coming back, once you have your green and blue flame, the third one is the yellow flame. Suppose your flame turns into yellow color. Now here you have a few differentiations which have to be made. Can either be polystyrene or ABA PET. So in that case what they do is, you go in for, you react it with acetone.

Now you find out if your sample does react with acetone or not. If it does react, if your answer is yes, if it does react with the acetone, then you can guarantee that it is your acronitrile. Butadiene styrene or polystyrene which you can use in many of your thermoform trays and your hangers is also made of polystyrene. Polystyrene usually is opaque to glassy surface. It's generally rigid, hard and brittle.

Now usually they are used in yogurt bottles or containers like I told you. Fast food containers are very commonly used that you use your thermoform trays as polystyrene, video cases, venting cups, brittle toys, all these are made of polystyrene. So if your flame becomes yellow in color and if it reacts with acetone, you can say it is polystyrene. If it is yellow and does not react with acetone, then it is PET.

Polyethylene terephthalate. Now this is also very commonly used plastic. It's a very common term to say a PET bottle. Most of your bottles are made of PET, very hard, clear, tough, solvent resistant and it's very good gas and moisture barrier. It has got very high heat resistance and microwave transparency. And because it has good gas and moisture as a moisture barrier, these can be used for your fizzy drinks and beer bottles are made of PET.

That's where common term of PET bottles come from. Most of your bottles are made of PET. It is also ideal for pre-prepared food trays, boiled in bag food pouches and used for clothing and carpets, trapping and mouthwash bottles. So if it does not react with acetone, you can say that it is PET. Now I think this picture looks much more clearer to you, not as confusing as you first saw it.

We started with the bottles, so we went through the different, it has a code and then we talked step by step. We first put it in water, you see if it floats in water, if it does not have silvers, then you put it in water. If it floats, polyolefins, you can differentiate from the polyolefins by putting it in either vegetable oil or your alcohol test. Further we went to the flame test and tested out the colours. It came either green, blue or yellow and we differentiated the different plastics.

Now these plastics in the form of films, as shown in the first one, again you can do the flame test. Green, yellow and blue which is the same as that that you found in the bottles. Similarly for the foam, you can again go in for the flame test directly. So now once we

go in that, there are other tests that can be done to identify your plastics and one of them is you stretch or non-stretch. Suppose you just give it a slight pull and see if it is stretchable, it can be either polypropylene, nylon or PVDC, polyvinylidene chloride.

If it is non-stretchable, it will be cellophane, PVC, PET or polystyrene. The other test that they do is they pass an extinguished match through the flame. Now suppose the matchstick does not easily pass through these plastics, then it can be cellophane and if it does pass through easily, it will be your thermoplastics. Another thing is they do is in cellophanes, how do you differentiate the different types of cellophanes that you use for wrapping paper, that you use for wrapping films. One of the tests is you put a droplet of water onto the film.

If it spreads, it will be a PT cello and if the droplets are non-sticky and they are spherical, they form a round shape, then it is coated cello. It is coated cellophanes. Another test is you put a drop of diphenyl amine in 95% concentrated H₂SO₄ on the film. If you get a dark blue colour, it is supposed to be nitrocellulose coated cellulose or cellophane. And then there is another test which is a copper wire test and if this test is positive, the cellophane film is coated with the PVDC.

So all cellophanes usually burn like paper. So if that happens, it is a positive test. This table here differentiates the different classes of plastics. It is not exactly related to the identification but at the end of it, if you can give just a revision as to what are the different classifications and what are the properties of these three different plastics that we identified. We have thermoplastics, thermoset plastics and elastomers. So most of your thermoplastics, they have linear or branched macromolecules.

They usually sell either crystalline or they may be amorphous. Usually the density is between 0.9 to 1.4 grams per centimeter cube and for amorphous, 0.

9 to 1.9. Now these materials, if it is crystalline, they usually soften and become clear on melting while the amorphous ones are usually heat sealable. So most of your thermoplastics which are familiar with your LDP, HDP, DP, polystyrene, everything comes under your thermoplastics. The second set which is a thermoset plastic, they are usually highly cross-linked macromolecules. Now in thermoplastics, it was just addition of monomers. But in thermoset plastics, this is a condensation reaction with removal of water.

So it is kind of a settling as we explained before. Once it is formed, you cannot reheat and remold it. So these are usually hard. It contains fillers and they are usually opaque.

The density is a little higher, 1.2 to 1.4 grams per centimeter cube. It remains hard. Now that is what on heating, it remains hard and usually stable until the chemical decomposition takes place. Elastomers are something between these two.

They are likely cross-linked macromolecules. They are usually rubber elastic or stretchable. The density is also between these two, 0.8 to 1.3 grams per centimeter cube and they do not flow until close to the temperature where chemical decomposition occurs.

Okay. So we have gone through all the different tests on plastics and papers and we also found out how to identify it. Now shelf life studies are usually done for the products but this topic is kept under this portion because a packaged food product shelf life estimation is very important. What is shelf life? You must all be familiar with that because that is something that everybody looks at. The first thing when they take up a product on the back, what is the shelf life? What is the expiry date? What is the shelf life? Or how used before date? These are some of the terms that they use for shelf life. Now it is the time after production and packaging that a product remains acceptable under defined environmental conditions.

So these are not those numbers that they gave on the package three months or one year or six months. It is not something that they arbitrarily write. Those are tests that are done in the lab, real test times and then only they do write that. So they find out how long the product will stay intact or acceptable and that time is taken as the shelf life.

There are three things that govern this shelf life. One is the product itself, one is the package and one is the environment through which it goes. All three things are equally important when you talk about shelf life. Now coming to product, the first thing we will see is what is the perishability of the products. Now there are products which are very perishable, products which have moderate perishability and third, they are very shelf stable products. So shelf stable products can become sugar and salt, can stay for a long time.

If you talk about perishable products, the first thing that comes to your mind is your meats, milk, eggs, fruits, vegetables. So these are very perishable. Your moderately perishable products like your jams and jellies, sausages which are not fermented foods, which are not as perishable but these products, depending on the product, the shelf life will change. Now depending on the product, we will change the package also. Now the package, what are the things of the package, what are the characteristics of the package that will govern the shelf life.

One is the permeation rate. What is the barrier property of these packages? How good are they? Do your product need such big barriers or is it has to be free enough to allow the passage of gases or if not, is it supposed to be highly impermeable or good barrier properties. Now certain products are very susceptible to oxidation. So if that cases the package, if it's got good barrier properties, the shelf life naturally increases. Package size is important. The bigger the product, your packages, the chances of spoilage also will increase.

Net weight of the product. Depending on all this, the package will change. Environment is the third factor on which the shelf life depends. Very important. Now every package you would see, you would see a term like store under cool and dry conditions or store under refrigeration or store under freezer conditions.

The environment is very important. It's not enough that you just package the product and keep it outside. If the packaged product requires refrigeration, it has to be done. This environment plays a very big role in the ultimate shelf life of the product. Now there are some traditional approaches to shelf life testing and one of it is the shipping test. A shipping test is the product with the package is shipped to the warehouse.

It is stored for a specific time, say six months, three months and then it comes back to the R&D quality control section and is examined for its acceptability. This is real time testing. Now this shipping test will check the product deterioration and also any shock or vibration that it experiences during the shipment and such shipping test shows real world situations. So it shows how protective your package is, what are the changes or experiences it goes through during the transportation. Once tested, you can see if your package is going to withstand all the difficulties or hazards it's going to experience.

These tests usually do not represent all the conditions that the product will experience. So they have something else called a storage test. In storage tests, unlike a shipping test, you're going to keep the product under static facility. You're not going to move it from one position to another in a specific time. You will keep it under specified storage condition for a specified time and then evaluate the quality after that time.

Now this storage condition, they can either be controlled or it can be uncontrolled. If it is controlled, they usually use storage cabinets and these storage cabinets, they maintain the temperature and the humidity and other specific conditions that they have too. So this usually gives a reproducible data. This case itself is something called accelerated condition.

Now what's accelerated? Increasing the rate. So what happens is if your product is

supposed to be stored usually at room temperature, say around 25 degrees to 30 degrees centigrade, you can keep it at higher temperatures, 40 degrees, 50 degrees and find out how quickly it deteriorates. Now why is an accelerated condition applied we learn in the coming slides. Now these accelerated conditions usually vary and they usually are 39 degrees centigrade and 80% relative humidity. Why you want to do an accelerated study? So we talked about shipping tests and we talked about storage studies under controlled, uncontrolled conditions. And under these controlled conditions, we were talking now of accelerated shelf life studies.

I told you that they will be kept at higher temperatures. At higher temperatures, natural deterioration is faster. So you will get your test result faster and you can manipulate or you can, from that you can calculate what will be the shelf life at your normal temperatures. So in this accelerated shelf life studies, the test or the products is kept both at ambient conditions, conditions at which the shelf life is kept and at higher temperatures. And then the shelf life of these two conditions is tested. It's usually advised in a food environment to keep it at one at ambient temperature around 25, 28 degrees centigrade and one 10 degrees above it, say around 38 to 39 degrees centigrade.

So that gives you a 10 degree difference between the two temperatures. And you will evaluate the shelf life. And one of them shelf life is six months, the other one might be four months. So what happens is you can compare these two shelf lives and there are a number of data you can get from this comparison. Now this comparison can be done through actual kinetic studies called Q10 analysis. That involves testing the products at various temperatures and it is defined as the difference in the reaction rate.

What is it? The difference in the reaction rate for a 10 degrees temperature increase. That's what I said. You can keep it at 39, 29 degrees centigrade, another 39 degrees. What is the difference in shelf life for a 10 degree increase in temperature? Now a Q10, suppose you get a Q10 of two, it means that the reaction will double if there is a 10 degrees increase in temperature.

Again this is usually based on the Arrhenius relationship. The Q10 itself is temperature dependent. But the products are usually studied under limited ranges. Why do you need an accelerated shelf life testing or studies? So many foods have a shelf life of around one year. Now suppose you want to make a change in the formulation and you want to test a new antioxidant or a thickener or the process itself.

The shelf life is one year, it's too long a time. And companies cannot actually afford to wait for such a long time before knowing whether they can actually go for it or not. Because there are other things that have to be, other decisions that have to be made. For

example, they may need to construct a new factory or new equipment, have new contracts. So this time of one year might be too long for them.

That is when they go in for accelerated shelf life studies. It has been used in pharmaceutical industries for a long time. But in the food industries it is less used. It's not as much widespread. Some of the reasons are one is lack of basic data based on the extrinsic factor.

Another factor is ignorance of the methodology itself. And third one which is very interesting is skepticism. It's not many people doubt if such accelerated shelf life studies can actually predict what will be the shelf life at normal real time temperatures. Let's look at the calculation. You now understand that accelerated shelf life, you'll keep the product at higher temperatures, preferably 10 degrees above the one that you have two temperatures.

One will be at ambient temperature, one will be 10 degrees above it. Now if there's only a small range of temperatures considered, then the former shelf life plot usually fits all this. Let's look at this equation. Q_{10} is usually a ratio of the shelf life at temperature T degrees centigrade divided by the shelf life at $T + 10$ degrees centigrade. Q_{10} is 2, that means all the reaction doubles at a 10 degrees increase.

This table is very interesting. If you look at this, Q_{10} 2, 2.5, 3, and 5. These are the shelf life. So if you have, here we are arbitrarily keeping it, we're assuming that at 50 degrees it's got a shelf life of 2 weeks. At all of these, they've got 2 weeks shelf life at whatever Q_{10} it is. At 50 degrees centigrade, it's a shelf life of 2 weeks.

At 40 degrees, naturally the shelf life should double 4 weeks. At 30, again double of 40, which is 8 weeks. And at 20, it'll be 16 weeks. So as the temperature decreases, shelf life increases.

But it's also interesting, same thing here. Q_{10} 2.5. At 50, if it is 2, at 40, 10 degrees less than 50, it'll be 2 into 2.5, which is 5 weeks. And at 30 degrees centigrade, you'll have 12.

5 weeks. And at 20 degrees centigrade, you'll have 31 weeks. But it's very important to estimate your Q_{10} properly. For example, there's a big change here. If you look at this, a product with a shelf life of 2 weeks at 50 degrees centigrade at Q_{10} 2, at 20 degrees centigrade, it'll have a shelf life of 16 weeks. But when the Q_{10} has increased to 2.

5, this itself, the shelf life at 20 degrees centigrade, has increased to 31 weeks. It's very

important that you do your Q10 properly, that you measure your Q10 properly, because that would make a huge difference in the estimated shelf life. Let's look at the Q10 of some of the important foods.

For canned products, it's usually 1.1 to 4. And for dehydrated products, 1.5 to 10. And for frozen products, 3 to 14. Now for technologies, always it's important that you confirm your accelerated shelf life studies result of a particular food by actually conducting real-time shelf life studies also. Under real and environmental conditions. Once it is set, for the rest of the products, you can go in for an accelerated shelf life study.

This helps to eliminate any error that can occur. So we've come to the end of today's class. Today we've learned about the identification of different polymers, plastics, whether they are in the form of a film or a form or a bottle. You can identify based on different tests, either your floating test or your flame test or you have even different physical tests like stretchability and other similar tests that we have just gone through. We also talked about accelerated shelf life studies and shelf life estimation, which is also a part of different tests. So with that, we've come to the end of the four-part testing of packaging materials.

I hope it's more clear now. In the next class, we'll go into testing of packaging performance, which is almost similar but a wholesome concept of what we have studied till now. See you in the next class. Thank you.