Course on Industrial Biotechnology
Professor Debabrata Das
Department of Biotechnology
Indian Institute of Technology Kharagpur
Lecture 48
Module 10
High Fructose Corn Syrup Production

Welcome back to my course Industrial Biotechnology. In the last lecture I tried to cover the alpha amylase, now alpha amylase appears to be the very very useful enzyme in the industry particularly in the food processing industries particular we have seen that during industry during malting process yeast produces the amylases and protease and this helps in the matching process for the solubilisation of starch and protein.

Now today I want to discuss the high fructose corn syrup which is very much useful for the industry particularly western country, they use this for confectionary industry that most of the confectionary industry they use the high fructose corn syrup and as the (())(01:15) dipped with corn corn is kind of food product that we have and this corn contains mostly the starchy material and this special type of corn and and this starch we with the help of alpha amylase and glucoamylase we convert it to glucose and and finally the glucose is converted to fructose with the help of the enzymes glucose isomerase.

So this is the main purpose of converting glucose to fructose if that the fructose it 10 times sweeter than glucose and that is why it is mostly used for the diabetes patient and and one important reason why the the the of using the fructose that fructose that low temperature it does not crystallize. Particularly when we talk about that the different medicinal tonic that usually that is we use some kind of sweetening agent and if we use the glucose and and usually the tonic medicinal tonic comprises of some amino acids some vitamins.

So those are the things those are very susceptible for the temperature if we increase the temperature the denaturisation of vitamins and amino acid will take place. So that is usually recommended that should be stored under low temperature particularly under in the freeze you should store it. Now if we have a high glucose concentration then then if we keep it at a low temperature we know sugar that glucose has no temperature it crystallizes out we will find in the tonic lot of crystals formation is there, so that is undesirable that is why that most of the pharmaceutical industry for the preparation of medicinal tonic it is recommended to use fructose in place of glucose.

So today I want to share with how the high fructose corn syrup is produced by the industry and and detail information about that.

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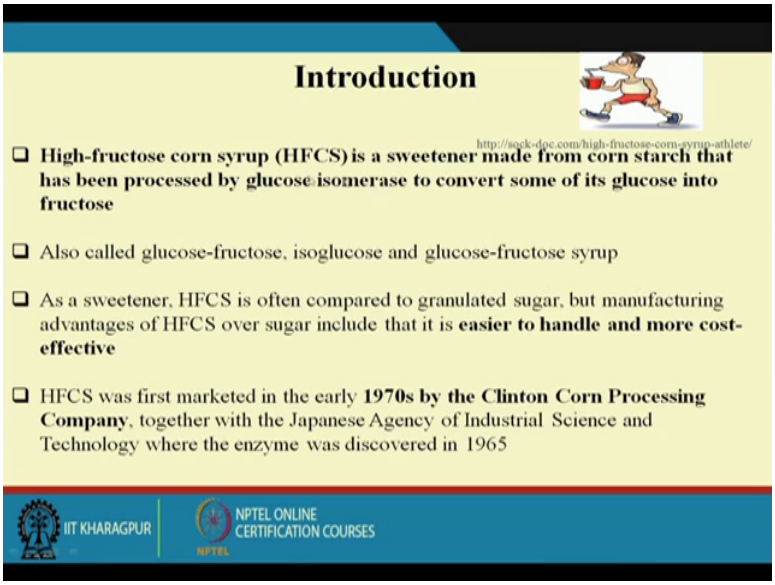

The high fructose corn syrup is a sweetener made from corn starch that has been processed by glucose isomerase to convert some of its glucose into fructose now also we called glucose-fructose or isoglucose or glucose-fructose syrup.

As a sweetener high fructose corn syrup is often compared to granulated sugar but manufacturing advantage of high fructose corn syrup over sugar include, it is easier to handle and most cost effective. High fructose corn syrup is first marketed in the early 1970s by the Clinton Corn Processing Company, together with Japan Agency of Industrial Science and Technology where the enzymes was discovered in the year 1965. The enzymes as I pointed out three different enzymes take part in this process, one is alpha amylase another glucoamylase, another glucose isomerase enzyme.

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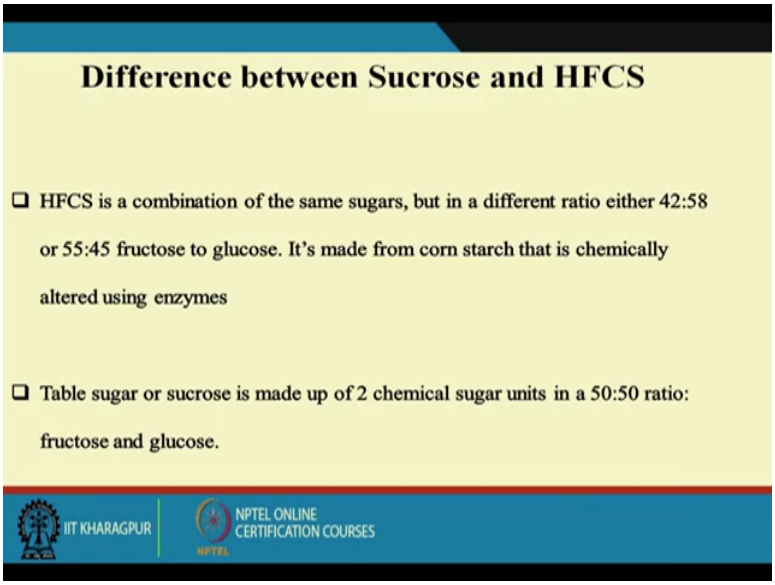

Now the high fructose corn syrup is a combination of same sugar but in the different ratio as for example 40:58, 55:45 fructose to glucose ratio and it is it is made from corn starch that is chemically altered using the enzymes, so this this combination we get by enzymatic conversion process. Table sugar or sucrose is made of two chemical sugar unit 50:50 fructose and glucose so we consider we we call that that sugar is a is a is a uhhh made of two monomer, one is glucose, another is fructose and if we hydrolyse and the enzymes that is responsible for the hydrolysis of glucose that is that is inverted enzyme. That inverted enzyme that can hydrolyse this sugar to glucose and fructose.

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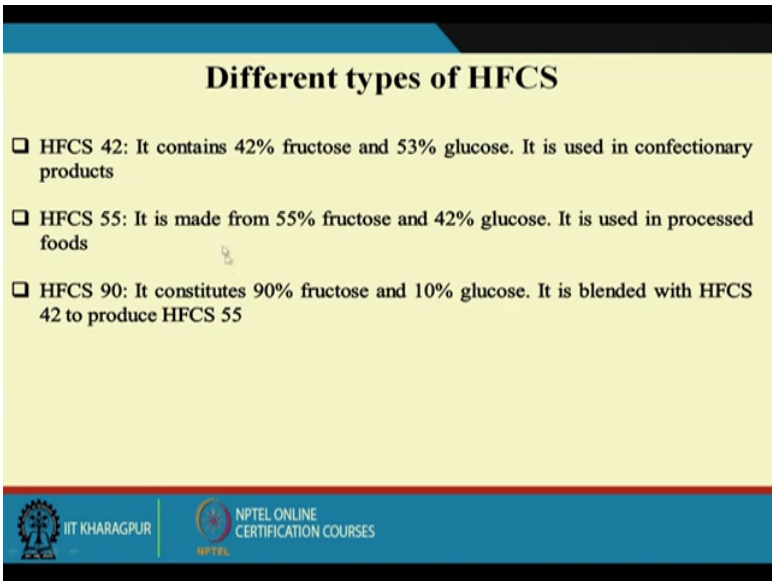

Now high fructose corn syrup 42, it contains 42 percent fructose and 53 percent that is glucose. It is used in the confectionary product. High fructose corn syrup 55, it is made of made of 55 percent fructose and this is 42 percent glucose. It is also used in the processed food. High fructose corn syrup 90 it is 90 percent fructose and 10 percent glucose, it is blended with high fructose corn syrup 42 and 52. We can blend it to convert the high fructose corn syrup 42 to high fructose corn syrup 55.

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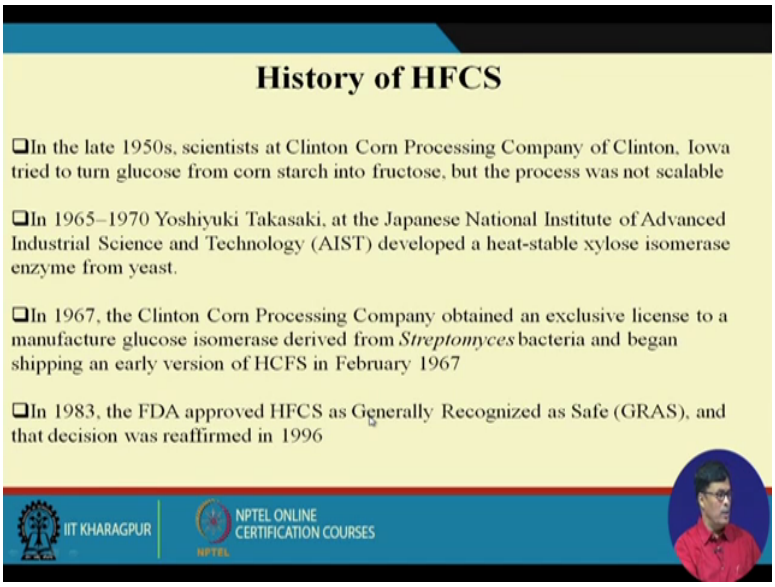

Now if you look at the history of high fructose corn syrup in the late 1950s scientists Clinton Corn Processing Company as I mentioned before in Iowa, USA tried to turn glucose from corn starch into fructose but the process was not scalable. Now in 1965 to 70 the Takasaki Japanese National Institute of Advanced Industrial Science and Technology developed a heat stable xylose glucose isomerase enzyme from from from yeast then xylose isomerase enzyme form yeast. Then then 1967, Clinton Corn Processing Company obtained the exclusive license to a manufacturing glucose isomerase derived from Streptomyces bacteria and began the shipping as early version high fructose corn syrup in February 1967.

Now 1983 FDA approved that high fructose corn syrup as generally recognised as safe and and that decision reaffirmed in 1996. So so this has been approved by food food product association for the for the human use. Actually this is this is permitted.

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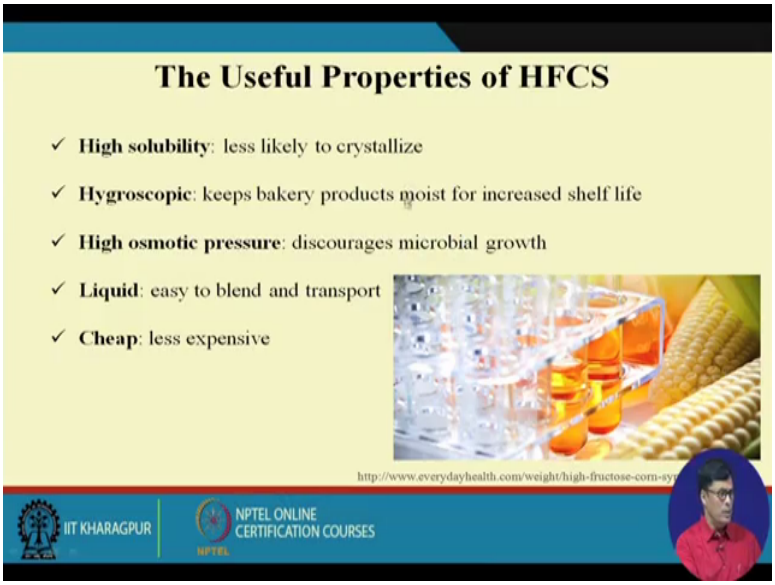

Now if you look at the what is the useful property of high fructose corn syrup. First is highly soluble, less likely to crystalize. As I told you since it contains the fructose, so even at low temperature the no crystallization no sugar no precipitation of sugar or glucose will take place.

Now hydroscopic keeps the bakery product moist for increase the shelf life this is and high osmotic pressure that discourages the microbial growth now here I want to point out, if we increase the sugar concentration the osmotic pressure increases that will not encourage the growth of bacteria. The contamination problem will greatly reduce and liquid is easy to blend and transport this is the one and less expensive and this is the corn you can see this is the corn that is used for the production of high fructose corn syrup.

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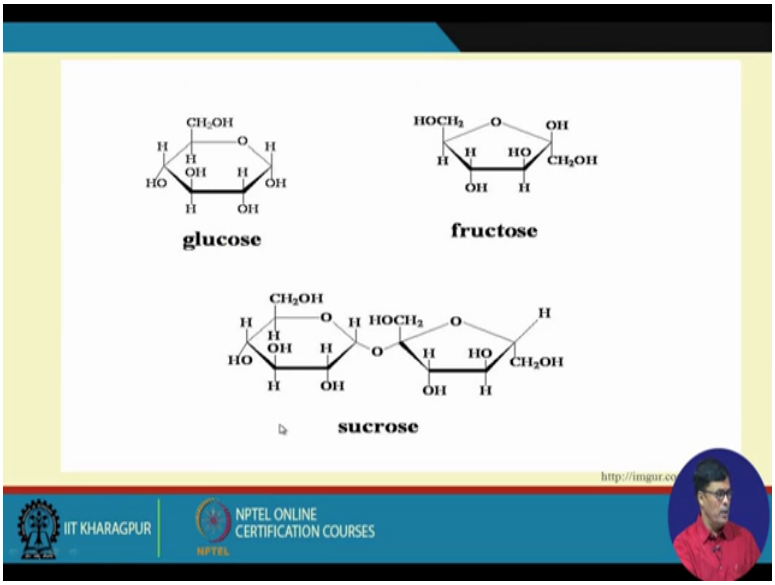

Now we have we know that glucose, fructose and sucrose so this is the hexose sugar both are hexose sugar both having the glucose and fructose has has same empirical formula.

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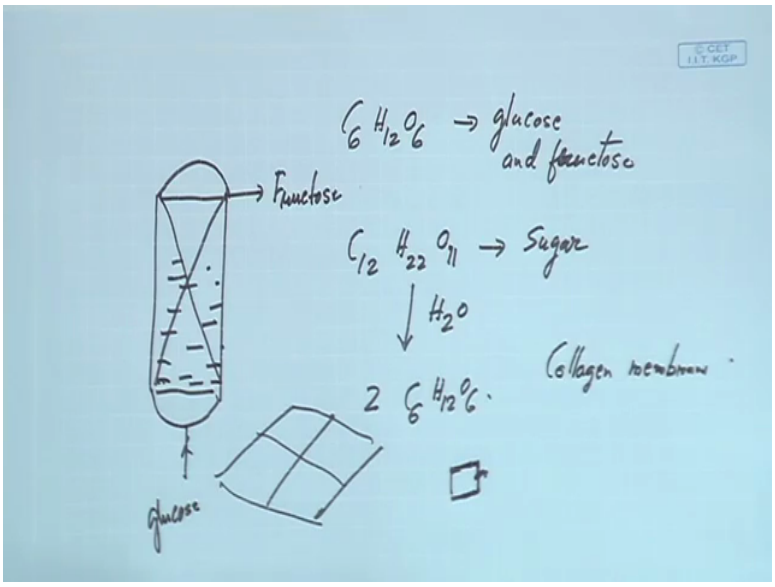

That is C6 H12 O6, now if you this is both glucose and fructose. But if you look at sugar it will be it will be something different 12 H22 O5 O 11 actually this is sugar. Now sugar I told you when hydrolyse hydrolysis reaction all is one molecule of water is required it produced two moles of 12 O6. Now it comprises of both both glucose this is the glucose and fructose unit. Now if you look at the glucose they have aldehyde group and in case of fructose they have the ketone group and and when they combined it looks like this this is the sucrose molecule and this is what I told this is 10 times sweeter as compared to glucose.

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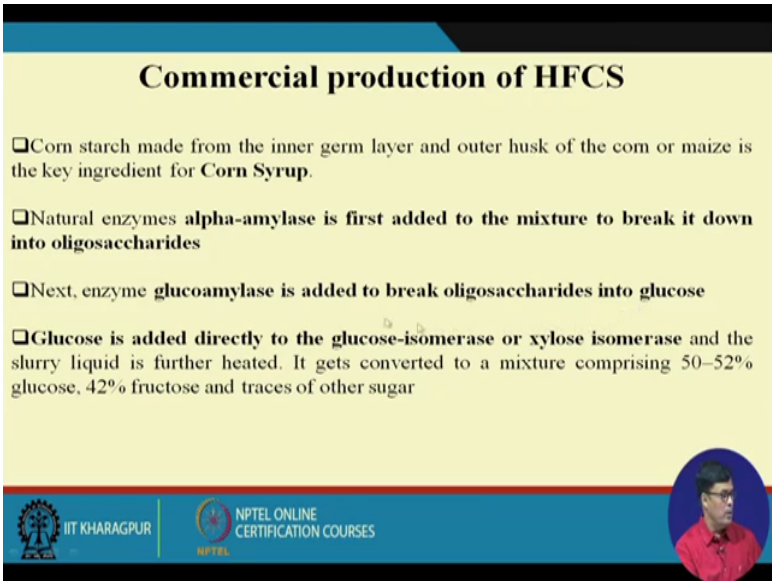

Now corn starch made from inner germ layer or outer husk of the corn or maize is the key ingredient for corn syrup. The natural enzyme alpha amylase is first added to the mixture to break down the oligosaccharides I think in the last lecture I tried to point out the how the alpha amylase act on starch molecule and I told you randomly attack the what did the starch molecules starch is the polymer of glucose now it has it is it can be available in two different forms either amylose and amylose pectin. Amylose is a straight chain I told you yesterday and amylose pectin they have both straight as well as the branch chain and the straight when it is straight chain the amylase it has alpha 1-4 glucosidic linkage.

Now when it is it has the branch chain then it has both alpha 1-4 and 1-6 alpha 1-6 linkage so that is thing that we have and alpha amylase is very much active in degrading this randomly attack the attack this molecule but as compared to beta amylase beta amylase always act close to the non-reducing end of the sugar and it releases mostly the maltose what you call dimer, dimer means two glucose units they they combine together with the help of alpha 1-4 linkage.

Now this is alpha amylase first added to the mixture to break down into oligosaccharides, next enzyme the glucoamylase is added to breakdown the oligosaccharides into glucose, now glucoamylase enzyme also required the oligosaccharide most of the oligosaccharide that usually comes in the starch usually they remain in the insoluble form that will be becoming solubilise when it produce the oligosaccharides and this glucoamylase when acts on oligosaccharide produce a glucose and this glucose directly converted to that converted to fructose with the help of the enzymes what you call glucose isomerase enzyme. It can convert the mixture comprising of 50-50 glucose 42 percent fructose and trace of other sugar.

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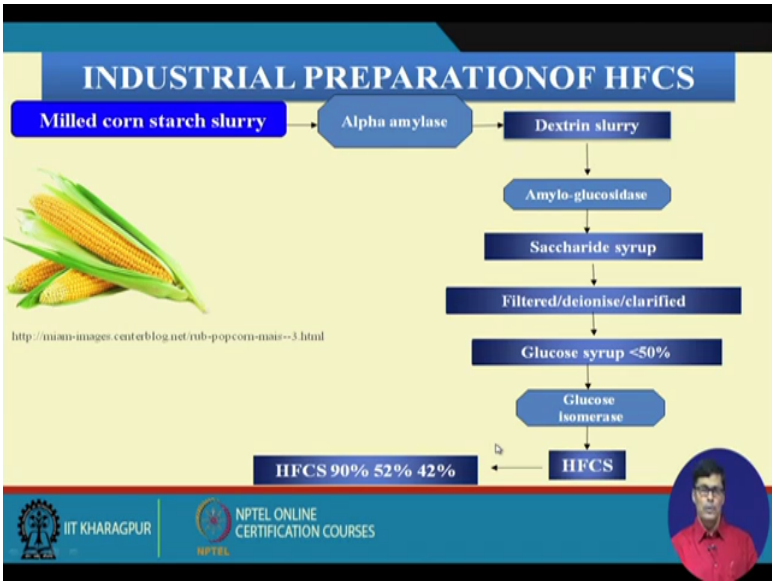

Now if you look at how industrially we produce this high fructose corn syrup is very important this is the corn and you know as per corn is concerned there is two type of corn, one is sweet corn and another is starch based corn. Now we had we had here we had genetically we can modify the the the the corns starch and we can give more starch content rather than the soluble sugar content. So this is the starchy molecule that we have.

And this milled corn starch slurry we first treated with alpha amylase then we get the dextrin slurry where we have oligosaccharide and then it is treated with amylo glucosidase enzyme and then it produce the sugar this glucose molecules what we call saccharide syrup and then we filtered or deionise or clarified. This glucose syrup contains about the 50 percent of glucose and then we use the glucose isomerase enzyme to convert the glucose to fructose we get high fructose corn syrup 90 percent 42 percent or 40 50-52 or 40 percent. So this is how high fructose corn syrup is produced by the industry.

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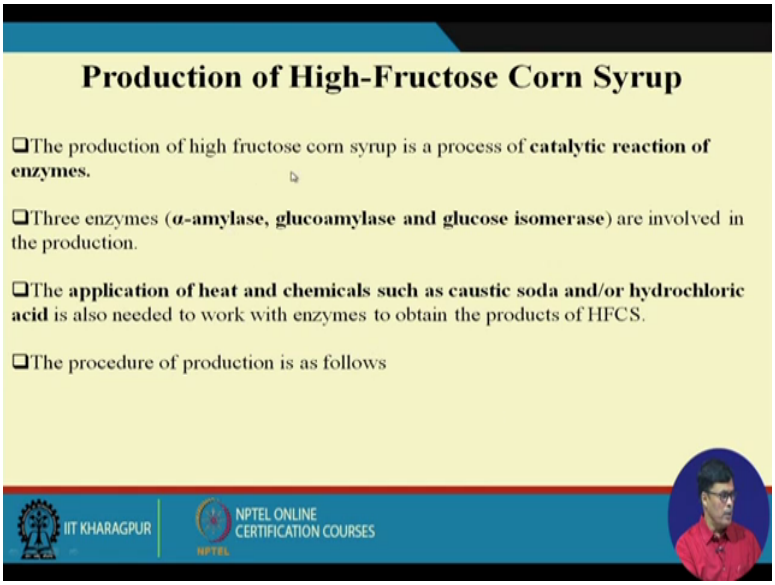

Now production of high fructose corn syrup is a process of catalytic reaction of enzyme. I do not like to spend more time on it.

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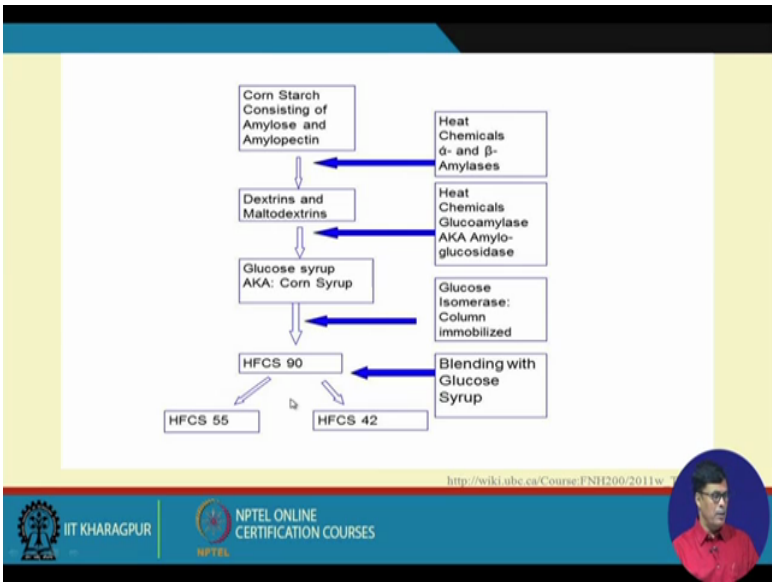

Now another block flow diagram is given here to have the clear cut concept on this process. The corn corn starch consists you known amylose and amylopectin I told you the starch all is available in two different form one is called amylose another is amylopectin. Now when we heat the chemicals are in presence of alpha and beta amylase we know the alpha amylase they are active at 460 degree centigrade and they required calcium iron that increases the thermostability range of the enzyme to a great extent we get the dextrin or maltodxtrine.

Then we add the glucoamylase enzyme to get the glucose syrup and and then we we add the glucose isomerase this column immobilization I I told you then when we get that the glucose, isomer is a isomerase enzyme we can immobilized on the on on a particular column that you know that collagen membrane I can collagen membrane, we can use collagen membrane we can we have the suppose we have this collagen membrane we can cut into different pieces and then we can make in the form of bag small bag like this and we can just fold it we can make it bag like this.

Then with the heat we can seal this side we can seal this side, then then this side is open we can we can put the powder of this glucose I isomerase enzyme and by heat we can seal it and then this we can stack one after another here we can put this material one after another here, this we can pack this we have to like this, then we pass the glucose solution from this from the bottom and the top we can get the fructose.

I think when we discuss the reaction kinetics and the reactor analysis we we we try to solve one problem by how to design the height of the the immobilized column to convert glucose to fructose. So please refer that lecture and you find that we already we talk about that how you determine what should be the height of the column to get the desired amount of conversion of glucose to fructose. So this is we have we can we can we can produce high fructose corn syrup 90, high fructose corn syrup 55, high fructose corn syrup 42.

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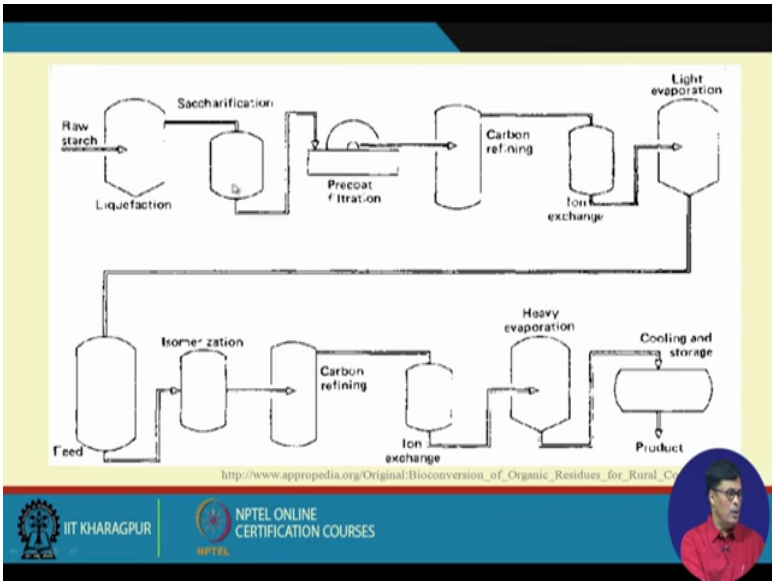

Now if you look at another schematically it can be represent like this kind of process flow diagram. The raw starch comes here in the tank, in the tank first the liquefaction take place I

told you the liquefaction is taking place by the enzyme alpha amylase and beta amylase then we get the oligosaccharide and then oligosaccharide then we use some kind of the glucoamylase enzyme to form the glucose, then we pass through the filtration to remove the insoluble material.

Then we we add some kind of carbon refining we know the activated charcoal that remove the colour that use as a bleaching agent then you passes through the iron exchange that column and then light evaporation to concentrate the liquor and it is the it is coming as a feed then we have isomer as this the immobilized column where we immobilize the isomerase enzyme we pass this here and then we get fructose again we do the carbon refining again we pass through the ion ion exchange that the column and again we do the evaporation and we cool and store it we get the product high fructose corn syrup.

This is this is largely used in the western country and that is in practise and that is why I told you this is in the confectionary industry to a great extent.

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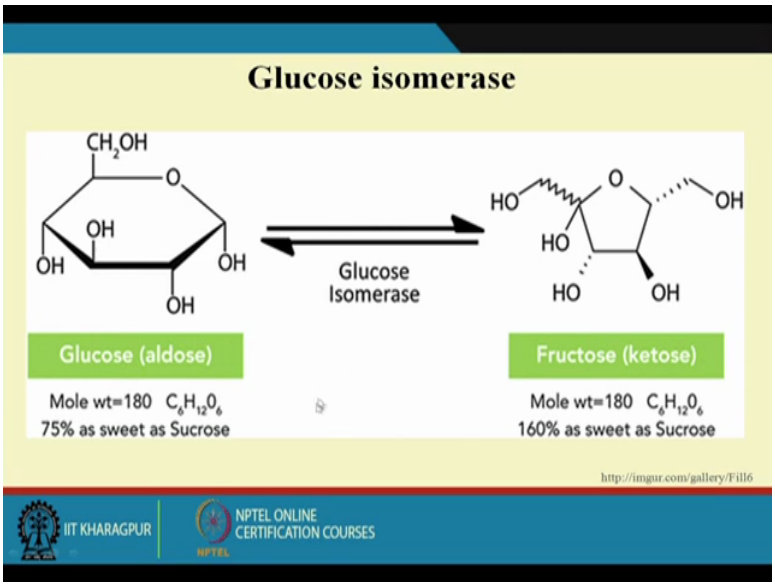

Now the reaction is like this the glucose that converted I told you the glucose is containing one aldehyde group and fructose contains one ketose this is called aldose this is called ketose. So it has the ketone group so so this is this is with the help of glucose isomerase enzyme glucose is converted to fructose. So here it is 70 percent as sweet 75 percent as sweet as sucrose but 160 percent as sweet as sucrose. This is how they are differ from each other.

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Now why do the food manufacture use it that is the question that we had in our mind. The first reason is that it is the cheaper raw material because corn because if you look at the western country they have that high every year they have excess amount of corn production that they have, so since they have high amount of corn production so it is the cheaper raw materials.

So since it is a cheaper so the the cost of the high fructose corn syrup also will be cheaper because any kind of product cost I told you it also depends on the cost of the raw materials. Now cheaper than sugar as I as I pointed out lower manufacturing cost, easy to transport because it is it is liquid we can easily we can we can transport even if you want to transport by pipe line that also can be done because I told you even at low temperature there is no crystallization take place the fructose never crystallize at the low temperature this the added advantage that we have with the fructose and flavour you know enhancement for both sweet and spice flavours the baked goods baked goods then fruit fillings, tomato products canned fruits and beverages.

They use as a as a that additives here both as a sweetener they use in the baked goods we have in a day to day life lot of baked goods then fruit fillings and tomato products like tomato products we have ketchup we have some other tomato sauce that we have and then canned fruits we have canned fruits also we usually we know those who are involved with the canning product they know that how the canned food production takes place because this usually take in a syrup and then we we that fruits that is so that you know that so we put in the syrup and then we seal the can and we we and then we stay like that.

So that you can preserve the fruits for longer period of time, because why we keep the syrup because syrup that usually that sweetener to maintain the taste of the of the of the fruit products so fruits are usually sweet in taste that is why we use a syrup, then then then enhances the moisture control retards the spoilage, enhances texture and extends of products freshness of baked goods, granola, breakfast and cereal bars because is a different cases we different fruit products largely used this high fructose corn syrup.

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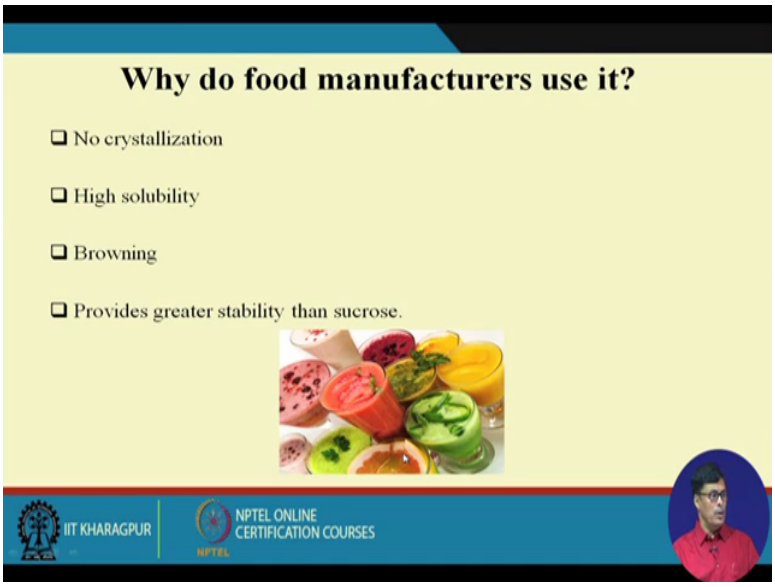

Now the why do the food manufacturer use it because as i pointed out one important factor is that it does not crystallize because I told you if you if you use the glucose at low temperature the solidification of glucose will take place usually food products we usually store at low temperature and the high solubility this is one of the reason and browning this is another reason and provided greater stability than sucrose that is why we use this.

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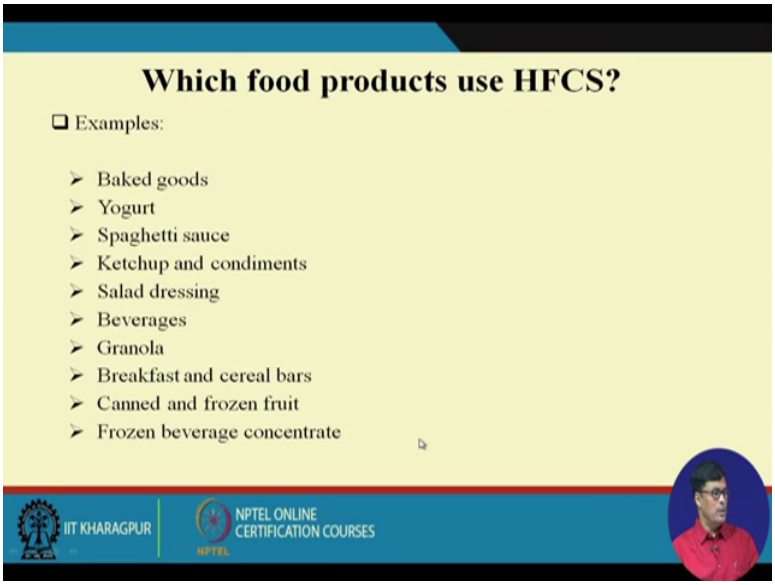

Then then which product is high fructose corn syrup this is we have baked good, yogurt, we have spaghetti sauce, we have ketchup, condiments, salad dressing, beverages, granola, breakfast, cereal bars, canned and frozen fruits and frozen beverages concentrate. So there are different different food products we use this high fructose corn syrup is largely used by the industry and western country in our country we do not have much of use of high fructose corn syrup but some places we might be using but in the western country they largely use high fructose corn syrup.

Though because in the foreign country they use though in our country also now we are using the lot of canned canned fruits we are using so in the foreign country they they they are using the canned food long before because I I told you the what is the purpose of using the canned food because suppose most of the fruits they are seasonal, seasonal in spite they are available in a particular season.

Now if you want to use uhhh throughout the year so you have to preserve that fruits and vegetables. So naturally canned food is largely used and the the added advantage of this is that we are not using any kind of preservative in it, when we use any kind of preservative it has some kind of detrimental effect to our health so when we when we produce the canned food may be when you heat it some of the loss of vitamins and other is there but we are not using any kind of chemicals, so side effect will not be there. So this is the reason why we use.

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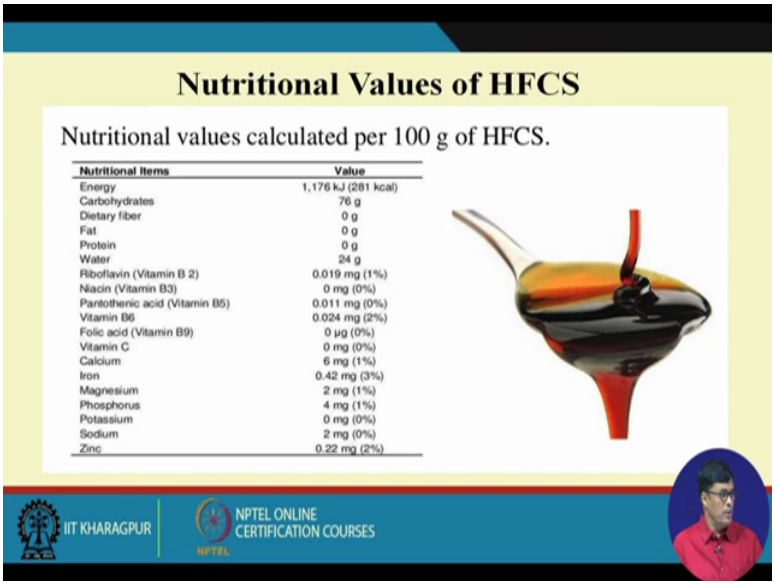

And this is this is the nutritional value of 100 grams of high fructose corn syrup that that is that is given here. You see that the energy content is about 1176 kilo Joules and this carbohydrate is 76 grams that we have we have dietary fibre and fat contents and protein contents is not there because mostly in the high fructose corn syrup we convert the starch present in the corn that we converted into the fructose that is that is the thing that we have.

Then we have this it contains the water significant amount of water then riboflavin that is vitamin B2 and nacin that also contains pentothainic vitamin B6, folic acid vitamin C, calcium, iron, magnesium, phosphorous, potassium, sodium and zinc. So you can find out lots of lots of materials it has it has lot of food value because not only it contains the glucose and fructose but also it contains the other ingredients because since we are producing it from the corn starch, corn starch we are is a agricultural product and it contains other trace element which is very much useful for our for our health.

And now in conclusion I want to tell that high fructose corn syrup is largely used by the western country and and it has also some kind of side effect because high amount of high fructose corn syrup also it is has some kind of detrimental effect on our health, so everything we know that that all most of the food product also if you take very high amount it has some kind of bad effect on our on our health.

So small amount it does not have much of bad effect on our health it can be safely used so already that the Food Product Organisation they recommended this is a safe product and I told you the high fructose corn syrup largely used by the western country as a sweetening

agent for the confectionary energy I told you not only used in the confectionary industry but also used both the production of different food products, so this is this is this is all about the high fructose corn syrup, thank you very much.