

Food Packaging Technology
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Week – 01
Lecture – 06
Glass as packaging material

Welcome back. So, we are going to start another session on Food Packaging Technology. So, in the last sessions, we had discussed about what is food packaging technology and what are the needs for adopting food packaging? What are the functions of food packaging and how the different packaging materials they differ and how we choose the packaging materials depending upon the product quality or product requirements? And we had also discussed about the paper as a packaging material and in today's class, we are going to discuss about glass as a packaging material. So, glass, it is a best packaging material and it is known for its beauty, fragrance and medical applications. So, it can be used to pack the medical products and also it is available in different forms as bottles and jars and this is because glass is unreactive, they are inert and heat resistant, they are easy to open and they can be reclosed and they are transparent and readily available.

The raw materials are readily available for glasses, but the disadvantage on the part of glass bottles or glass containers are that they are very fragile. So, they can break easily and the weight is also heavier compared to the other materials and the cost is very high and the cost it increases with the thickness of the material. Glass is the only packaging material that has been recognized as glass by FDA. Glass has been defined as an amorphous inorganic product of fusion that has been cooled to a rigid condition without crystallizing.

So this is the definition which was set by ASTM in 2010 and we are still following this definition. Glass is considered as a synthetic material though the origins are not natural and it can be taken from natural sources on the earth crust, obsidian from magma or molten ignitions rock, tektites from meteor or pumice which has formed glass and which is also a natural form. There can be different sources of glass oxides or the glass material. There are two types of glass containers. Generally, in food packaging industry we use bottles or jars.

70% of the food products they are packed in bottles, where 30% they are packed in jars and most of the food packaging materials or glass containers, they are transparent. That is 85% of the containers or glass containers they are transparent. However, in case of pharmaceutical industry the containers they are opaque and amber colored. This is to

protect the contents from the light so that does not undergo any deterioration or degradation. Now composition of glass it can change from one to another.

It depends upon its targeted use, where it is going to be used and accordingly the color and properties will change. Now basically the composition of glass it contains four different components that is primary component sand, soda ash, limestone and cullet. Cullet is the broken glass mixed with sand, soda ash and limestone and it is heated at very high temperature. Then glass may also contain other cations like silica, aluminum, boron, sodium, potassium, magnesium, zinc and barium and the only anion that we find is oxygen in the form of oxide and these are melted at very high temperatures around 1500 degrees centigrade. Now it also may contain minor elements such as fining agents, decolorizers or colorizers which are added to glass to get unique color or particular properties.

The most common fining agents are sulfates and these are added in combination with carbon and these can be in the form of sodium sulfate or salt cake and sodium sulfate it is also used as a wetting agent because it helps in melting of silica and it is also fining agent. So, if you look at the table here, you can find different types of raw materials that are available and most of these raw materials they have silica, aluminum, sodium and potassium as oxides and their concentrations are also given. So, we have silica sand which is otherwise called glass sand and phelsiphetic sand it is alumina sand and you can also see the composition of alumina sand, silicon oxide and the composition ranges between 83 to 91 percent, aluminum oxide it is 4.6 to 9.3 percent, sodium oxide is 1 to 2.

4 and potassium is 2.8 to 4.1. So similarly, we have sodium carbonate, calcium carbonate, sodium carbonate is otherwise called soda ash it is the main components are sodium and limestone or calcium carbonate has high amounts of calcium and magnesium carbonate it is otherwise called dolomite and it has high amounts of magnesium and the rest other raw materials are feldspar, neflinsenite, apalite and sand spur they also have components are same the concentration of these components will vary. Now silica is the principal ingredient in a glass and it is derived from sand, flint or quartz.

These are melted at very high temperature around 1723 degree centigrade it is usually above 1500 and they are converted to molten silica glass and different glasses can be developed by combining different raw materials along with silica and melting temperature of silica is above 1500 this can be brought down to 800 or 850 by increasing the viscosity of molten silica and this can be done by adding alkali by fluxing alkali into the molten silica we can reduce the temperature and usually we add sodium or potassium carbonates for this purpose calcium and magnesium carbonates they are otherwise called limestone or dolomite they prevent the dissolution of glass in water and therefore these

are considered as structural stabilizers so glass will not easily dissolve in water. Again, when we add usually the glass is amorphous in nature but when we add these components in higher amount the glass has a tendency to lose its amorphous structure so this process is called de-vitrification and this will induce de-vitrification thereby the amorphous structure of the glass will be lost. Alumina it is used to increase hardness and durability and boron it is added to glass in very less amount it is generally 6% and when boron combines with glass it forms borosilicate and it is otherwise called Pyrex and Pyrex is used for many experiments and many purposes and this helps in reducing the leaching of sodium and boron it combines with alkali oxide, metal oxide and silicate dioxide and it prevents the dissociation of alkali or prevents the leaching of sodium. Now glass is generally represented by the formula X_2O plus YO plus SiO_2 . X_2O it is X stands for the alkali metal it is a monovalent so it can be sodium or potassium and then Y stands for a bivalent metal it can be calcium or PB and then we have silicon dioxide.

Silicon dioxide is a main ingredient but X and Y it can change depending upon the type of glass. So, in soda lime glass the composition will be sodium oxide and calcium oxide plus silicon dioxide and in case of lead glass it will be the combination of potassium, lead and silicon and this is the composition of a typical soda lime glass which is very commonly used in food packaging industry. We have silicon dioxide which is taken from sand and this is the major composition or major component and it accounts to about 71 to 75% by weight and followed by this we have sodium oxide which is taken or extracted from soda ash and along with this we add cullet. So, mixture of soda ash and cullet it contributes to 12 to 14% followed by this calcium oxide and cullet that is 9 to 10.5% aluminium oxide from feldspar and along with cullet it is 0.

15 to 1.3 and the remaining components the by weight percent they are below 1 that is it ranges between 0.1 to 0.4. Now there are different properties of glass the first most important property is optical property. Due to the amorphous structure glass is homogeneous and it is free from stress and it exhibits optically isotropic property that means it allows light to pass through it and it is transparent in nature.

So optical properties these are related to degree of light penetration and transmission at a particular wavelength. So, it is a function of wavelength and in order to control the transmission glasses are coloured if it is transparent then the entire light spectrum will be transmitted. To control it we add additives to glass and make it coloured and this can be modulated by adding different metal oxides it can be cobalt, nickel, chromium or iron and these metal ions they help in absorbing one particular wavelength or specific wavelength of light and it transmits the light so that it appears or it has that particular specific colour. So, for example iron it helps in giving green colour to the bottle. So the colour of bottles they are contributed by different components different metal oxides and in this table you

can see the metal oxides that are used to give typical colour in soda lime glass and in the colourless and UV absorbing light usually the metal oxides are cesium and titanium and for blue colour we use cobalt, copper and for purple it is manganese and nickel, green it is chromium, iron and copper and brown manganese, iron, titanium and cesium and amber it is sodium sulphide and for yellow colour we use cadmium, cesium and titanium, orange cadmium and selenium then red it is a combination of cadmium, selenium, gold, antimony and copper and black it is cobalt plus manganese, nickel, iron, copper, chromium oxides.

Similar to optical properties chemical and functional properties are also very important and as we all know silica is the main component that contributes or that is used to make the glass. So, it is the chemical properties of glass is mainly influenced by silica and it is also influenced by sodium and potassium carbonates, calcium and magnesium carbonates and these components they affect the melting temperature and its physical property. Lead for instance it influences the clarity and shyness, flexibility and fragility, aluminium oxide it increases the hardness and durability and boron it combines with silicate to give borosilicate and which prevents leaching of sodium. So, glass is very strong and Pyrex glass they are used for heating chemicals at very high temperature and glass they generally corrode by three ways that is etching, leaching and weathering. Etching it is mainly due to the attack of alkali compounds which destroys the silica network and the glass gets disfigured or disoriented the shelf life comes down and leaching it happens because of the acid attack.

The hydrogen ions they are replaced by alkali and other positively charged ions. Weathering it happens because of extended storage that is long periods of storage and which induces surface blooming and usually on the glass surfaces we can see if it is stored for a very long time, we can see the milky or hazy crystalline residues on the surface this is called weathering. Normally glass exists in glassy state where molecules are organized randomly but with enough cohesion to obtain the mechanical rigidity and this form is in the solid form. The glass it has very high viscosity and because of this it acts like a solid and it has the properties of solid and during manufacturing cool down its viscosity is reduced it is a reversible process so melting the glass will give you again the liquid molten and also by for solidifying it has to be cooled and by this process the glass becomes rigid or brittle. Now glass they can break or they can fracture under three circumstances.

First if it has high internal pressure for example if you are going to use any pressurized liquid into the container then glass bottle it should be able to withstand the internal pressure otherwise it will burst and also it should be able to withstand the excessive vertical pressure which is observed during stacking. So, if glass bottles are stacked one

above another then the glass at the bottom or the container at the bottom it will be under pressure so it should also be able to bear the stacking pressure. Then impact during rapid moments so during transportation also there will be a force or stress which will be felt by the container. So, in that circumstance also there is a chance of breaking and also if there is a weakening on certain parts certain defects may happen during the manufacture process in such circumstances also the glass may break. And there are four different types of glasses this is according to US pharmacopoeia and the glasses are classified into type 1, type 2, type 3 and type 4.

Type 1 is highly resistant and they are generally borosilicate glasses and type 2 these are treated soda lime glass; type 3 is soda lime or regular soda lime glass and type 4 is general purpose glasses. Type 1 these are highly resistant and borosilicate it contains 80% silica and 10% boric acid and small amounts of sodium oxide and aluminium oxide these are highly inert they do not react with the contents inside so any chemical compound can be stored in the borosilicate containers they will not react with it. And for this reason, we use borosilicate containers for storing acids and alkalis and these are also exhibiting high hydrolytic resistance and this is mainly because of the boric oxide and it has low coefficient of expansion and high thermal shock properties so it can withstand thermal shock and also it does not expand randomly. Now let us see how the glass is manufactured there are four major operations that can be observed first melting, shaping, annealing and finishing. Let us see one by one this is the general picture so if you can see these are batch ingredients sand, sodas, limestone and collet these are minor ingredients these are collected these are called batch ingredients and using a conveyor they are put into the furnace where they are melted at very high temperature and then they are fed into the mould and initially it will be converted to gob or parison and then it is moulded.

This is a two blowing stage so you have blowing in one that is in the blank mould first blowing is done and then second blowing is done in the next mould and after that the glasses are cooled again it is sent to the annealing layer where it is cooled you cannot cool the glass randomly it has to be done slowly so in the annealing layer it is done slowly and then it is cooled and then it is sent for any other printing or any other thing that has to be done on the glass it is sent to that section and also simultaneously it is checked for any defects once it is confirmed that glass does not contain any defects and it can withstand breakage conditions so in that circumstances it is sent to the packaging section or it is shipped to the companies where it is required. So now let us see one by one each step so first one is melting so here the ingredients they are mixed in appropriate proportions they are heated to fusion in furnace and generally we use two types of furnaces that is pot furnace and tank furnace. Pot furnace the charge is fused in fire clay pots that is you have a fire clay pot where all the ingredients are added these are called charge and the pots may be opened or closed type generally it is closed to protect the

contents from combustion products. So, during combustion many components will be formed they should not react with the glass contents to avoid that usually cover the pots and keep it closed but where it is not required if the combustion products they combine with glass and if it is not going to interfere with the contents or any other properties in such cases we can go for open combustion. And after the batch materials has been melted, they are converted to plastic mask and then they are taken to the shaping section and pot furnace generally it is used to develop high quality glass as charge remains protected from combustion products.

Now this is a pot furnace so you can see here there is a furnace inside which the pot is placed it can be closed or it can be kept open and there is a flame which is surrounding the container and the flue gas it is sent out through another outlet there will be outlets like smoke outlets how we have in traditional kitchens. So, there is a flue outlet through which the smoke and other things go out and again this is a diagrammatic picture you can see pots here each pot is placed here melting pots and the fuel gas it will be moving around the pots and it melts the contents and the flue gas which is unburned or which is not required it is passed through the flue chamber. Now we have tank furnace is also used for melting the ingredients raw material generally it is a large rectangular tank and it is built of fire clay blocks. So instead of having pots here we use blocks and if this is the large tank furnace the walls of this will be made of fire clay blocks and batch materials are fed into the tank and produce a gas is fuels the furnace and generally it is heated at very high temperature of 1400 to 1500 and it is kept in such position for 10 to 12 hours. So, it is a time-consuming process this is chamber the large rectangular chamber inside this the ingredients are placed and the walls of this will be lined with fire clay blocks and flame allows the temperature to raise to 1400 to 500 degrees centigrade.

There is an outlet for cool flue gas to come out. Now once the contents have been melted it has to be sent for shaping is also called molding and plastic glass formed in furnace, they are shaped in the side forms depending upon the requirement of the consumer. It can be accomplished manually or mechanically also shaping is an art if it is done manually then the person needs to be highly skilled and generally it is considered as a skillful art. For shaping the glass, the mold has to be hung down it should face down and the elongated lump is used for molding and it is called gop and it is inflated by a blowing air and on cooling the bottles are cooled and it is separated from the molds. So, if you look at the picture here you have fused glass it is hung in the upside mode so the mass will elongate and it is called gop and it is taken into the mold where it is molded and you get the desired shape of the bottle and then after cooling it is taken and sent to the annealing layer.

Now shaping process that is fabrication of glass it can be classified as three categories

and discrete process that is discrete process is generally used for bottles which is are concerned where in food industry then continuous process is used to develop flat glasses like sheets plates or tubings and fiber making process these kinds of glasses they are used for insulation fiberglass composite material and other fiber optics. So spinning is another step in developing glass during this process it is based on centrifugal action so the cast is or the gop of hot glass it is placed inside the unit so it has a centrifugal action it moves and it occupies the shape of the centrifugal container so what is the shape of the equipment that shape will be occupied by the mold. So generally this will be similar to funnel and then there is another action called pressing this is more like a plate or a very wide mouth container so gop it is fed into the mold and it is pressed using a plunger so you can see here the plunger is there and it is pushed over the gop when it applies pressure on the gop, gop obtains the shape of a plate or other material and it will have a very wide mouth or wide opening. Then blowing is very common method which is used to develop the bottles or jars and there are two types of methods blow and blow method and we also have wide mouth press and blow method. Now let us see each of them blow and blow method the bottles are produced in two steps that is first blowed and then second again it is blowed.

So, in the first step includes the parison or the molten glass drop it is inserted inside the blank mold and the first blow is given from the bottom where it inflates and this is taken to the finishing mold where second blow is given and it attains the shape of the mold. So, if the shape of the mold if it is a bottle, it will attain the shape of a mold so that is in the finishing mold and once the second blow is done it will have a definite shape and after cooling and the bottle is extracted and in the wide mouth press and bold the gop is put inside the blank mode where it is pressed using a plunger. So, plunger gives a shape that is called press and then it is inserted into the finishing mold where it attains the shape of the mold. So, it is an open jar with wide mouth that is why it is called press and blow. So, first step will be press and then it will be blow and we also have another method narrow neck press and blow.

This is a recent method and this is generally used for developing lightweight bottles. So, the neck is very narrow again here it is pressed and then blown. Now after blowing it enters into the annealing stage. Annealing is the place where slow cooling happens, we cannot cool the glass material glass container immediately because it will affect the quality of the product. So it has to be cooled slowly and this takes very long time and generally it is done in a chamber called lehr which has a length of 50 to 60 feet and the end point from where the containers enter they usually have very high temperatures it may go up to 500 to 600 degrees centigrade and slowly it comes down by the time it reaches to the other end of the layer the temperature will be approximately almost equal to room temperature and from there we can collect the containers.

So, if it is cooled immediately the container will be brittle and it may break also. So, these are the different parts of bottle and we have a body and a shoulder and above which the neck is there and the neck portion it contains bore finish and there are also beads and sealing surface where the caps can fit easily and the containers, they have a punt or a push up on the bottom which helps in withstanding the pressure. Now these are the different types of bottles. So once the bottle has been annealed it may have some sticking material or some kind of extensions will be attached to it the surface may not be smooth this has to be smoothened.

So, this is done at the finishing stage. So finishing is like polishing, cleaning, rounding the edges which are sharp they are rounded so that is done in the finishing stage and at this stage we get different types of finished bottles. So here you can see different types of bottle designs that are currently being used. So, we have champagne bottle we have amphora then burgundy bottles you can see here different types of bottles. So, we have come to the end of this session where we have discussed about glass as a packaging material. We have also seen what are the different materials being used in the manufacture of glass and what are the different processes by which the glass can be manufactured.

So with this let us wind up for today and we will meet in the next session. Thank you.