Thermal Processing of Foods
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Lecture No. 24
Changes of properties and functional components of extruded foods

Good morning everyone the next lecture is all about the changes of properties and functional components of extruded foods.

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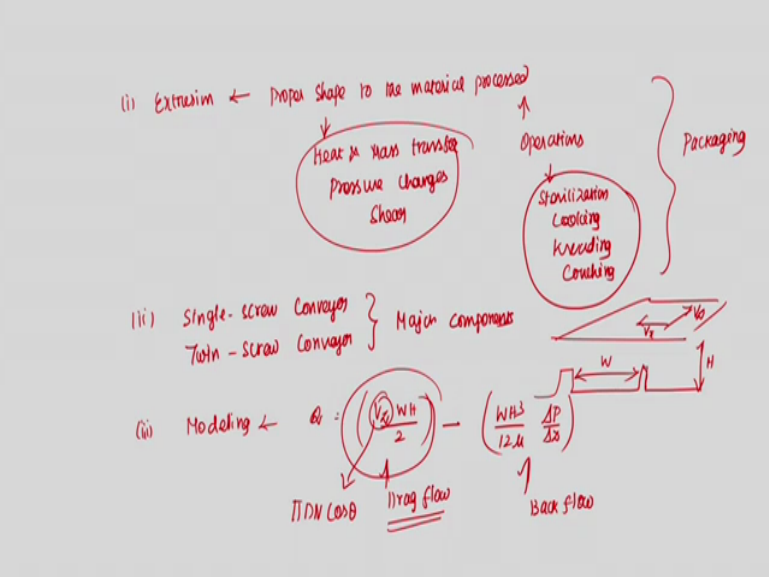

So in yesterday's lecture what we have seen is, the process of extrusion so that means a this is nothing but gives the proper shape to the material, proper shape to the material processed. The mechanism involved are heat and mass transfer, so pressure changes and shear and this is not only gives the proper shape there are lot many operations are, operations so which are what I remember is sterilization can be done, sterilization cooking can be done.

So then kneading and conching, so etc., the many operations can be done individually or all together in the extruder and the mechanism of operation is all these, so, we can say as a this is a single packaging unit. It is nothing but the one step process so then we have also seen the equipment used, one is single screw conveyor, single screw conveyor, and twin screw conveyor, so what are all the major components of them, major components and the third one is the modeling we have seen little bit.

So, we also told this particular equation cannot be used for design but, you can calculate the throughput which is nothing but the Vz because if you remember the channel is made into rectangular so with the width of W and the height of H along the length this is a Vz velocity

so this is nothing but in x direction this imparts to mixing and this imparts to throughput of the extruder upon 2 so minus because this has got drag flow.

Drag flow in the sense, the food materials drag to between the feed to the end, the second one is nothing but this Vz can be written as the pi DN cos theta because the whole V is divided into 2 components one is on sin another is on cos. So pi DN cos theta so this is due to drag flow and the second one what we have seen is WH cube by 12 mu into del p upon del z so this is due to back flow because your pressure at the end of the extruder is high compare to a inlet section. So this is what overall we have seen yesterday.

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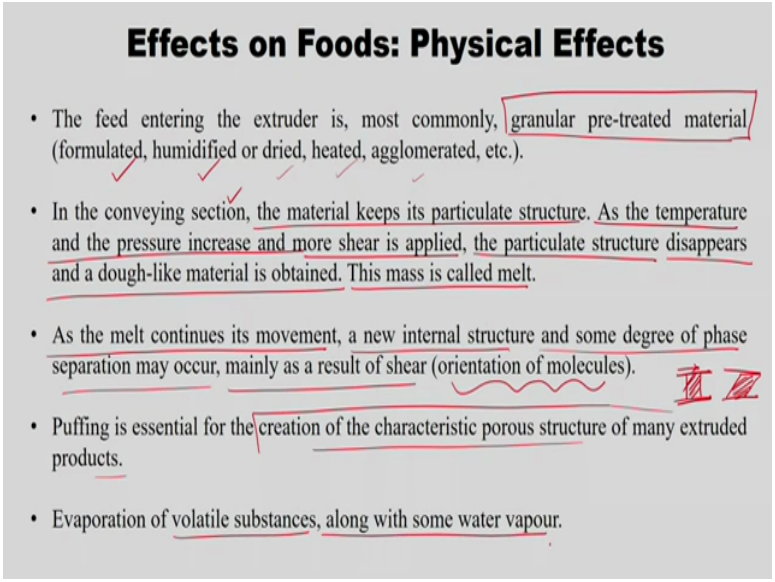

So now, we are going to see what is the physical and chemical effects of this extrusion technology on food. And also we will see 2 or 3 examples how the extrusion technology is applied in food processing. So the feed entering in the extruder is most commonly granular pretreated material so pretreated material in the sense, the formulated, humidified or dried or heated or agglomerated etc. so as we said yesterday, though we are employing some 1015 food processing operations in the extruder so it has also got the upstream as well as downstream processing so those are not included in the extruder so whatever the feed we are employing in the extruder is of granular pretreated material.

The pretreatment can be formulation, humidification or drying or heating or agglomeration. In the conveying section which is nothing but a first section of the extruder the material keeps its particulate structure, this also yesterday we have seen the, there is no mass change in the conveying section as the temperature and the pressure increase more shear is applied on the material then the particulate structure disappears and a dough like material is obtained so, this

is called melting. This process is called melting. And this mass is called melt. When the temperature and pressure is increases the more shear is applied on the material the particulate structure disappears and a dough like material that means high viscous material so this particular mass is called melt.

So the analog is to the polymer processing is as I said the earlier it is the melt extrusion. As the melt continues the its movements a new internal structure and a some degree of phase separation may occur so when the melt further moves along the length the extruder a new internal structure or degree of phase separation so, mainly as a result of shear because shear is nothing but a tangential component force. So tangentially for example so your material is kept in between the 2 plates so when you apply a shear so which is nothing but a tangential stress, tangential applied along the plates. So, what happens is your material go something like this, so it deforms so that is nothing but the shear as a result of shear so there may be a new internal structure will be formed so this is due to orientation or de-orientation of the molecules. So puffing is essential for the creation of the characteristic porous structure of many extruded products.

So we are seeing here, physical effects so, when I apply extrusion on the food material what are all things happen one is first is, the melt mass is produced and the further movement along the length of the extruder forms a new internal structure so that is due to orientation or arrangement of the molecules. And the puffing is also characteristics of the extrusion so which is essential for creation of the characteristic porous structure of the many extruded products. And in the extrusion the evaporation of volatile substances along with some water vapor also can occur.

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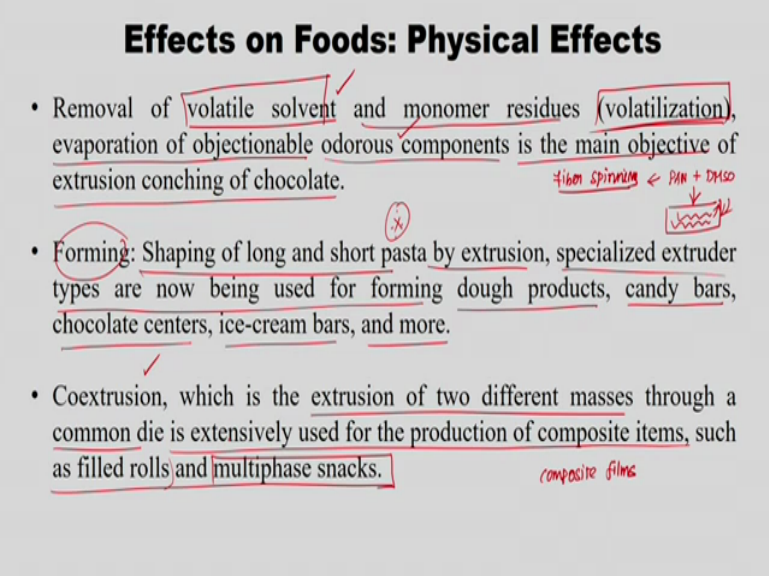

The removal of volatile solvent and monomer residues, volatile solvent and monomer residues so this is one example would be the fiber spinning so the melt extrusion comes from the polymer processing only, so I am taking the polymer example so you got you suit PAN a polyacrylonitrile so this is dissolved with a DMSO solvent dimethyl sulphoxide so after the extrusion so the fiber whatever you get out of the extruder will have DMSO solvent in it.

So further it is passed through those fibers produced during the extrusion will be passed through the water so that the DMSO solvent will leach out of the fiber and the water replaces the its place. So this is nothing but the like removal of volatile solvent so you can remove by you apply heat also you can remove by applying other solvent material as well. And the removal of volatile solvent and other monomer residues which is called volatilization. And evaporation of objectionable odorous component in the main objective of extrusion of conching of chocolate.

So it is not only the physical effects happen on the food material melt or change in the internal structure but the physical effects also included evaporation of volatile substance and removal of volatile solvent and monomer residues, and evaporation of objectionable odorous components. And there is another physical effects which is nothing but a forming so, forming is nothing but a shaping of long and short pasta by extrusion specialized extruder types are now being used for forming. forming dough products, candy bars, chocolate centers and ice cream bars and many more.

So this is what we told industrially the extrusion means the terminologies understood as a shaping, giving proper shape to the food material. So the forming is also the process of

extrusion so which has got physical effects forming is nothing but a shaping of long or short pasta by extrusion. so nowadays a different kind of dies are available to produce different shape of the products. So which are formed from the dough products, candy bars, chocolates centers, ice-cream bars and many more. There is a process called co-extrusion so, which is the extrusion of 2 different masses through a common die is extensively used for production of composite items such as filled rolls and multiphase snacks.

So instead of one particular food material sometimes the more number of food materials are also combined to together and the processed in a single extrusion process in that way you get a filled rolls. If you remember yesterday's class, we discussed something about composite films. So composite films is, so 2 products combined together to achieve for particular specified applications. So here also same thing so multiphase snacks so, 2 food materials can be combined together and co-extruded to yield a the single product, so which is nothing but a filled rolls or multiphase snacks.

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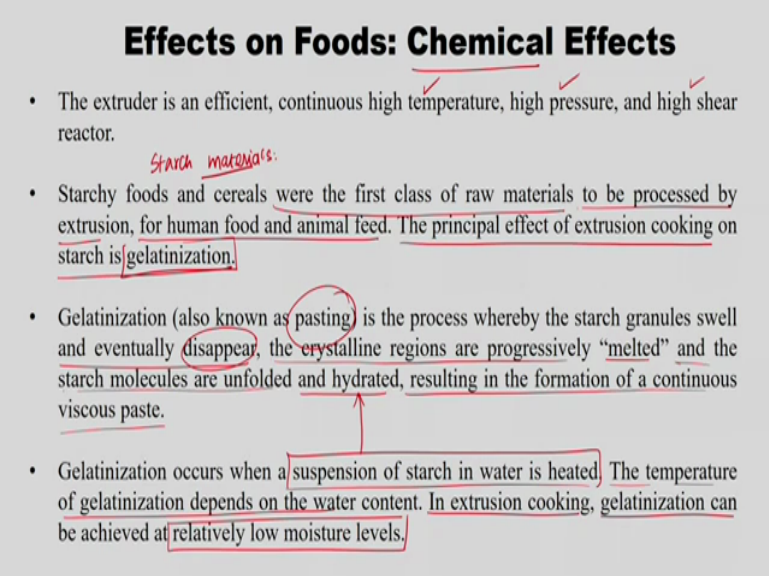

And the second is chemical effects the extruder is an efficient continuous high temperature, high pressure and high shear reactor. So what happens when we process starch materials in the extruder. Physical effects wise so one is it produces the melt mass and also it forms a new internal structure and it also gives the puffing effect and the evaporation of volatile substance, volatile solvent and odorous components everything getting volatized during extrusion this process is called volatilization and forming also possible during extrusion this is also physical effect and co-extrusion also physical effects extrusion.

So in the chemical effects we are going to see so when we process starch materials so what are the chemical reactions happens when we process protein materials what are all the chemical effects happen during extrusion. The starchy foods or cereals were the first class of raw materials to be processed by extrusion for human food and animal feed. The principal effect of extrusion cooking on starch is called gelatinization. So this is important terminology in food processing. So the effect of extrusion cooking on starch is nothing but a gelatinization. So what is called gelatinization, sometimes it is called also as a pasting is the process whereby starch granules swell, eventually disappear, the crystalline regions are progressively melted and the starch molecules are unfolded and hydrated, resulting in the formation of a continuous viscous paste.

So this is called gelatinization. First is starch granules gets swelled and the crystalline regions are progressively melted so, that is what we call it is a disappearance so once it swells and after that it melts so these starch molecules are unfolded if you see in terms of chemical reaction these molecules are unfolded and it is hydrated so that particular molecule or it has got amylopectin as well as amylose. So this is replaced with the water so, the molecules are unfolded and hydrated, the water gets inside which results the formation of continuous viscous paste, so instead of solid starchy material it becomes a viscous paste so that is nothing but a gelatinization.

Gelatinization occurs when a suspension of starch in water is heated. The temperature of gelatinization depends upon the water content. In extrusion cooking gelatinization can be achieved at relatively low moisture level compare to other process. So these starchy materials can be also processed by other thermal processing but when you are processing it in extrusion so it can be achieved using relatively low moisture level compare to other processes. So this gelatinization when it occurs when a suspension of starch in water is heated. So that is a way it gets hydrated and the molecules were unfolded. And it melts and further forms a viscous paste. So the temperature of gelatinization depends upon the water content.

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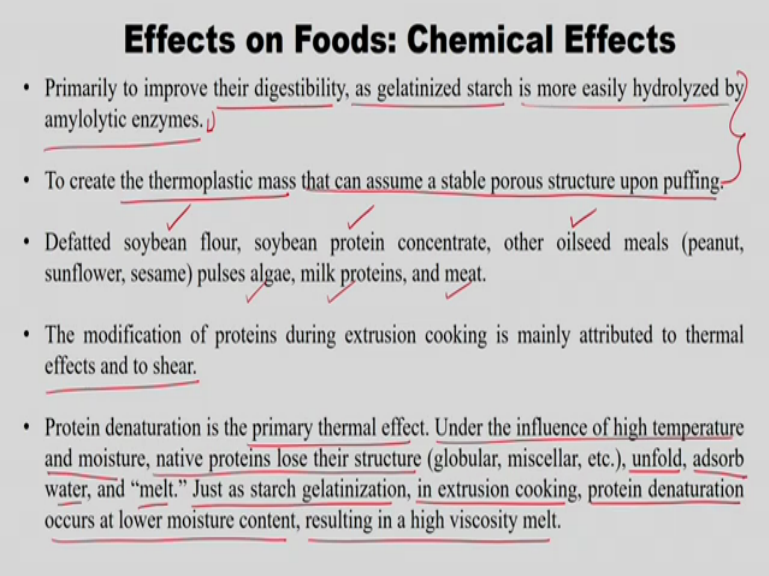

So, the extrusion in starch materials are done for two purposes one is primarily to improve their digestibility. So as gelatinized starch is more easily hydrolyzed by amylolytic so this is what I told, so when the starch molecules are unfolded and hydrated, so it improves the digestibility of the starch why, because the gelatinized starch is more easily hydrolyzed by the amylolytic enzymes present in the human body. And also the extrusion on the starch material is done for other purpose to create a thermoplastic mass that can assume a stable porous structure of a puffing. So instead of solid starchy material if it a gelatinized starch so, when puffing it forms a stable porous structure so because of these two reasons the extrusion is applied on the starch materials.

On the proteinaceous material, so the defatted soybean flour, soybean protein constraint and other oilseed meals, peanut sunflower, sesame, pulses, algae, milk proteins and meat these are all protein products which are processed using extrusion technology. The modification of proteins during extrusion cooking is mainly attributed to the thermal effects and to shear. The protein denaturation is the primary thermal effect which is happening during extrusion of proteinaceous material.

Under the influence of high temperature and moisture the native proteins lose their structure, so it loses the globular or miscellar structure, unfold, absorb water and melt. The same thing whatever happened in the starch. Just as starch gelatinization in extrusion cooking protein denaturation occurs at low moisture content resulting in high viscosity melt. So similar to starch gelatinization, the protein materials also lose their structure, lose their globular structure, unfold and absorb water and get melted. So the same way what we have seen in

starch gelatinization so here in protein extrusion cooking the protein denaturation occurs at a low moisture content which results in high viscosity melt.

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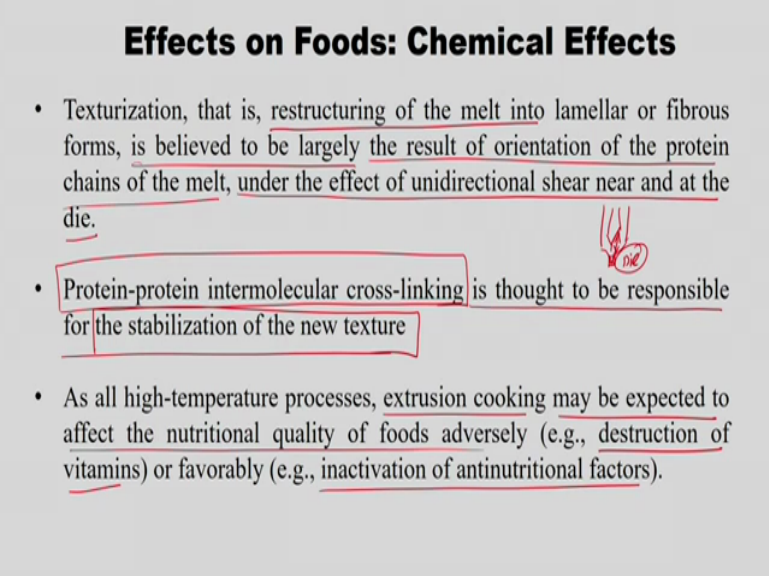

So then another chemical effects of the extrusion processing is, texturization, that is restructuring of the melt into lamellar or fibrous forms which is believed to be a largely the result of orientation of the protein chains of the melt under the effect of unidirectional shear near at the end of the die. So this is nothing but a texturization, texturization we already told that is a giving proper shape. So what we are doing here we are restructuring the melt which is at the highly compressed to stage near the die, in lamellar or fibrous forms which is believed to be largely result of orientation of the protein chains of the melt under the effect of shear. So shear in the sense, so here a is a barrel surface so here you have got the screw, so here, you have got your die. So when you are applying the shear here, so the molecules deorient themselves and it gives the proper shape of the die material, die, d i e die material.

So that is what it is said it is a restructuring of the melt into lamellar or fibrous forms so the die is shaped here is, fibrous or fibers just I explained you pan fiber protection through the extrusion technology. So it believed to be largely result of orientation of the protein chains of the melt under the effect of unidirectional shear near and at the die based on the shear which is applied on the food material so it forms the fibrous material. The protein–protein intermolecular crosslinking is thought to be responsible for the stabilization of the new texture. Because already the protein material is in the melt form, that is high viscous paste to form so that becomes the fibrous form so what is happening chemically, chemically protein-

protein intermolecular crosslinking happens, so crosslinking increases like a (()) (20:09) structure will increased.

So this is thought be responsible for the stabilization of the new texture because if it is amorphous it can go back to that position but here, the stabilization of new texture is because of intermolecular crosslinking. As all high temperature processes extrusion cooking may be expected to affect the nutritional quality of the foods adversely, so this is common thing because the thermal processing the temperature employed here is 180 degree to 200 degree see obviously it affects to the quality of the food material so that is destruction of vitamins or favorably inactivation of anti-nutritional factors. So these both also happens in the extrusion processing. So, we just reviewed the physical chemical and nutritional effects of the extrusion cooking.

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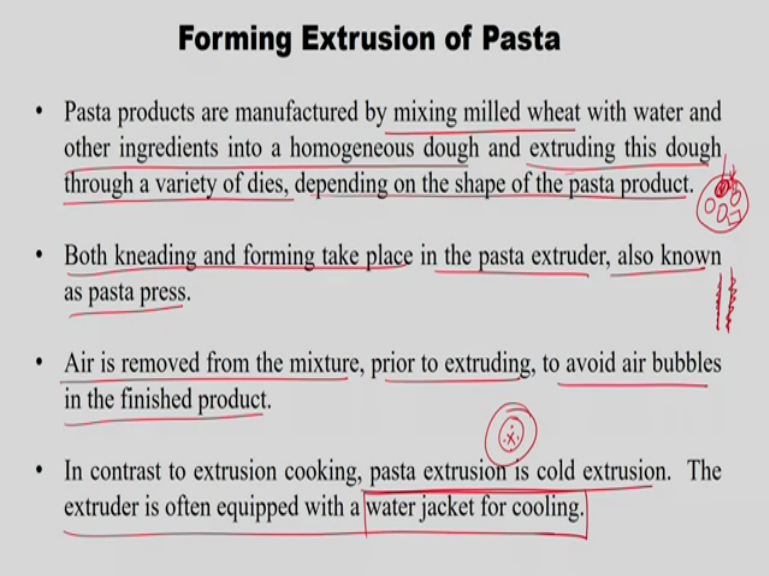

So we will also see some of the examples so how, pasta and expanded snacks and ready to eat cereals are being made using extrusion technology. The pasta making the pasta products are manufactured by mixing a milled wheat with water and other ingredients into a homogeneous dough and extruding this dough through the variety of dies, depending on the shape of the pasta product. So the dies are nothing but a for example you can imagine something like so I want some circular structure.

For example, the fiber, your extruder die got this shape so, when the melt is passing through the circular pores so it will come as a fiber so based on the diameter of the circle in the die so it comes as a same diameter fibers. So this is what here it is told, first mixing milled wheat with the water and other ingredients into homogeneous dough extruding this dough through

the variety of dies, for example you can have circular shape you can have rectangular shape you can have the star shape so based on the which shape you want you can put that particular die in the extruder and get your shapes done.

Both kneading and forming take place in the pasta extruder also known as pasta press, so the extruder has got name which is nothing but a pasta press. So I told earlier the past was the one in 1930 itself the started processing using extrusion technology. Air is removed from the mixture prior to extruding to avoid air bubbles in the finished product so if you have got air in the melt so what happens is this will not be smooth surface your fibrous material or the shape of the pasta will not be the smooth surface so it will get the protrusions or it may get swell.

For that reason, air should not be there in the dough mixture before extrusion. In contrast to extrusion cooking a pasta extrusion is a cold extrusion so this is what I told it is not need not always be employ a heat as in your barrel. Or you employ jacket in the barrel so this past extrusion processing is the cold extrusion, the extruder is often equipped with the water jacket for cooling. So this is the cold extrusion it is not a melting so, it will not melt. So this particular dough itself will be going into the die and forming the pasta product, so there is no melt here, so only high viscous product so, your extruder got water jacket for cooling. It is cooled extrusion not a melt extrusion.

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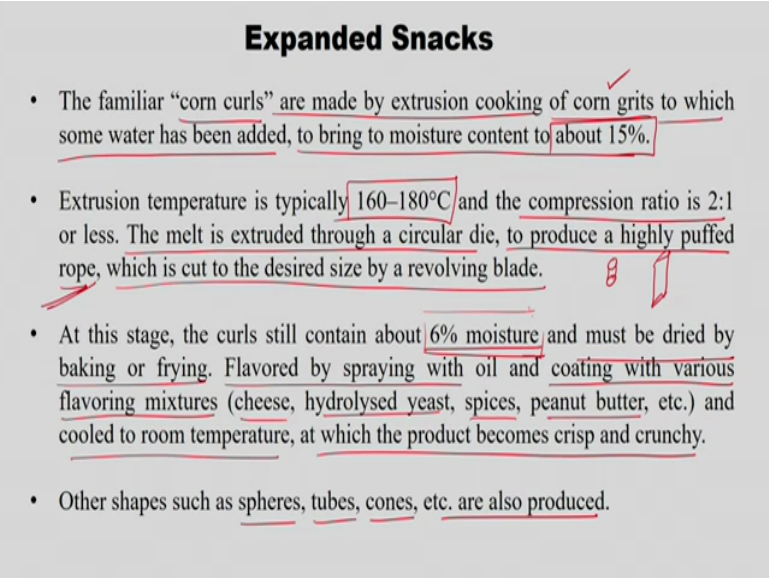

So then another example would be expanded snacks. So, the familiar corn curls are made by extrusion cooking of corn grits to which the some water has been added to bring to moisture content about 15 percentage. First your corn grits are added with the water so to make it a moisture content of about 15 percentage, then the extrusion temperature employed in the

extrusion processing is about 160 to 180 degree centigrade and the compression ratio is above 2 is to 1, or less than that the melt is extruded through a circular die to produce a highly puffed rope, which is cut to the desired size by a revolving blade.

So, when we discussed yesterday class we also told after the extruded there is the rotating knife so, this got application here, so what happens to produce the expanded snacks. So first the corn grits are mixed with the water to bring the moisture content of about 15 percentage. After that the extrusion temperature of above 160 to 180 degree centigrade is employed with the compression ratio of 2 is to 1 or less then the melt which is produced by this temperature of about 160 to 180 degree centigrade, is extruded through the circular die to produce highly puffed rope, which is cut to the desired size by a revolving blade.

So, based on which size as I told you can have small pasta of this shape or you can also get something of a larger size also based on your size you can cut with the revolving blade. At this stage the curls still contain about 6 percentage moisture and must be dried by a baking or frying. So it came out of the extruder so in this stage also it has 6 percentage moisture content so this is further removed in the baking section or frying section which is flavored by a spraying with oil and other coating with various flavoring mixture for example, cheese, hydrolyzed yeast, spices, peanut butter etc. and cooled to room temperature at which the product becomes crisp and crunchy.

So till now, it is being done in the extruder then after it comes out of the extruder it has got some moisture content that is dried in that baking or frying section and the flavoring agents were added so which is may, which may be cheese, yeast, spices, peanut etc. and it also cooled to room temperature and after which the product becomes crisp and crunchy. Other shapes such as spheres, tubes, cones, etc. are also produced so now, you are familiar with our commercial products which is available in the market in snacks so, you got various shapes not only the round shape so you have got cone shape, tube shape, sphere shape etc. so this is a process about expanded snacks which is produced using extrusion technology.

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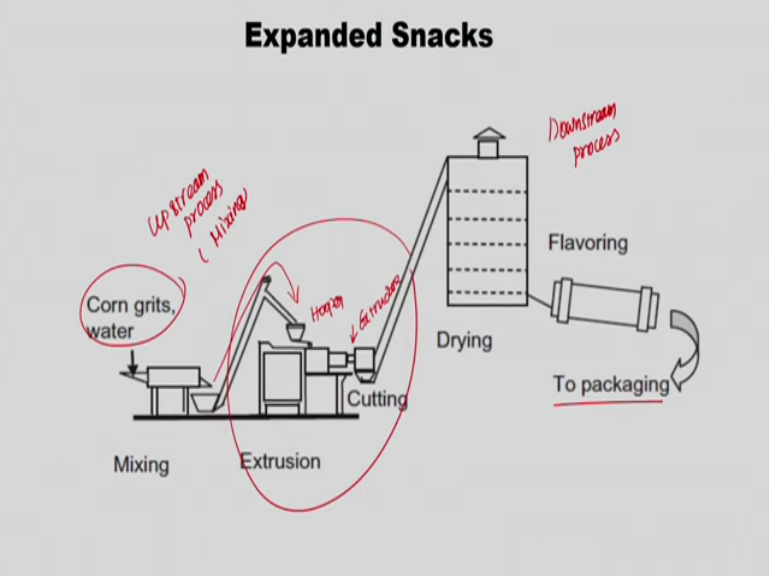

Here is your figure so, here you got mix your corn grits and water so this is the mixing so this is further fed into the extrusion. This takes the food material to the hopper, so this your extrusion., so your extrudate comes out of this extrusion so this is nothing but extrudate, further cutting is done then it goes to drying section where frying or baking is done then after that flavoring is added in this section then it goes for packaging. So this is extruder so these are upstreaming process, upstreaming process, upstream process which is nothing but a mixing. So these are downstream process which is got frying, baking or flavoring.

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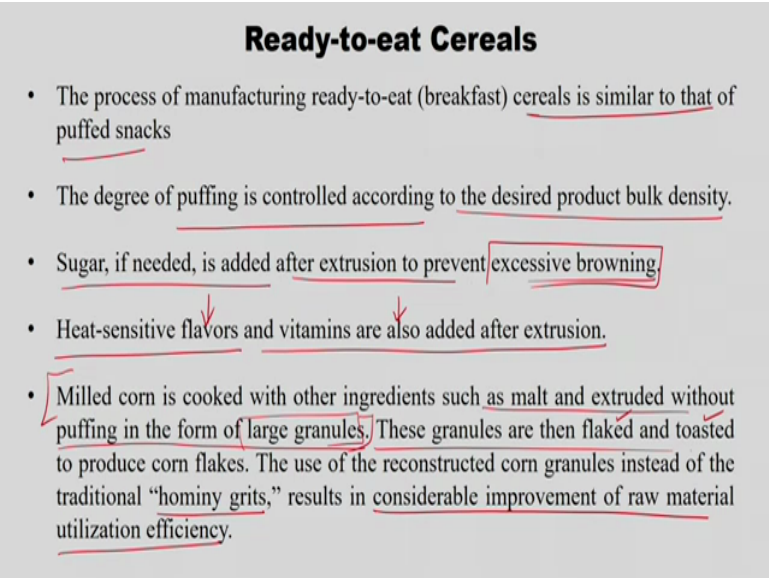

The third one is, ready to eat cereals. The process of manufacturing ready to eat breakfast cereals is similar to that of the puffed snacks whatever it was produced using previous

extrusion technology, it is not previous extrusion technology, here in expanded snacks in the process is almost same. The degree of puffing is controlled according to the desired product bulk density so, how much puffing you wanted, and sugar if needed is added after extrusion to prevent excessive browning.

So if the sugar is added in the product itself so the in extrusion the melting is happening, we are employing a high temperature and melt the product in such cases if the sugar is already added, it causes the excessive browning so the sugar is added after the extrusion is done. It is to only sugar, sometimes, heat sensitive flavors and vitamins are also added after extrusion. So in certain lectures we also talk about this especially so, in after the sterilization the nutritional quality is degraded below the needed level.

So whatever is needed for that particular product if the nutrition quality is degraded to the lower level then it can be added separately as well, so in such case the heat sensitive flavors and vitamins are also added after extrusion. so this is also down streaming processing, so the milled corn is cooked with other ingredients such as malt and extruded without puffing in the form of large granules. The milled corn is cooked with other gradient ingredients which is a malt and extruded without puffing in the form of large granules.

So these granules are then flaked and toasted to produce corn flakes. The extrusion process ends here. So the milled corn is cooked with other gradient ingredients which is nothing but a malt and extruded without puffing in the form of large granules. Then these large granules further flaked and toasted to produce corn flakes. The use of reconstructed corn granules instead of the traditional hominy grits results in considerable improvement of the raw material utilization efficiency.

So that means so earlier days the grits were used directly to produce the corn flakes. The grits were used directly for flacking and toasting but, after the extrusion technology first the milled corn is cooked with other gradient in needed and extruded without puffing in the form of large granules. So with these large granules if flaks are formed so that was got a better quality. So the use of reconstructed corn granules that means larger granules from extrusion operation, instead of the traditional hominy grits this is pure corn, results in considerable improvement of the raw material utilization efficiency. So that is the reason in the corn flakes the extrusion is used.

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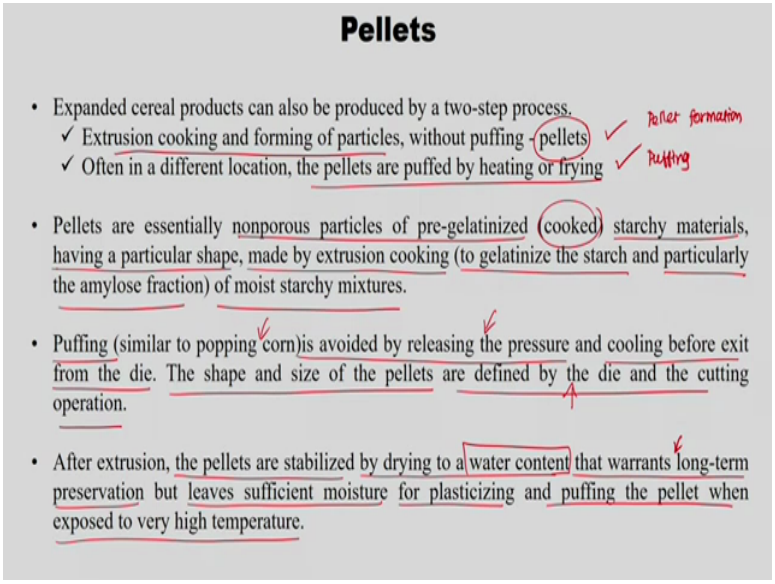

The next one is pellet, this pellets forming has got two step process so one is nothing but extrusion cooking and forming of particles without puffing so these are all called pellets. Then after forming the pellets then in different location most often the pellets are puffed by heating or frying. so the pellets are essentially non-porous particles of pre-gelatinized already we have seen the process of gelatinization so we can tell the term as a cooked, gelatinization is a proper technical word so we can call them as a cooked also.

So the pellets are essentially non-porous particles of pre-gelatinized starchy materials having a particular shape made by extrusion cooking so these pellets are defined in that way they are nothing but a cooked starchy material with the proper shape. In the extrusion cooking so what exactly happens is the starch is getting gelatinized and also in particularly the amylose fraction so if you see the gelatinization process with the increase in gelatinized temperature the amylose fraction also get increases because we are all know the starches comprises of amylose as well as amylopectin fraction.

So the extrusion cooking this is what mainly happens the starch is getting gelatinized in particular the amylose fraction so the pellets are nothing but a non-porous particle of pre-gelatinized starchy materials which are having proper shape which is made by extrusion cooking of moist starchy mixtures. From the moist starchy mixtures, the non-porous particles of pre-gelatinized starchy materials are produced during extrusion cooking.

So after these particular pellets are formed then, there is a puffing so which is similar to puffing of the corn so that we know already how the the corn is being puffed. So the puffing is avoided here by releasing the pressure and cooling before the exit from the die. So this we

have seen already in the lecture. So near the metering section of the extrusion process the pressure is so high, so when it comes near to the die, the function of die is nothing but giving proper shape as well as releasing the pressure.

Which is builded up in the metering section and in between section, so when the pressure is released so their me a flash evaporation. So in pellets forming that is to be avoided because the pellets are not puffed food materials. This puffing is avoided, puffing is avoided in the sense we have told two step process. One is, first one is pellet formation so in the pallet formation (()) (35:04). That is the way flash evaporation happens so your product get swelled. So in the pellet formation puffing is avoided by releasing the pressure and cooling before the exit from the die. So this we have seen, so in between the (()) (35:29) and compression section there is a venting section we keep to release the pressure.

The shape and size of the pellets are defined by the die so already we told the die only gives the shape for the food material during extrusion and the cutting operation is done after the extrusion process. So after extrusion these pellets are stabilized by drying to a water content that warrants long term preservation. So we told the water content during the storage is to be avoided because of contamination reasons. So moisture content is very much favorable for the microorganisms to grow but here the pallets are stabilized by drying to the water content to the permissible water content which warrants long term preservation which does not affects the food quality or which does not wait for the microorganisms to grow.

So this is stabilized, the pallets are stabilized by drying to a water content that warrants long term preservation but, also it leaves sufficient moisture for plasticizing and puffing the pallet when exposed to very high temperature. So here in this process we are only forming the pellet so in the pellet how the moisture content is decided is means the percentage of moisture content in the pellets are decided by optimizing which should warrant the long term preservation at the same time the moisture should be sufficient enough for further plasticizing and puffing the pallet when exposed to high temperature.

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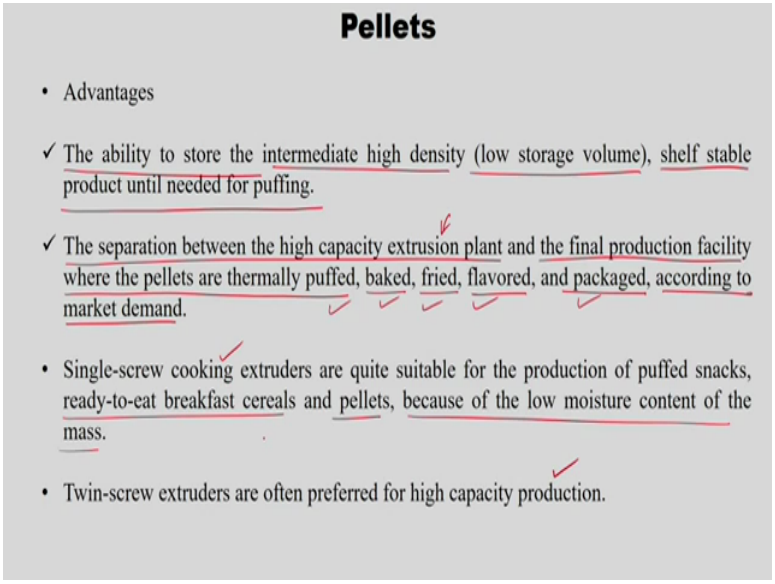

So advantage of having pellets so instead of going directly for puffing what are all the advantage of having pellets, so one is the ability to store the intermediate high density high density in the sense, low storage volume, the ability to store intermediate high density shelf stable product until needed for puffing. So before going for puffing so we can store them, these intermediate products and the separation of high capacity extrusion plant, because this is the extrusion process.

The further is your finishing stage or maybe we can call it as a downstream processing, the puffing. So the separation between the high capacity extrusion plant, and the final production facility where the pellets are thermally puffed, baked, fried, flavored and packaged according to the market demand. So based on the marked demand the final downstream operations are being done so, those were puffed, baked, fried, flavored and packaged. So these operations we can do later based on the marked demand so till then the intermediate products in the form of pellets can be stored. So that is the another advantage.

So single screw cooking extruders, this we have seen are quite suitable for the production of puffed snacks because the moisture content is very low, and ready to eat breakfast cereals, pellets because of low moisture content of the mass. So we do not need to handle with high moisture content. The twin screw extruders are often preferred for high capacity productions so these pellets formation can be done using single screw cooking extruders itself.

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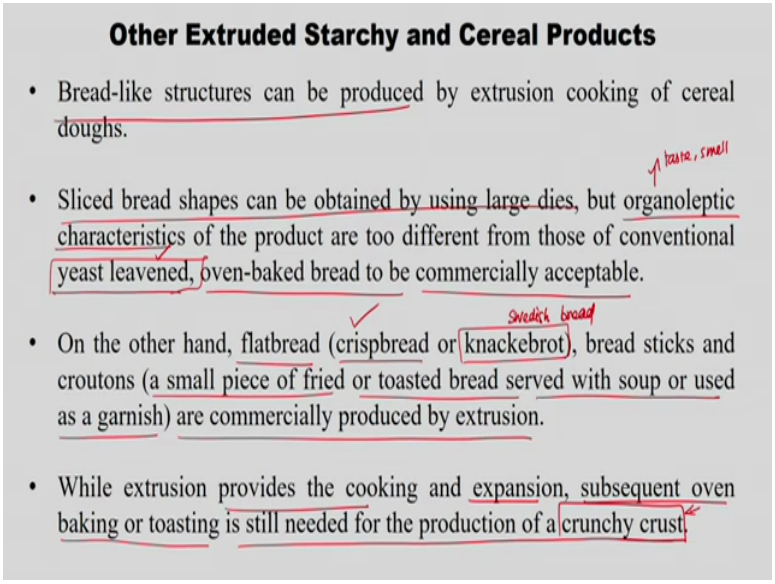

The fourth one is the extruder starchy and cereal products so in what way extrusion cooking helps to produce extruder starchy and cereal products. So here, the bread like structures can be produced by extrusion cooking of cereal dough. So the sliced bread shape can be obtained using large dies so whatever the bread shape we wanted so that can be fixed by the dies which is used in the extrusion. But, organoleptic characteristics of the product are too different from those of conventional yeast leavened oven baked bread to be commercially acceptable. So normal conventional bread making involves yeast leavened so that puffing nature that soft nature we will get that if the dough is activated by the yeast and also after the activation we bake it in oven, so the conventional process of bread making is nothing but yeast leavened and the oven baked.

So but, the same thing can be done by extrusion cooking as well because it can handle, the extrusion process can handle the dough the processing of dough so, the bread making can be done using extrusion cooking as well and the shape and size of the bread samples can be varied using various dies. But, the organoleptic characteristics so this includes taste, smell etc. But, this is different from the conventional processes may be here it is low because we are not leaven that using yeast or other baking process, so the products organoleptic characteristics may be different from conventionally baked a breads. On the other hand, flat bread so we call it as a crisp bread or this also called as knackebrot. So this is nothing but a Swedish bread, the bread sticks and croutons, so the croutons is nothing but a small piece of fried or toasted bread served with soup or used as a garnish, so these kind of crisp bread varieties so these are commercially produced by extrusion.

May be normal bread what we use speed breads with which contains the moisture that fluffy nature so that may be having different organoleptic characteristics from a conventionally produced breads but the extrusion cooking seems to be very much fine with the crisp bread varieties. While extrusion provides the cooking the expansions subsequent oven baking toasting is still needed for the production of crunchy crust so this is what probably is missing in the extrusion processing.

So, if we feel that the final crunchy crust we are not getting using the extrusion process the initial operations can be done using the extrusion cooking then subsequent baking and toasting can be done using a still conventional method. So these kind of processes we have seen even in the drying itself. So the microwave drying helps in inside moisture the bound moisture removal but, normal hot air drying seems to be fine with surface moisture removal.

So in that case we combine both the technologies and one more is we have seen in the high pressure thermal processing and UV light so both can be combined for specific purpose so here also in extrusion also before baking process can be done using extrusion cooking so that means the preparing dough for a bread making. After that the baking and toasting can be done using normal conventional process.

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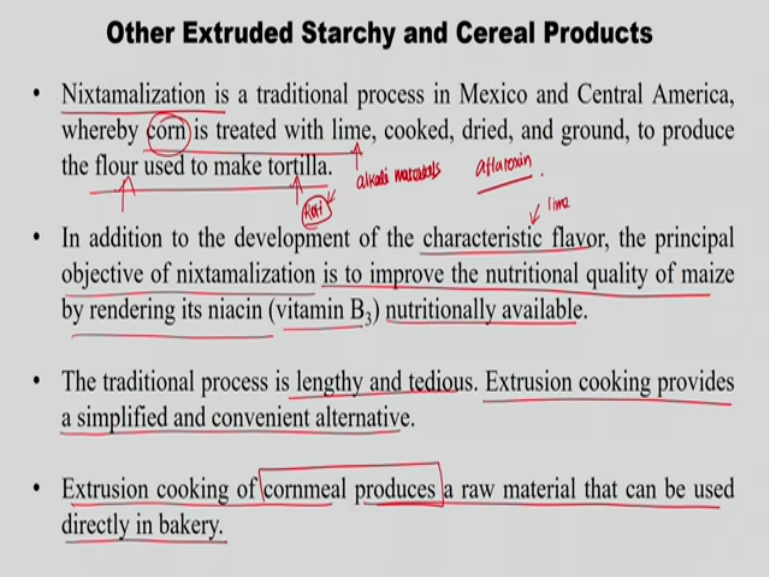

The another important traditional process in starchy and cereal product is nixtamalization. So this is a traditional process in Mexico and Central America so where corn is treated with lime, so here it is given as lime, so normally (()) (43:26). So the nixtamalization is a traditional process where corn is treated with lime, cooked, dried and ground to produce the flour used to make tortilla.

So the flour used to make tortilla. tortilla is nothing but like over Indian chapattis so it is a kind of roti, but this is made using corn, corn flour. In the corn flour they also use the lime or any alkali material. So the advantage of this particular corn material with the lime is normal roti, what you use like a wheat material so there you will not get that high fat content but, here in the tortilla so you get extra fat content.

The objective of using lime here in the corn is nothing but to remove the toxic materials as well the aflatoxin can also be removed from the corn using alkali materials. So nixtamalization is a process where corn is treated with lime, so in general alkali materials then it is cooked dried and ground to produce the flour which is used to make tortilla. tortilla is nothing but equivalent to Indian roti varieties.

So this treating corn with lime is especially done with the objective of removing aflatoxin. In addition to the development of characteristic flavor, characteristic flavor lime also gives the characteristic flavor to corn. The principle objective of nixtamalization is to improve the nutritional quality of maize by rendering its niacin so which is nothing but a vitamin B3 nutritionally available. So the objective here is, to remove aflatoxin and another objective is nothing but to improve the nutritional quality of maize by rendering its niacin nutritionally available.

The traditional process is lengthy and tedious so making tortilla so extrusion cooking provides a simplified and convenient alternative in the making of tortilla or preparing the corn for making tortilla. So extrusion cooking of cornmeal produces raw material that can be used to directly in baking. So, the aim of extrusion cooking here is, to make corn flour as a raw material that can be used to directly in bakery as well.

So here, the nixtamalization is a process where corn is treated with lime, cooked, dried and ground to produce flour used to make tortilla. So here, the using of lime has got 3 fold usage one is it increases the characteristic flavor and also it reduces the toxic contents of aflatoxin and also it improves the nutritional quality of maize by rendering its B3 nutritionally available. So normal process of making tortilla is very lengthy and tedious here in extrusion cooking so this helps extrusion cooking helps to make corn flour ready for further bakery usage.

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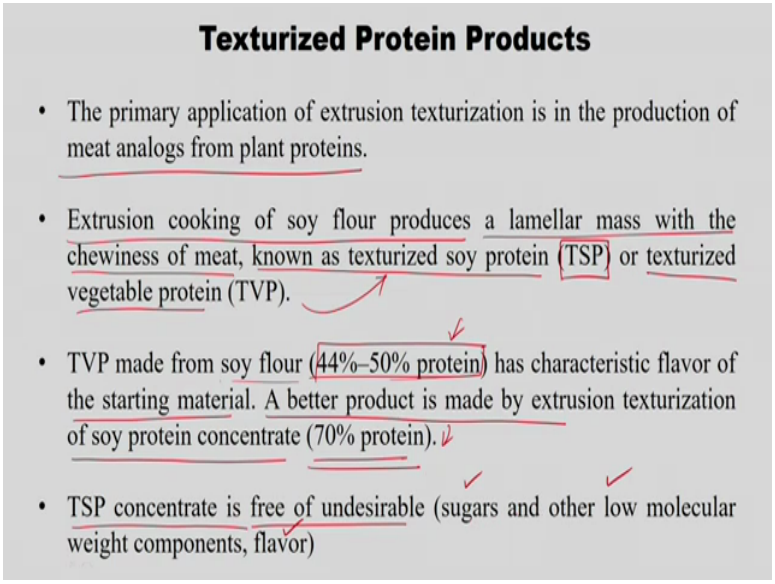

So the next one is texturized to protein products the primary application of extrusion texturization is in the production of meat analogs from plant proteins. So texturization here means the production of plant proteins which is analogs to meat. But, they are meat so, extrusion cooking of soy flour produces a lamellar mass with chewiness of meat known as texturized soy protein, so that texturized soy protein is nothing but a lamellar mass with the chewiness texture.

So which is equivalent to meat so this is generally called as texturized vegetable protein. So under this category texturized soy protein will come. The TVP which is nothing but a texturized vegetable protein made from soy flour of concentration 44 to 50 percentage protein has a characteristic flavor of the starting material the better product is made by extrusion texturization of soy protein concentrate.

So if the TVP is made from the concentration of 44 to 50 (()) (48:16) then you will have the natural characteristic flavor but if the concentrate is further improved which is around 70 percentage using extrusion texturization you may be losing that characteristic flavor. So the TSP concentrate is free of undesirable, so in the high concentrate TSP you want get sugars and other no molecular weight from components as well as flavor. That is what I said here. So if the concentrate is of 44 to 50 percentage protein then you will get the characteristic flavor so further increase in concentration loses not only sugars and low molecular weight components but also flavor.

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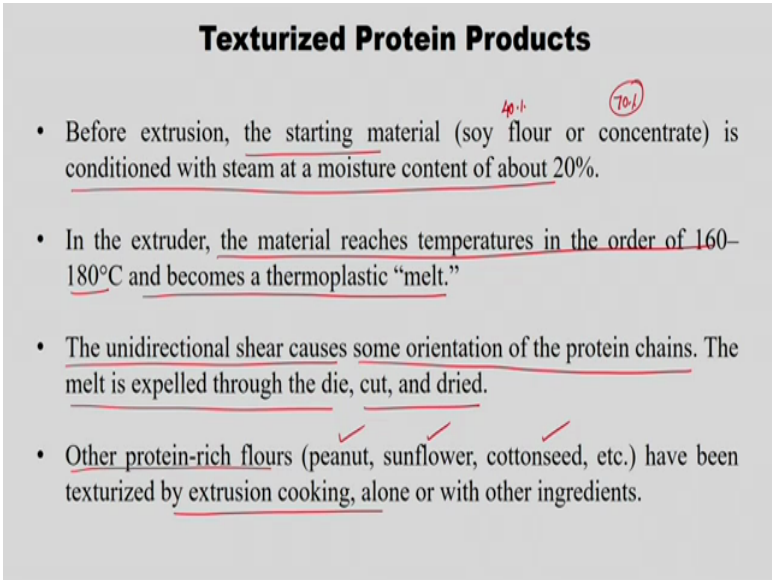

Before extrusion the starting material which is nothing but a soy flour concentrate or may be a 40 percentage or 70 percentage based on which one you need at the final product is conditioned with steam at a moisture content about 20 percentage. So that is the pretreatment, first is the starting material is conditioned with a steam at a moisture content about 20 percentage. In the extruder the material reaches the temperatures in the order of 160 to 180 and becomes thermoplastic melt.

After conditioning using a moisture content of about 20 percentages it is put into a extruder, so where it reaches the temperature of about 160 to 180 and becomes thermoplastic melt. The unidirectional shear causes some orientation of the protein chain, the melt is expelled through the die and cut and dried. During the process of extrusion, the unidirectional shear causes orientation of protein chains that is a way the final product is expelled through the die and cut and dried.

So other protein-rich flours, peanut flours, and sunflower and cottonseed flour, so have been texturized by extrusion cooking in the same way or they may be combined with other ingredients. So in texturized protein products so one is texturized vegetable protein under that category texturized soy protein is produced using extrusion cooking methods. So there are different varieties we can use the soy flour directly or the soy protein concentrates so of two categories one is 44 to 50 percentage other one is 70 percentage, so this also can be used during extrusion process so, this concentrates we used based on our applications.

So if we want to have a flavor then we will use concentrated protein if we want the flavor along with sugars and other low molecular weight components we use high concentrate. So

this particular protein concentrates or soy flour directly first it is conditioned using a steam at a moisture content of about 20 percentage, then the melt is produced at the temperature of about 160 to 180 then after than the unidirectional shear is cause during the extrusion so which orients the protein chain, that is the way the product texturized protein products are formed through the die and further it is cut and dried. So this way this is what we explained is for soy flour. So this is the process is same for peanut sunflower and cottonseed flours as well, so from this also we can produce the texturized protein products.

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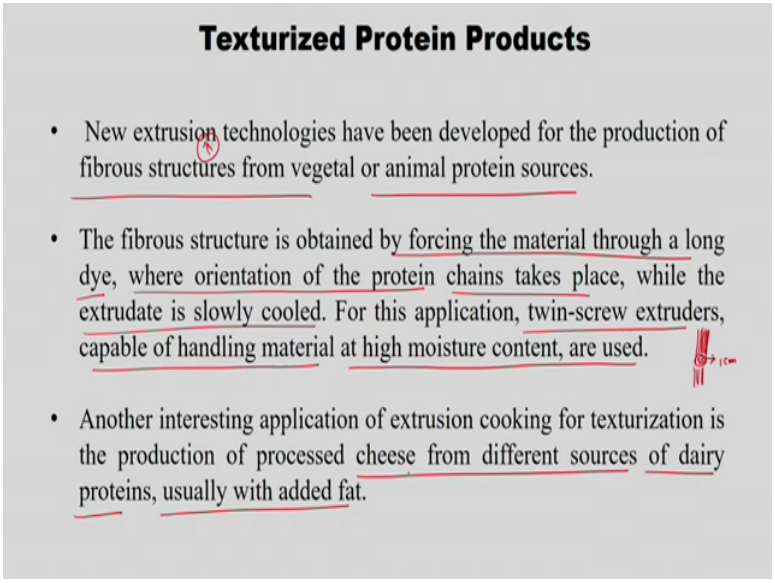

And sometimes it is formed as a fibrous structure from vegetal or animal proteins sources so the same extrusion technology also can be used for texturized protein products in the fibrous form. So the fibrous structure is obtained by forcing a material through a long die so where orientation of the protein chains takes place while the extrudate is slowly cooled. So this I think probably I have explained it the lecture itself so I have a extrudate plate so where I have a small small holes so, this we call it as a die.

So your protein products or any flours can be processed here in the extrusion then when it comes through the die so it comes in the fibrous form. So this holes of whatever the fibrous diameter for example I want some 1 centimeter fibrous product so the hole will be of around 1 centimeter so, the product is or the fibrous structure is obtained by forcing the material food material through a long die so where orientation of the protein chains takes place while the extrudate is slowly cooled.

For this application mostly twins screw extruders capable of handling material at high moisture contents are used. So especially for fibrous structure protein products, twin screw

extruders are used so another application of extrusion cooking for texturization is the cheese from different sources of dairy proteins usually with added fat. So from the source of dairy proteins we can also prepare the cheese and this also can be processed with added fat.

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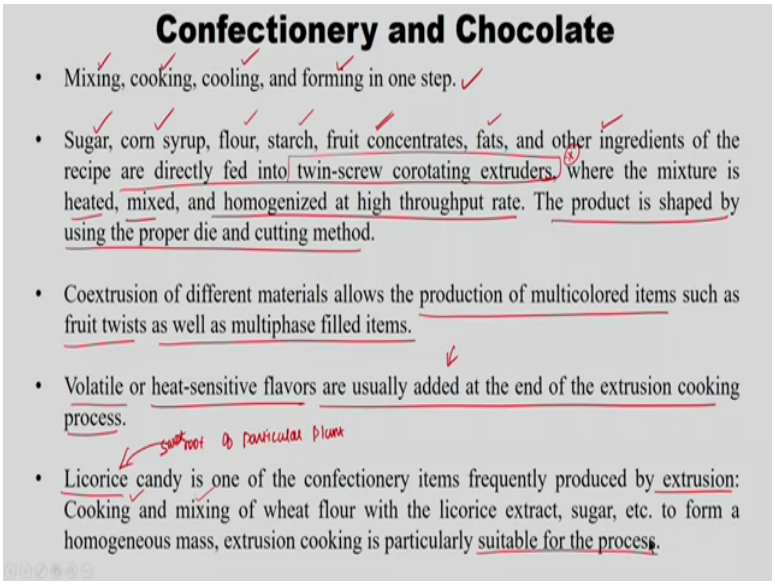

So then chocolate making so here the operations were mixing, cooking, cooling and forming. So, normally the ingredients are sugar, corn syrup, flour and starch, fruit concentrates, fats and other ingredients. So remember here we have got different viscosity material and also solids and liquids all of them are involved. So mostly we can call it as a multiphase source, multiphase food material or directly fed into the twin screw co-rotating extruders so this is very much important because we cannot handle high moisture content food material that too multiphase food material in the single screw extruders.

Where, the mixture is heated mixed and homogenized at high throughput rate, the product is shaped by using proper die and cutting method. The co-extrusion of different materials allows the production of multi colored items such as fruit twists as well as multiphase filled items. So here the fruit concentrates also we used and sometimes the flavoring agents what we use, so that has also got multi-color as well as the multiphase filled items.

So the volatile or heat sensitive flavors are usually added at the end of the extrusion process. This we have already discussed because your extrusion got some preprocessing as well as post processing. Preprocessing we have told here, one of the processing is nothing but conditioning so here, in the texturized protein products the conditioning is done before is fed into the extruder.

Same thing here, the heat sensitive flavors and volatile flavors can be added after extrusion because extrusion also has got high temperature processing of about 160 to 180 degree centigrade processing. Then licorice so this is nothing but a root of particular plant or I should call it as sweet root of particular plant you may check it later. So licorice is nothing but sweet root of particular plant.

So from that candy is made so the licorice candy is one of the confectionery items frequently produced by extrusion processing. So this requires cooking, mixing of wheat flour with the licorice extract, sugar etc. to form a homogeneous mass extrusion cooking is particularly suitable for the process.

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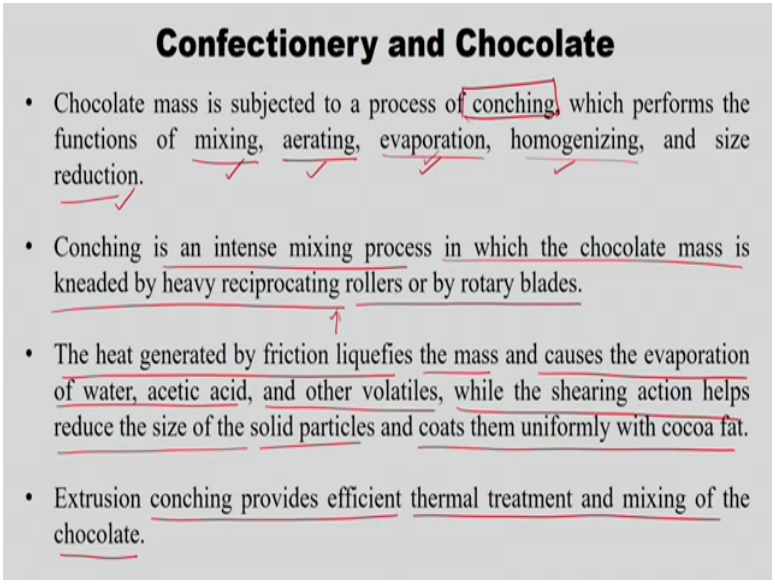

So the chocolate mass is subjected to a process of conching, so conching I have already told it is nothing but a mixing which performs the function of mixing, aerating, evaporation homogenizing and size reduction. So everything altogether put it in the term of conching. The conching is an intensive mixing process in which the chocolate mass is kneaded by heavily reciprocating rollers or by rotatory blades.

So the heat generated by friction liquefies the mass and causes the evaporation of water, acetic acid and other volatiles while the shearing action helps to reduce the size of the solid particles and coats them uniformly with cocoa fat. The chocolate mass is subjected to a process of conching which performs mixing, aerating, evaporation, homogenizing and as well as size reduction.

So in the conching process first we do mixing, so the mixing is done by the reciprocating rollers or rotatory blades so while doing the mixing process many things happens one is, the heat generated by friction liquefies the mass and also causes the evaporation, so this is the evaporation of water, acetic acid and other volatiles while mixing itself so it creates the friction so, further heat is generated that evaporates the water, acetic acid and other volatiles at the same time their shearing action helps to reduce the size of the solid particles and normally when the size is reduced so the (()) (58:05) coated with the (()) (58:07) very uniformly.

So the extrusion conching provides efficient thermal treatment and mixing of the chocolate so normal mixing, instead of normal mixing if we do extrusion cooking so that provides the proper mixing for the chocolate process and also we need to remember here, the conventional process always got its own flavor but the extrusion cooking here ace away the many complex processes. So that is the advantage of extrusion and some of the products even got good organoleptic properties then the conventional processing.

The main advantage of extrusion cooking is to ace the cooking process because especially for example when you see here when you have got multiphase products. So the sugar, corn syrup, flour, starch, fruit concentrates, so this is about the solid materials, the corn syrup is very high viscous and flour is also there so those were like dough like structure very very high viscous products. So different multiphase products processing together it is very much complex in normal conventional process. So, that process complexity extrusion cooking ace away. So that is the main advantage of extrusion cooking.

So then I would like to end the lecture with that so here we have seen different products from forming extrusion of pasta, expanded snacks, then ready to eat cereals then pellets forming, and how to make extruded starchy and cereal products using extrusion cooking and what is the role of extrusion cooking in extruded starchy and cereal products, so then a texturized protein products TPP, so which comes under this category the texturized vegetable protein is there, but among the category of texturized vegetable protein the texturized soy protein is commercially available but not other texturized vegetable proteins are picked up. So then after that we have also seen confectionery and chocolate items and also there pet foods also produced using extrusion cooking but that is similar to what we have seen in the cereal products making using extrusion cooking. So that is all with the extrusion cooking so we have got to see many applications.

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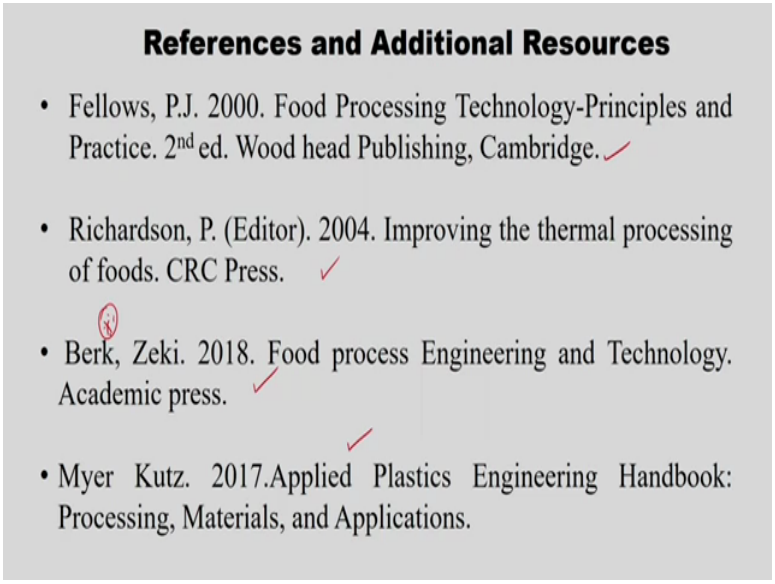

So, the reference additional resources I used for this lecture are these 4 books the specially this particular lectures mostly taken from Berk, and Zeki, Food Process Engineering and Technology. I would like to insist this particular thing because this got two lectures the extrusion technology so, we have discussed very briefly so, what is a process what are all the equipments used and some of the examples, but, as in extrusion technology in food processing is very vast, so I would like to request you to check for further references to get to know more about the extrusion technology. Thank You.