Food Packaging Technology

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Week – 02
Lecture – 09
Plastic as packaging material – P1

Welcome back to the NPTEL course Foot Packaging Technology. In the previous classes, we had discussed about different types of packaging material like glass and metal and we had seen how these can be manufactured. We had also discussed about the lacquers and importance of lacquers in developing cans. Now in today's class, we are going to discuss about plastics as a packaging material. Under this, we will be discussing about different types of plastics, films, laminated plastic materials, flexible films and we will also discuss about their manufacturing process. Now coming to the plastics as a food packaging material, this polymer it has lot of advantages and unique challenges. The heat sensitivity of thermoplastic polymers limits its suitability for some food processes.

These packaging materials, they are not rigid like metal or glass packages. They also have poor barrier properties with respect to low material density which is around 1 gram per cc. And the plastic containers though, they have these disadvantages, they are very light in weight and they can be less stiff and weaker.

To provide the strength during stacking and during transportation, these needs additional packing which is not quite often found in other packaging materials like metal cans. Now flexible films, these are non-fibrous materials in continuous sheet form and these have a thickness of 0.25 millimeter and these are termed as packaging films. Since they are flexible in nature, these are also called flexible films. These are transparent and they can be made into colored by pigmented by adding different types of pigments to it and these are thermoplastics and heat-soluble.

These types of polymers, they consist of one or two or more than two polymers and these polymers are added to improve its functionality and handling properties like plasticizers, stabilizers, coloring materials, antioxidants, anti-blocking and slip agents. So, these are additives which are added to the plastics or flexible films to improve its characteristics and these are generally manufactured using extrusion process. The mixture polymer or additives, they are fed into the extruder which consists of a screw and it revolves inside the closed fitting heated barrel and the heat is applied. It also creates friction. The materials which are inside the barrel, they rub against each other and generate friction.

So, the external heat as well as the heat generated from the friction, they help in melting the mixture and then this is forced through the die to form tube or flat films. These are then stretched to prepare film and the thickness can be controlled according to the necessity and these are rapidly cooled. The co-extrusion process is another process which can also be adopted for preparing films and in this case, we have special adapters like where two or more polymers, they are extruded simultaneously to fuse to form a single well. So, you have one extruder which will produce one kind of polymer, the other extruder will produce another polymer and these are fused together to form a single well. And then in the bottom table, you can see some of the common polymers.

We have LDPE, which is low density polyester, which has a melting point of 110 degrees centigrade and we have other polymers like LLDPE, nylon 6, nylon 6 x 66, EVOH and EVA will be together and we will be discussing these polymers individually in the coming sessions. Calendering, it is another technique to produce polymer films and sheet and the heated polymer and the additives, they are squeezed between a series of heated rollers with a progressive decreasing clearance. Calendaring is a unique process which is commonly seen in the manufacturing of plastics and there are a lot of series of rollers are placed. These help in squeezing the film and reducing the thickness of the film. The films pass through the calendaring, they are passed over cooled rollers to cool it and some of the copolymers which are calendared are polyvinyl chloride, ethylene, vinyl acetate and ethylene propylene copolymers. Apart from the extrusion and co-extrusion method, polymers can also be developed using solution casting method. Solution casting method is a very easiest method and it is like the commonly adopted one and usually at laboratory scale, we go for solution casting method. In this, the plastic material and the additives, they are dissolved using a solvent, then it is filtered and it is cast on a slot or it can be a metal slot, a stainless-steel belt. If it is an industrial scale, usually we go for a stainless-steel belt.

In the laboratory scale, you can use some trays or you can use petri plates and the solvents, these gets evaporated by heating and the film can be peeled off. This film, they are clear sparkling in appearance and usually cellulose acetate and ethylcellulose films are produced by this method. Now orientation is another process which increases the strength and durability of the films and it involves stretching the film in one axis that is uniaxial orientation or it can be stretched in two directions which are at right angle to each other. This is biaxial orientation. In this process, it helps the polymer chains to line up in a particular direction and which in turn increases the strength and durability of the polymers.

Oriented films, they also have better flexibility and clarity, but the permeability comes

down and so it is low permeable to water and gases. Oriented films, they tear easily and are difficult to heat seal. It involves heating the film till it becomes soft and then stretching it. The flat films are passed between heated rollers and then stretched on a machine called a tenter and after once it is stretched, it is passed through the cooling roller which helps in cooling or reducing the temperature of the stretched films. Films can also be developed into the form of tubes which are then flattened by passing through nipped rollers.

These are heated and stretched by increasing the air pressure within the tube. It's more like blowing action which we had seen in the previous session. So, the air pressure, it helps in forming the tubes. Polyester, polypropylene, low density polyethylene, polyamide, these are the main films which are used to orient this thing to increase their functional properties. The properties which we had discussed, they are the physical methods to increase the functional properties like durability, strength and other functional properties.

But irradiation is another method where which we can increase the properties of thermoplastic films and irradiation, it helps in increasing the cross-links between carbon and carbon bonds. So, this in turn, it increases the tensile strength and heat-sealing range and it also increases the shrink characteristics. Polyethylene is very commonly radiated. It is irradiated using electron beam accelerated. Now this is a flexible film extraction unit where you can see there's a hopper over here through which the ingredients are added.

So, you can add the raw materials and additives and it is extruded out and is passed through the sheet die. And then this is the calendaring rollers through which helps in stretching the films and then it is passed through a cooling roll and then it is found on the rolls where it can be stored for later use. There are different types of plastic materials that are used in food industry and other industries. So, this is polyethylene tetra-thalate or PET and then we have polyethylene, high density polyethylene. This is how it is notated in the plastics or containers.

So, if you have a plastic bottle, you can look at the bottom of the plastic, you will find a triangle like this with the number. So, if it is number one, it indicates that the material is PET. Similarly, we have PVC, 03 stands for PVC, then LDPE, this is low density polyethylene 04, then polypropylene 05, polystyrene, 06 and then 07, these are others and this include bisphenol A and others. There is a controversy that bisphenol, it can lead to cancer. So, this kind of plastic materials, they are not used in food contact surfaces.

Then coming to PET, it is commonly used as water bottles, soft drink bottles. It is also used to develop post drink bottles and other condiment bottles and HDPE is used in dairy

industry and beverage industries. It is also used in other industries as detergent bottles, shampoo bottles, grocery bags, etc. PVC is used for plumping pipes. It is also used as packaging material for food as a carry bag and then it is also used in shrink wrap, then plastic children's toys.

These are some of the applications of PVC and then LDPE is again, it is used as dry-cleaning bag and bread bags, newspaper bags, even the garbage bags are low density polyethylene, polypropylene, it is used as containers, delivery containers, yogurt containers and polystyrene, it is styrofoam. The other name for polystyrene is styrofoam. It is used to develop the cups and plates and take out containers and then bisphenol A we had already seen. Now cellophane, it is the first commercial flexible film. It's a natural plastic film which is derived from bleached pulp.

This is generally done using treating the pulp using acid and alkali and then plasticizing the same. This can be coated on one side to impart functional properties and again, this has a low cost and these are designated by different letters C, M, S, T, D. C stands for color and M stands for moisture proof, S stands for heat sealability, T stands for transparent and D stands for demi-coated that is coated on one side. If you have a cellophane labeled as MST, it stands for moisture proof, heat sealable and heat transfer. So according to the need of the customer or need of the product, we have to select the packaging material.

Next polymer is polyethylene. Polyethylene, it is denoted as PE, it is also called polythene. Ethylene molymers are polymerized at very high temperature and pressure. The polymerization can also be done at low temperatures and pressures, but this to get a good polymer, it has to be done in the presence of a catalyst that is alkyl metal is used as a catalyst and the films developed, they can be categorized into three types that is LDPE, low density polyethylene, then MDPE, medium density polyethylene and high-density polyethylene. This categorization is based on their density grades and the lower density grade is most widely used in food packaging.

LDPE, it has low permeability to water vapor, it has a very strong heat sealability and it's a poor barrier to gases, volatiles and oils and it is generally used in the form of pouches, bags and snacks. It is used for coating papers, boards, plain regenerated celluloses and other components in laminates. Whereas HDPE, it has height and size, strength and stiffness, also has low permeability to gases, but it can withstand high temperature and for these reasons, they are used to develop bags that can be subjected to high temperatures. So, they are also called boiling bags and they can be used for developing these things. So, wherever you need to heat the food along with the packages, we can use HDPE.

This is the structure of polyethylene and commercially it comes as small white beads. The right figure, it shows the structure of LDPE and HDPE. So here you can see that LDPE is highly branched and HDPE is not that much branched and this structure it influences the properties of the polymers. Linear polyethylenes use alpha alkenes, example butane, hexane or octane and temperature, pressure, they determine the number and pattern of side chain branches. We can manipulate the side chain by changing the temperature and pressure.

Side chain, it interrupts the linear chain formation and more the side chains, the ability to form tightly packed crystal decreases. So that is the reason why the functional properties are more superb in case of HDPE than LDPE and this is mainly because of its structural modifications and this results in high density, crystallinity and stiffness and moisture vapour barriers. So, these properties we can be observed in high density polyethylene. Now the next polymer is polypropylene. Polypropylene it is again a polymer which is developed by the polymerization of propylene molecules in the presence of a catalyst and this polymerization is done under low pressure and this polypropylene it can be used to develop rigid as well as flexible packaging materials.

And ethylene-propylene copolymer, we can use these also to develop flexible packaging heat sealant that can withstand high temperatures. Example the temperature which are seen under food sterilization conditions. And oriented polypropylene films, they have increased stiffness, they are highly crystalline and the permeability of water vapour also comes down. Whereas homopolymer polypropylene, they are thin oriented films and these are developed by stretching them in cross and down directions and then cooling it or annealing it. And this is the chemical structure of polypropylene and the polypropylene or LDPE or polyethylene beads they all look similarly but the chemical differences will be there.

The film is extruded into chilled rollers and these are called cast propylene and with this cast propylene they have good mechanical properties and at low temperature they become brittle. They have poor permeability to water vapour and gases but they are heat sealable, they can be heat sealed at very high temperatures also. And polypropylene films they can be coated with polyethylene or polyvinyl vanillidine chloride or they can be extruded as a copolymer and which will also facilitate the heat-sealing property. Coating also increases the heat shrinkability and it can be used to develop the laminated packs and laminated pouches. Generally, these are used as bags and wraps, over wraps and oriented polypropylene it has a good barrier property against water vapour but it has a poor barrier property against gases.

And these have high stability at high temperature and even fertilized polypropylene can be developed. These are wide or big form of oriented polypropylene which is a copolymer of polypropylene and polyethylene and again the functional properties are between polypropylene and HDPE. Next polymer is polyester, polyethylene tirthallate or PET it is again a condensation polymer which is developed using tirthallic acid and ethylene glycol and actually it is oriented form biaxially oriented form has wide applications than non-oriented forms of PET. And thermal conditions during cooling of moulded PET determines its crystallinity. So, it is more crystalline and oriented PET it has good tensile strength and it can be used even in thin forms.

So, it can be made very thin and it can be coated with polyethylene, polyvinylenedene chloride or PVC or it can be excluded along with them as a copolymer and this enhances the barrier properties and heat sealability of the polymer. And polyester again it is stable for over a wide range of temperature and also just like HDPE it can also be used as a boil in the bag application. So, food can be boiled inside the package. Metalized PET has very low permeability to gases and volatiles and these are extruded with PE and PET and these are used for snacks packaging. So, biscuits and other things they are usually packed in PET that are utilized and this is a chemical reaction tirthallic acid ethylene glycol and these together they give polyethylene tirthalate and several monomers of such units will together polymerize to give polyester and the above figure it shows the polyester fibres and the bottom figure is metalized PET foil it is a chocolate wrap.

Then we have polyamide, polyamide is otherwise called nylon and nylon 6 and it is also called polycaprolactam and usually it is used as very thin filaments and when caprolactam it has 6 carbon molecules that is why it is called nylon 6 and it heated at 260 degree centigrade for 4 to 5 hours in an inert environment it undergoes polymerization to give nylon and since it contains 6 number of carbons that is called nylon 6 and it is extruded or it can be solution casted to develop the filaments it has high degree of toughness and it can also resist the puncture forces and thermofoam containers can be developed using polyamide or nylon. Nylon 6-6 and nylon 6-10 are also formed by condensation these are diamines and dibasic. They have 6 diamine carbon and 6 dibasic acids if it is 10 then it will be 6-10. There are different ways to notate it and again nylon 11 and nylon 12 these are formed by the condensation of omega amino acids so based on the kind of raw material being used the notation will also change. Nylon films they are clear attractive they are strong mechanically they are strong they have very water wave up permeability it is usually high for nylon 6 and it goes down in nylon 12, it is very less and it has good gas barrier properties. It is stable over a wide range of temperature it is heat sealable and but it can absorb moisture but it is at a minimum level then it can be coated just like any other polymer or coextruded or laminated laminations and other coating or coextruding it enhances its sealability and mechanical and barrier properties.

Biaxially oriented nylon films they have improved functional properties and this is done by metalizing it under vacuum conditions and such packages they are used in meat industry to wrap meats and cheese condiments etc. This is how the nylon is developed chemically. It is a reaction between adipic acid and hexamethylenediamine. The reaction between these two gives polyamide or nylon 6, 6. It is a 6-carbon compound adipic acid and hexamethylenediamine against a 6-carbon compound it is written as nylon 6, 6.

The next polymer is polyvinyl chloride, polyvinyl chloride or PVC. It is a polymerization product of chloroethane vinyl chloride monomer. Here the chlorination of acetylene or ethylene is followed by polymerization under pressure and this is again done in the presence of catalyst. So, the raw material is acetylene or ethylene which is chlorinated and converted to vinyl chloride or chloroethane and these are polymerized to give polyvinyl chloride. These are clear transparent brittle but inexpensive. These can be molded into rigid forms and containers and when plasticized or stabilized. This can be formed into thin flexible films. These are done generally using extrusion and calendaring and VCM is again it is recognized as a carcinogen. It cannot be applied in food packages where the food comes in direct contact with the package. So, there we cannot use polyvinyl chloride but it can be used as a secondary or tertiary packaging material. And it has a permeability to water, water vapor, gases and volatiles and it depends upon the amount of plasticizer the composition of raw materials will determine the properties it has very good grease barrier property and heat sealability is also high. It can be oriented and it can be used to develop shrink packages. Pollutility and clinging property of polyvinyl chloride is also high it is because of the high plasticization and these are used to develop wrapping foods or containers and this is the reaction where vinyl chloride they are polymerized to give polyvinyl chloride. Next polymer is polyvinyl dinc chloride it is written as PVDC and this is again chlorination of vinyl chloride. Here you can see we have two chlorines and it is a homopolymer of vinylidene chloride the difference between polyvinyl chloride and polyvinyl dinc chloride is the presence of chlorine.

Polyvinyl dinc chloride you will find two chlorine molecules whereas in the case of PVC it is one single chlorine molecule and again it is the polymerization of monomer in the presence of catalyst and the film which is developed. It is unsuitable as a flexible film but it is stiff and brittle and copolymer of PVDC and PVC can be used for food packaging and also it contains less amount of PVC that is polyvinyl chloride. So can be used in contact with the food and it is generally developed using extrusion method. The properties depend upon the degree of polymerization monomers used and their proportion. So, if it is lesser than 20% then it is applicable in food packaging. Copolymer films they can be used very widely in food packaging because they have good functional properties, good mechanical properties, good barrier properties against water vapor, moisture, gases and volatiles, grease proofness, heat sealability. They can also

withstand high temperatures and these are available in oriented forms and it improves the strength and barrier properties of the material and again heat shrinkability of the polymer is also increased. Then PVDC and PVC copolymer these are also used as in shrink wrapping.

They are mainly used in meat and poultry products as a laminate also. So, this is the structure of polyvinyl dinc chloride. So, you can see here two chlorine molecules are there which in whereas in case of vinyl chloride. It will be only one single chlorine molecule and this on polymerization gives polyvinyl dinc chloride. The next one is polystyrene it is also called styrofoam and polystyrene is denoted as PS. It is formed by the reaction between ethylene and benzene which gives ethyl benzene and this on dehydrogenation forms styrene. So, styrene is not the starting material here we have to develop styrene using ethylene and benzene and this styrene on polymerization will give polystyrene and this is done at very low temperature and in the presence of catalyst.

And the polystyrene films they are produced by extrusion generally these are stiff, brittle and sparkling and polystyrene these are not used in foot packaging as foot packaging films but they can be used to develop molded classes or trays. High axially oriented polystyrene or BOPS they are less brittle and they have increased tensile strength and compared to non oriented films and relatively high permeability to water gases and grease proof they soften at 80 to 85 degrees centigrade and they are stable even at low temperatures. This can be shrink using heat or they have good heat sealability. Polystyrene films they can be used to wrap fresh food products. They can be developed into foams for egg cartons even for fruit trays takeaway containers can also be developed using styrene. Widely their application is in the development of thermo foam semi-rigid containers and blow molded bottles.

Polystyrene it can be co-extruded with ethylene and vinyl alcohol EVOH or PVDC or PVC copolymer. This will also improve the functional properties of the polymer or the film. And this is the structure of styrene and number of styrene monomers together they polymerized to give polystyrene and this figure it shows different types of thermo foam containers that can be developed using polystyrene. So, we have come to the end of this class and this session we had discussed about plastics as a packaging material we have seen different types of polymers that can be used as a film or extruded. They can be converted to different thermo foam containers how the properties and functionalities can be improved for these materials by adding different components or co-extruding them with other components. So, we had discussed about these things and we will be discussing for the polymers and other properties of plastics in the coming session. Thank you.