Organic Chemical Technology
Prof. Nanda Kishore
Department of Chemical Engineering
Indian Institute of Technology, Guwahati

Lecture - 09
Carbohydrates Industry- Sugar

Welcome to the MOOCs course organic chemical technology. The title of today's lecture is carbohydrates industry sugar. This lecture and coming couple of lectures we are going to discuss about carbohydrates industries, their major products and how those products are being produced industry level those things we are going to discuss. However, before going into the details of such industrial products, we will be having a brief introduction on carbohydrates.

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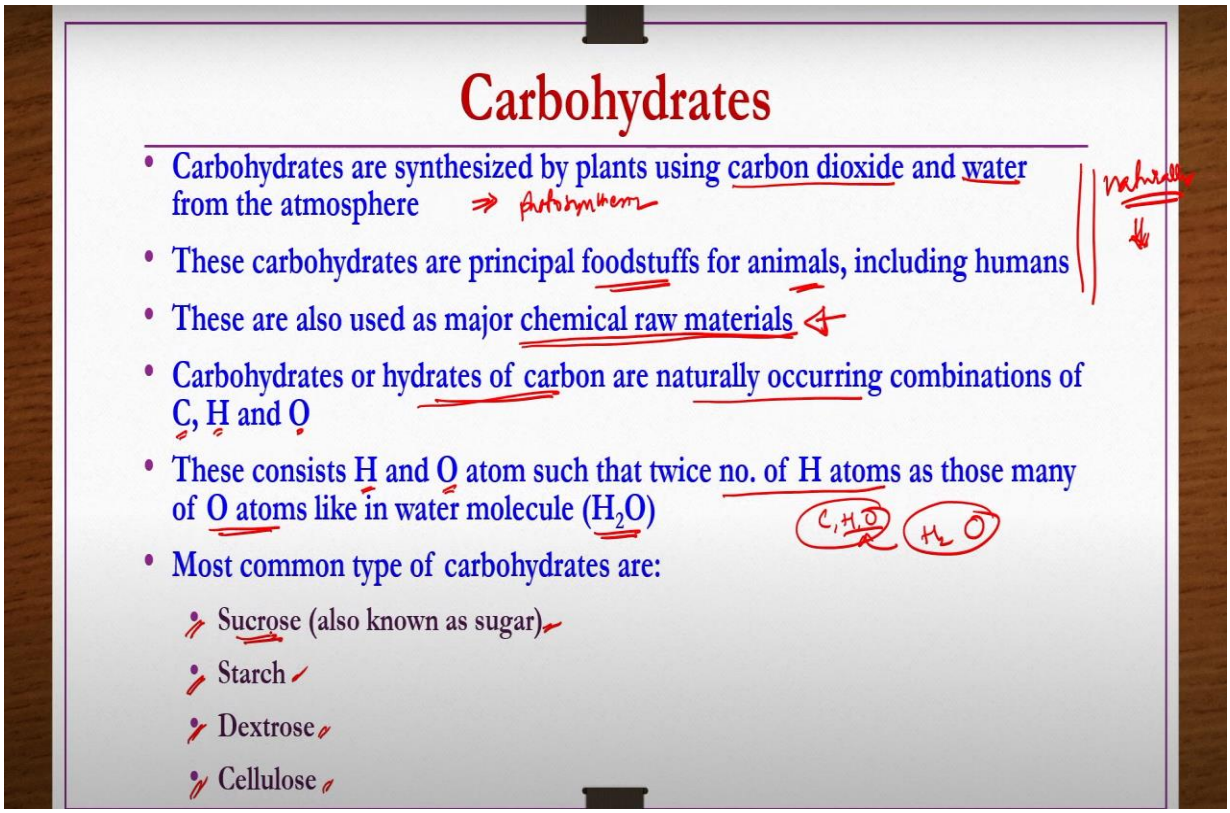

As we all know, carbohydrates are synthesized by plants using carbon dioxide and water from the atmosphere by consuming this carbon dioxide and water from the atmosphere and by utilizing the energy from the sun by photosynthesis reaction. These plants produce carbohydrates that we all know. These carbohydrates are principal foodstuffs for animals including human beings. These are also used as major chemical raw materials. We are going to see a few of them now so that to produce some chemicals also. In the fermentation industries and in upcoming weeks, we are going to discuss how these carbohydrates are being utilized as raw materials to produce different types of chemicals and then these carbohydrates are produced naturally by photosynthesis reaction.

So, that is the reason whatever the products that we are going to get all of them are counted or produced or included under the terminology of natural products industries, okay? Carbohydrates are hydrates of carbon, either way these are known. They are naturally occurring combinations of C, H and O, nothing else. If any other element other than C, H, O is there, then we cannot call them carbohydrates purely. They can be organic chemicals, but they cannot be carbohydrates. In carbohydrates, you are having purely combinations of C, H and O and then how they are included? These consist of H atom and O atoms such a way that twice number of H atoms as those many O atoms like in water molecule.

In water molecules, if you have one O atom, 2 H atoms are there. So, like that in carbohydrates, we are having only C, H, O, but the C, H, O are having the ratio of 2 H atoms and then 1 O atom as in water molecules. Most common type of carbohydrates that are oftenly utilized by many sucrose which is also known as sugar, starch, dextrose and then cellulose as well, right? So, we are going to discuss the properties and then production of some of these products anyway or some of these common type of carbohydrates in this and in coming lectures. So, let us start with the sucrose or production of sugar at the industrially that is sugar industry, okay?

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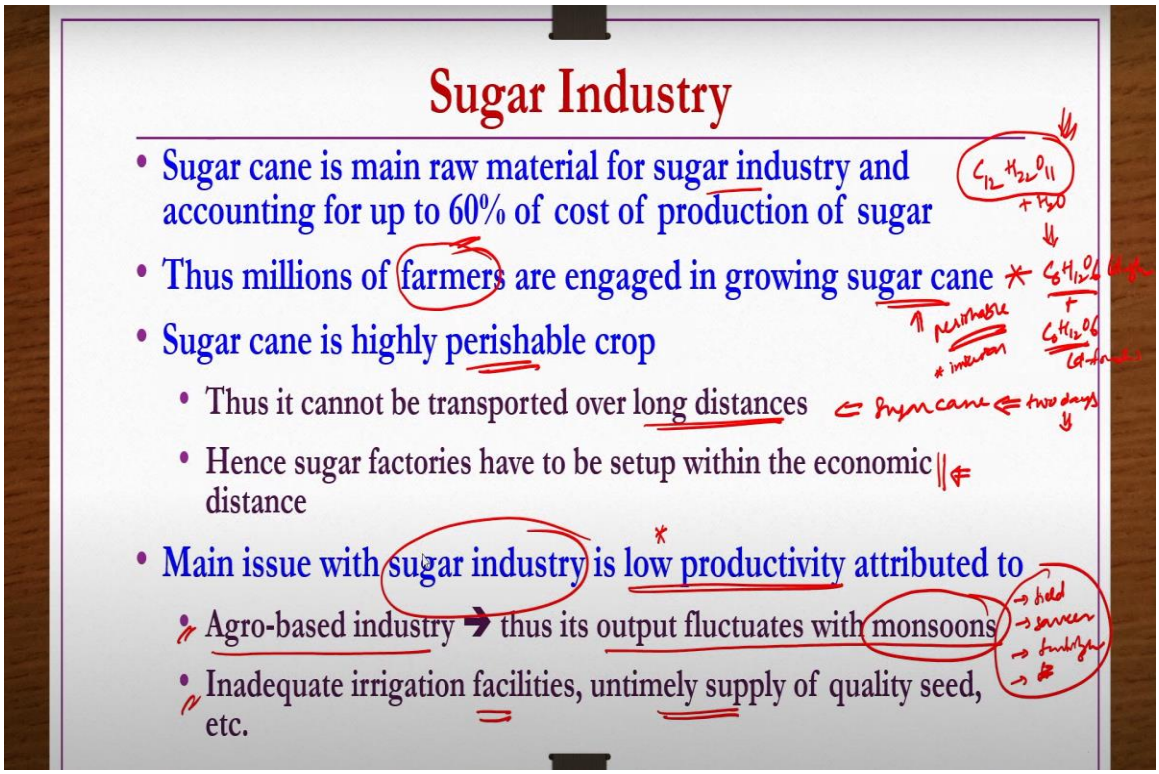

Sugar cane is main raw materials for sugar industry and accounting for up to 60% of cost of production of sugar, why? Because whatever the sugar cane that you in general get in that one, you hardly have 15 to 20% of sucrose only, rest all moisture etc. So, when you do the 100% extraction or with 100% yield, if you do the extraction, then also you can get only 15 to 20% of sucrose from this sugar cane or you know, mostly they consisting or majority of the sugar canes, you know, you can say that mostly moisture or water and then cellulose components are there and then with only 15 to 20% of sucrose that is what one can say in another way, okay? And then subsequently, we can realize when we discuss the corresponding flowchart to prepare the sugar from the sugar cane, there we can understand that only sugar cane is primary raw material, right? Whereas other smaller minor amounts of water etc. is required, steam etc. is required for flocculent agent purpose, you know, calcium carbonate, calcium phosphate and then SO2 etc., phosphoric acid etc. are being used for different purposes. They used as a flocculating agents as well as a kind of bleaching agent as well.

So, these quantities are very less, whatever the sugar whatever you are going to get that is primarily getting from the sugar cane. Let us say pure juice after removing all impurities by different process, whatever the juice that you get from the sugar cane after impurification, it will still have 80 to 85% of water. So that water content would be further reduced to 40 to 45% or something like this by evaporation, multiple effective operators are used and then further vacuum pan crystallizers are being used to make the crystals etc. So, this is the process. So, then primarily the sugar production is something like you know, extraction of the juice from the sugar canes and then concentrating it after removing the impurities concentrating it and then crystallizing it to get the required sugar that is the process.

So, that is the reason primary raw material is sugar cane and then that cost up to 60% of the production cost itself, whatever the production cost is there for the sugar 60% is gone for the sugar cane, right? Thus, millions of farmers are engaged in growing sugar cane that is one advantage. If it is advantage from the farmers point of view, but from the industry point of view it is disadvantage because they cannot control the quality, they cannot control the quantity of the sugar producing because the sugar industry is primarily depending on the sugar cane and then indirectly sugar industry is depending on the farmers. So, it is better to have sugar industries their own sugar cane cultivation fields themselves so that they can control the requirement of the sugar because further you know another problem with the sugar cane is that it is highly perishable. That means you cannot store it for a longer time, right? And then it has to be used at the earliest because another reason is that you know, inversion of sugars also takes place. Actually, this sucrose if you see its chemical structure is $C_{12}H_{22}O_{11}$, right? So this is what sucrose, right? If it is not properly handled during the extraction period itself, so then what happened? It will form $C_6H_{12}O_6$ as well as $C_6H_{12}O_6$ this is D-glucose and this is D-fructose.

These are the monosaccharides whereas this $C_{12}H_{22}O_{11}$ is disaccharides, right? So if you don’t do the proper processing during the extraction itself, then there is a problem that this sucrose content of the sugar cane may be inverted to the glucose and fructose like this. So that is highly perishable. So then industry people having control on the sugar cane cultivation and then transportation of this one to the industry is going to be very beneficial

for the industry itself. So, sugar cane is highly perishable crop, thus it cannot be transported over long distances. You have to use within 2 days in general.

Once the sugar canes are cut from the sugar cane cultivation field, so within 2 days, they should be utilized to produce the sucrose or sugar from the sugar canes. Otherwise, there is a danger that inversion of the sucrose or sugar takes place and then you may get glucose and fructose rather than getting the sugar, okay? Hence, sugar factories have to be set up within the economic distance. So, this sugar factories has to be very close to the sugar cane cultivating field, otherwise sugar industry themselves they should have their own sugar cane cultivation fields nearby their industries itself, okay? Why? Because this sugar cane is highly perishable crop. Main issue with the sugar industry is low productivity. Why this low productivity? As already mentioned here, it is a Agro-based industry.

Thus, its output fluctuates with monsoons and then farmers who are cultivating and then field, so many factors come into the picture. Field also makes different sources of water, etc., fertilizers, etc., if at all required for the production of the sugar cane. All these things are going to be having one or other effects along with the monsoons, right? So, that is the reason, that is one of the reasons that you know low productivity of sugar industry is there. In addition, inadequate irrigation facilities, untimely supply of quality seed, etc., also leading these sugar industries to be low productive.

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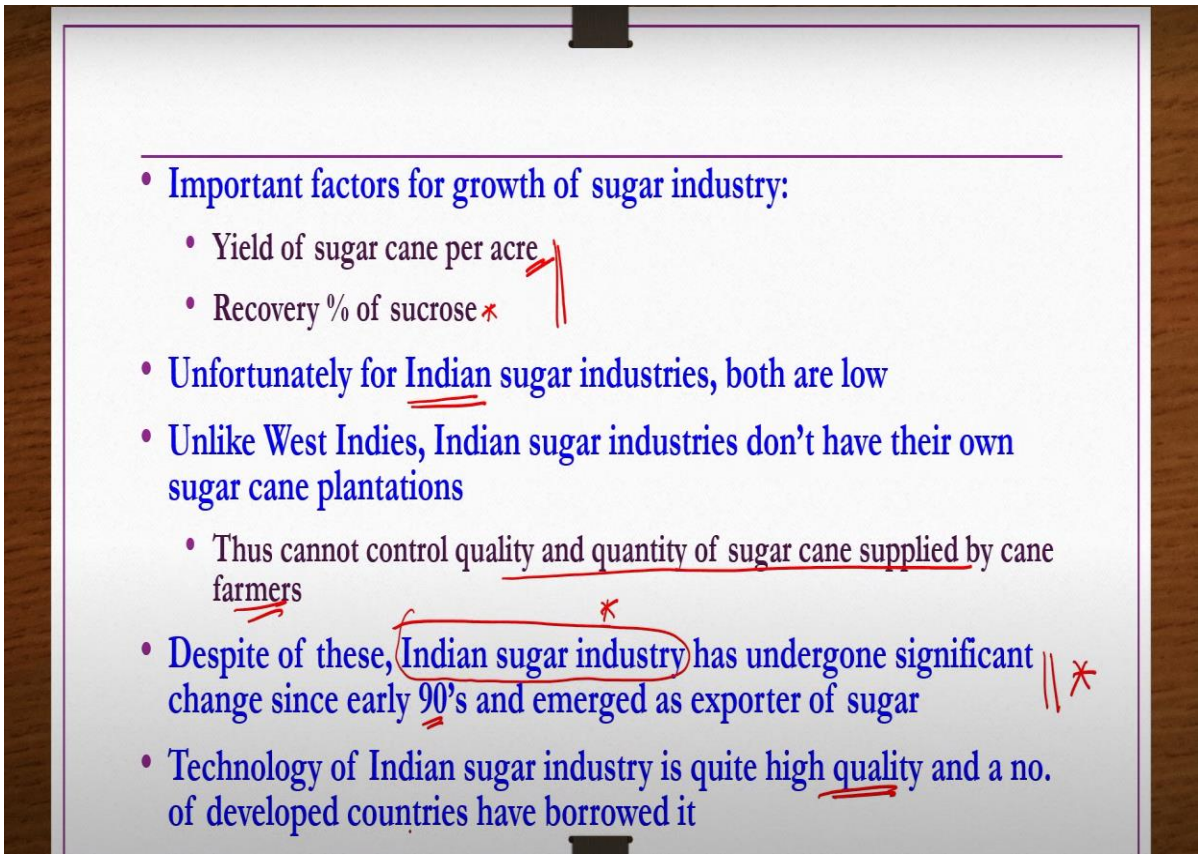

Now, what are the important factors for the growth of sugar industries? Obviously, we understand that 60% of operational cost of the sugar industry is going into the sugar canes, right? So, what does it mean? The sugar cane is a very essential component of the sugar industry. So, from that point of view if you see per hectare, how many tons of sugar cane are you able to produce? That is one of the important factor that is going to affect the sugar industry, right? And then second thing that we know that in the sugar canes, the sucrose content is very less actually 15 to 20% only. If you are not able to extract with a maximum yield, then again what will happen? The overall content of the sucrose or the sugar production is going to be affected.

So, yield of sugar cane per acre of the land is one important factor. Another important factor is recovery of sucrose from such sugar canes, that is the second factor, okay? But unfortunately for Indian sugar industry both are low. Per acre of field or the land, how many tons of sugar cane are being produced? That is less in India. Similarly, the recovery

percentage of sucrose from the sugar cane is also less for the Indian sugar industries, okay? Whereas unlike West Indies, Indian sugar industries do not have their own sugar cane plantations. They are depending on farmers, monsoons, field and then so many other factors, okay? Thus, cannot control the quality and quantity of sugar cane supplied by the cane farmers.

So, then this is adding another kind of demerit to the or disadvantage to the sugar industries because of that one sugar industries are low productive. However, despite of these reasons, Indian sugar industry has undergone significant change since early 90s and emerged as exporter of sugar despite having so many issues, right? Indian sugar industry has grown like anything and then it has started exporting the sugar by early 90s, 1990s itself, right? And then also Indian sugar industry technology is also so high quality wise also, it is quite high, right? The technology of Indian sugar industry is also quite high that a number of developed countries have borrowed it, okay?

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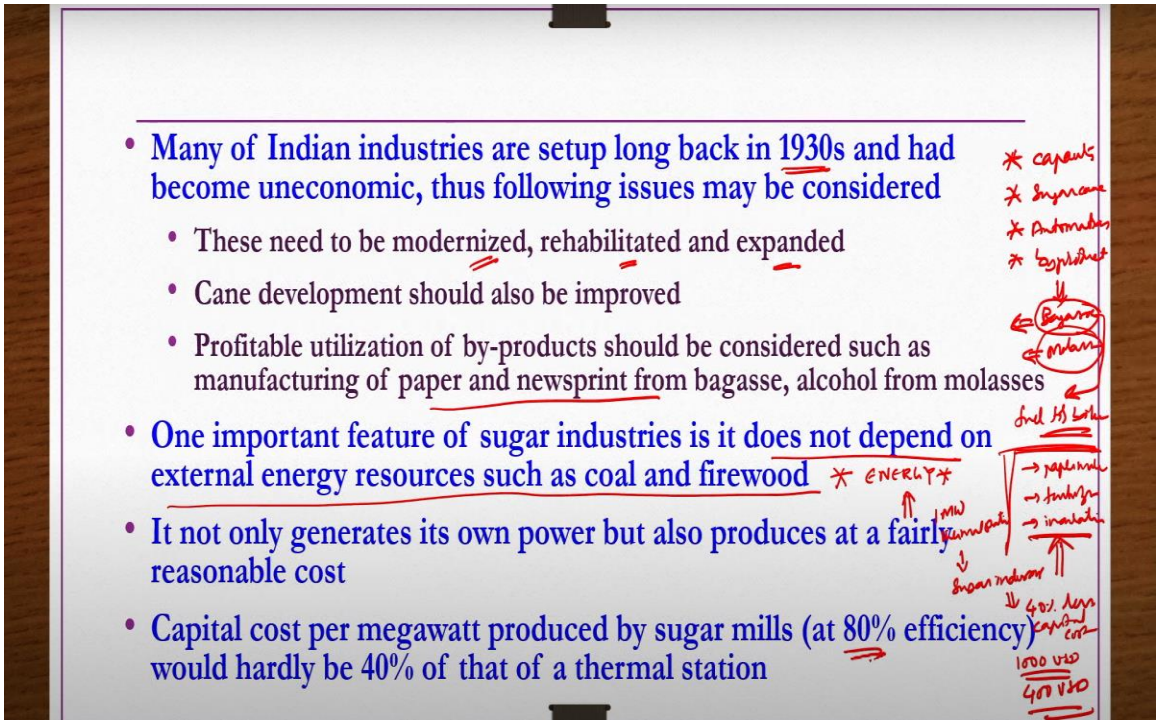

Despite of having good technology that many developed countries are borrowing technology from India, still for Indian sugar industries, there is a lot of scope for improvement. What are those kind of scopes of improvement that we are going to see now? Many of Indian industries are set up long back in 1930s, etc. and had become uneconomic or less economic. So, in order to improve the economic of such plants, what steps should be taken, right? One is that improve the capacity of the plants, right? Another one is to improve the sugarcane production, right? Most important thing is the automation of the plants, right? So, these kind of factors one should consider.

Let us say these need to be modernized considering the automation, etc., rehabilitated and expanded, capacity should also be increased. Also, the byproducts whatever are there. From the byproducts also, you should try to get the market so that to make sugar industries more profitable. What are the byproducts? Bagasse is one and then Molasses is the other one.This one can be used for the paper industries for the fertilizer production, etc., whereas this can be used for the production of ethanol in distilleries or may be taken to the fermentation industry for other products, etc., that is possible. So, how to utilize them should also be thing. What often it has been done in the conventional plants, this bagasse whatever is there, it is used as a fuel for the boilers, steam boilers are there in the plants.

So, for them as a fuel these are being used, these bagasses in general, but there is a feasibility that these can be used for the paper making, fertilizer industries, right? And then insulation material preparation, etc., for these kind of other purposes also one should think from this point of view or either they should have a tie up with such kind of industry so that these bagasses, etc., may be sold to them at appropriate prices or within the sugar industries they may be think how these plants can also be built in and make such kind of products, okay? So, cane development should also be improved, profitable utilization of byproducts should be considered such as manufacturing of paper and newsprint from the bagasse, alcohol from the molasses, etc. One important feature of sugar industries is it does not depend on external energy resources such as coal and firewood. Any plant it cannot run without energy, energy is very much essential for any chemical industry whether inorganic or organic.

But here you produce so much of bagasse that bagasse itself can be used to produce the energy which is sufficient enough for the plant to run, right? Not only that one, there are sources that you know technology is there that you know this can be utilized to produce energy for the other sources also for the other purpose also that also at reasonable cost. Let us say to produce 1 megawatt of energy from the thermal station, whatever the capital cost is there compared to that one in the sugar industries whatever the sources are there to produce the energy, from there you can produce the energy at 40% less capital cost. That means to produce 1 megawatt of power from the thermal stations if you are using 1000 USD, right? So, then the same thing you can do by sugar industry just using 400 USD that much you can save, okay? It not only generates its own power but also produces at a fairly reasonable cost. Capital cost per megawatt produced by sugar mills at 80% efficiency if you see would hardly be 40% of that of thermal stations.

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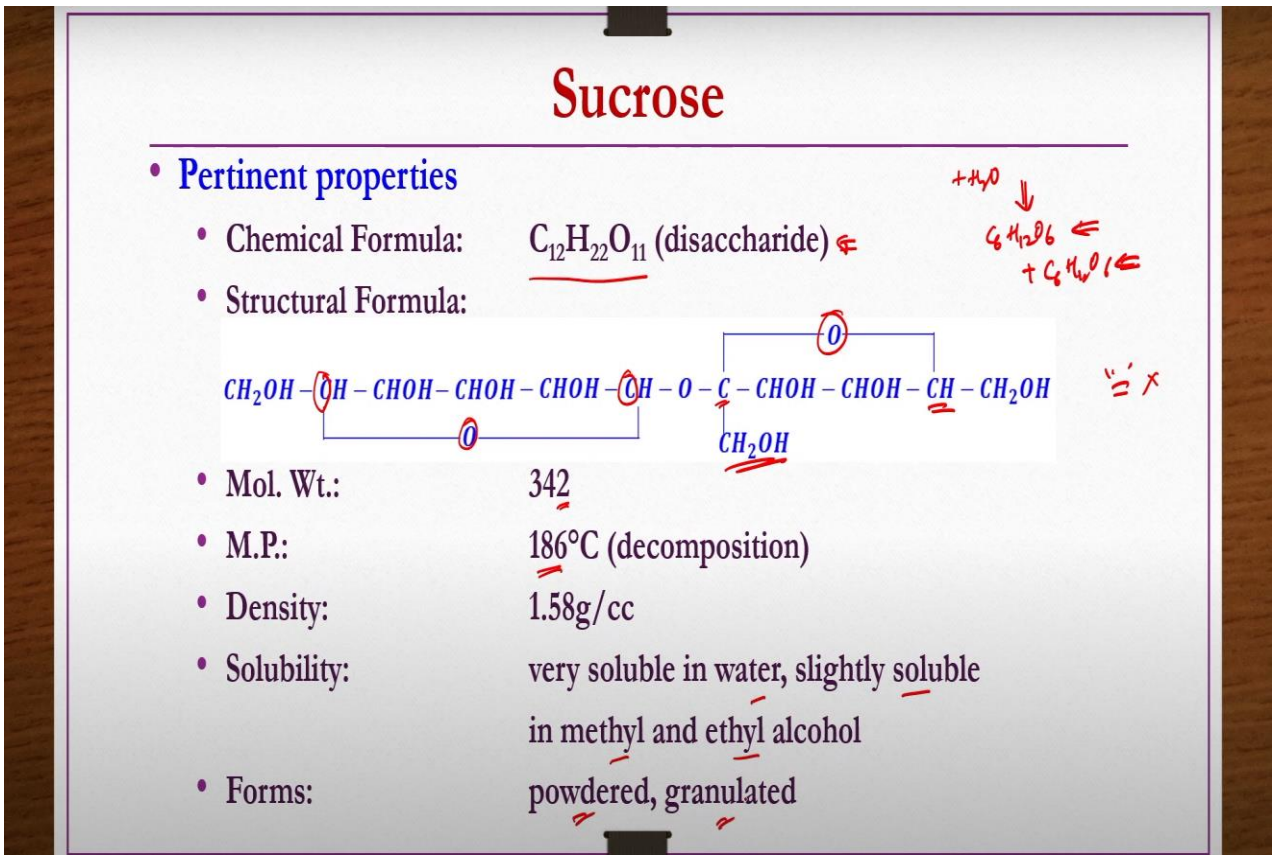

Now, we talk about the production of sucrose. However, before going into the production details, we see pertinent properties of sucrose. Chemical formula it is a disaccharide which is having formula C12H22O11. If you do not handle it properly during the extraction side or you know even sometimes after the crystallization also there is a possibility that this disaccharide may be capturing moisture to produce C6H12O6 D glucose plus C6H12O6 D fructose also, okay? So, these are the monosaccharides, this is the disaccharides, okay? So, structural formula you can see CH2OH, CH, CHOH, CHOH, CHOH, CHO, C, CHOH, CHOH, CH, CH2OH. Now, this CH and this C are being connected with O as well as this CH2OH whereas this CH, C of this CH, C of this CH is connected by this O. Now, what you can see there is no double bond at all in this one, okay? So, it is a saturated component because of that one its melting point is also very high, in fact it decomposes at 186 degrees centigrade. Molecular weight is 342, density is 1.58 gram per cc, solubility very soluble in water, slightly soluble in methyl and ethyl alcohols. Forms you can have powdered form, granulated form as well.

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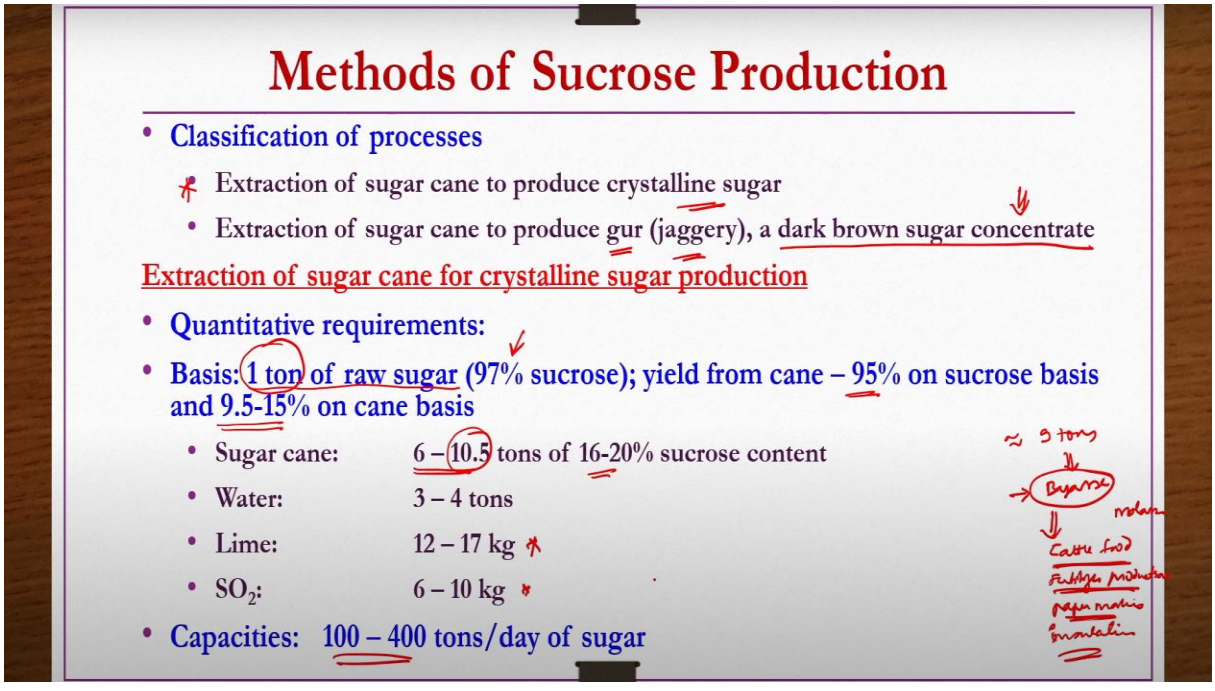

Methods of sucrose production if you see, classification of process, 2 processes are there. Extraction of sugarcane to produce crystalline sugar, then extraction of sugarcane to produce gur or jaggery which is a dark brown sugar concentrate which also includes some minerals like iron, etc., so which is more nutritious compared to the sugar. Now, we start with the first one, extraction of sugarcane for crystalline sugar production, okay? Quantitative requirements if you see, if you want to produce 1 ton of raw sugar which is having 97% sucrose that is yield from cane if you see 95% on sucrose basis and 9.5 to 15% on cane basis, then sugarcane requirement is 6 to 10.5 tons of 16 to 20% sucrose content. If you have sugarcane in which roughly 16 to 20% sucrose content is there, then if you want to produce 1 ton of sugar, you need roughly 10 tons of sugarcane.

That means, remaining roughly approximately 9 tons is coming into form of bagasse or with little bit of molasses, etc. So, now you see how much wastage is being generated if you do not utilize them as byproducts, right? That is the reason one has to find out the market for it like you know, it cannot be used as a cattle food completely. It cannot be used completely for the fertilizer production also, it is used as a fertilizer as well. So, for that purpose also it cannot be used completely. Paper making is one of the things and then insulation preparation, insulating material preparation for that purpose also these are used. So, one has to see the market for that to make this sugar industry more profitable. Water 3 to 4 tons. Lime 12 to 17 kgs, actually any impurities etc. are there colloidal dispersed one which are there present in the juice. In order to remove that one you need lime, calcium phosphate, phosphoric acid, SO2 etc. SO2 6 to 10 kgs. Capacity is 100 to 400 tons per day of sugar.

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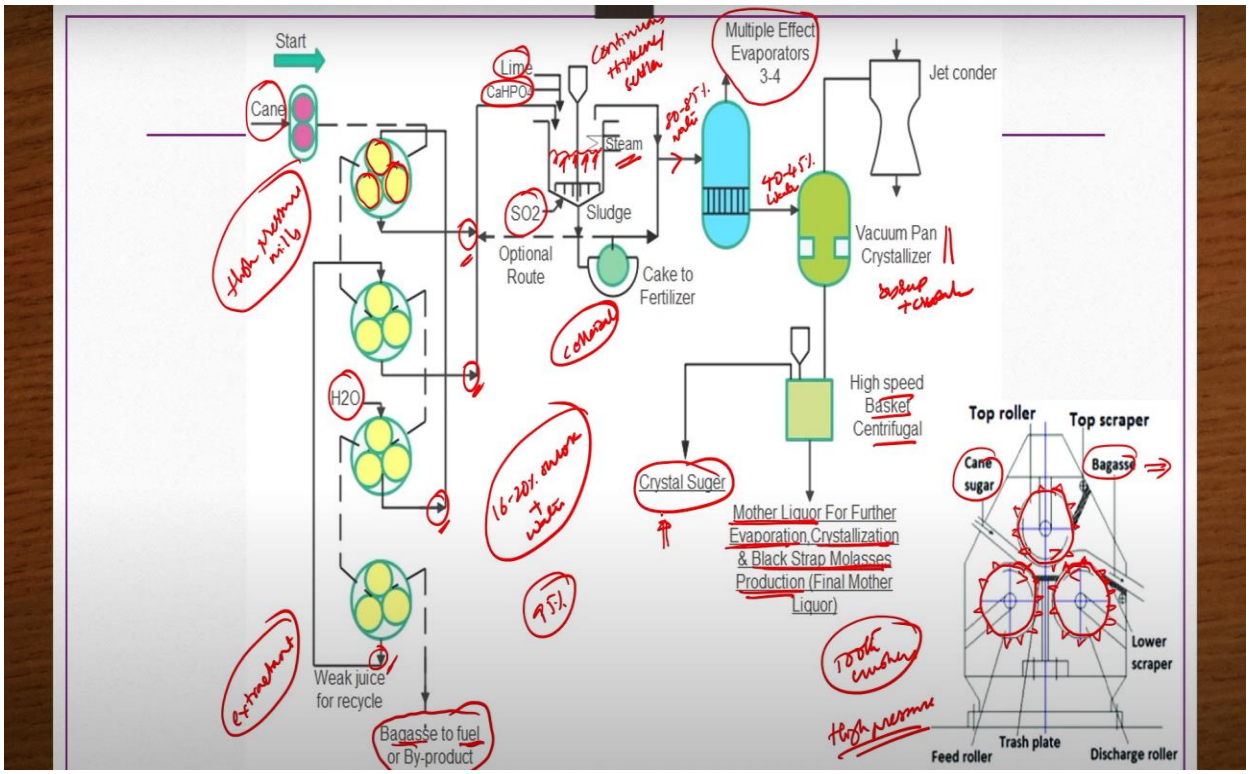

Now, this is the flowchart representing how to extract the sugarcane so that to produce crystalline sugar, okay? So, now what we have? We have cane, sugarcane we are having. We first wash it so that to remove mud and debris etc. After cleaning them, we pass through rolls or crush them or chop them into the pieces and then put them into pressure mills, high pressure mills. So, these are the high pressure mills in which 3 rolls are there. These are corrugated ones. If you highlight one of them, you can see so now this is the feeder roll here, one roll is here, there is another roll here. All these rolls are connected to the motor by shaft and then that motor rotates. So, then these rolls also rotates. These rolls actually they have corrugated surfaces like this.

It is not shown in the picture like this. On the surface of the rolls, corrugated bars would be there something like this, right? So all of them are having certain kind of bars. The distance between these rolls is small is not much, right? And this is rotating in this direction, this is rotating in this direction and then this is rotating in this direction. So, whatever the sugarcane is there that comes here and then when it traps between these rolls which are

having corrugated bars or teeths something like that. In some books, they are also known as the tooth crushers, right? So, these bars they exert high pressure, exert high pressure actually. Whenever the material is trapped between them, they experience high pressure.

These bars exert very high pressure that is the reason they are also known as the high pressure mills, right? When the sugarcane is trapped between these pressure mills that will be crushed and then you get the juice and then bagasse is taken as a discharge or wastage, okay? So, this is actually wanted to show how these pressure mills or tooth crushers look like. So for that purpose it is shown here, okay? So, how many are there? Multiple of such kind of mills are there. So, this material comes here and then being crushed here and then that material is again passed to the next pressure mills like that it continues. It continues and then finally bagasse whatever is there that is collected as a fuel to the steam boiler of the same plant or to produce the energy or as a byproduct which can have different kind of applications. So, the juice whatever is there you have to check its concentration, sucrose concentration.

You expect within the juice, you know 16 to 20% sucrose and then remaining is the water or cellulose something like that. That if you assume that approximately that much amount has been already extracted, so then that will be taken to the next level. Otherwise that weak juice along with water may be recycled to these mills again because this weak juice and then water may be acted as extractant to extract more sucrose from the cane or more juice from the cane. So, more juice is extracted, so then more sucrose will be extracted. For that purpose the recycling of weak juice or water or both are being done, right? Once you assume that sufficient extraction up to 95% of extraction of juice has already been taken place from the cane, so that juice you take to a continuous thickener.

This is nothing but continuous thickener or settler also you can say. To this one what you do? You add lime and then calcium phosphate one after other, so that whatever the impurities etc. are there, so there will be colloids are there, colloidal impurities whatever are there they will be flocculated, right? This continuous thickener there is a possibility to continuously you remove the mud from the bottom and then clear filtrate once the purification has been done that can be collected, right? To the same continuous thickener SO2 is also provided it will act as a bleaching agent as well as it will cause some kind of

bubbling action because of that one whatever the impurities etc. are there they will be flocculated to the top of the surface something like that and then they can be removed, right? And then this continuous thickener or settler operation whatever is there that is provided with the internal heating system that closed heating system is provided and then that heating is supplied by the steam that depends on the conditions. What are the optimum conditions to get effective impurity removal, okay? So, let us say the clarified liquid whatever is there you get from the continuous thickener if it is of sufficient quality or you know impurities are almost removed then that you send it to multiple effective operators.

The juice whatever is coming from here is still having 80 to 85% of water only. So, that is the reason that you pass through multiple effective operators, right? So, here what will happen the juice would be concentrated and then its content of moisture reduced to 40 to 45% even less also by the time you complete the evaporation. Evaporation what is happening here whatever the solution is coming that is being heated up so that the water is removed as a water vapour from the top and then concentrated juice as a concentrated one is collected from the bottom. That heating is done by the steam, okay? Because steam boilers are there and then fuel for that steam boilers are nothing but these baggases, okay? Now, this concentrated juice after passing through multiple effect evaporators, they will be passed through vacuum pan crystallizer where crystallization of the sugar takes place, right? Here some amount of syrup may also be there along with the crystals. So, then that is the reason they will be passed through high speed basket centrifuge so that to remove the syrup and then collect the crystal sugars.

So, whatever the final mother liquor that you are going to get from the bottom of this centrifuge that is sent further to evaporation depending on the quality or it is sent for the recrystallization tank again or if it is not having any use of redoing the evaporation or crystallization you can take it as a blackstrap molasses production, okay? So, this is about how sugar industry plant runs in general, okay?

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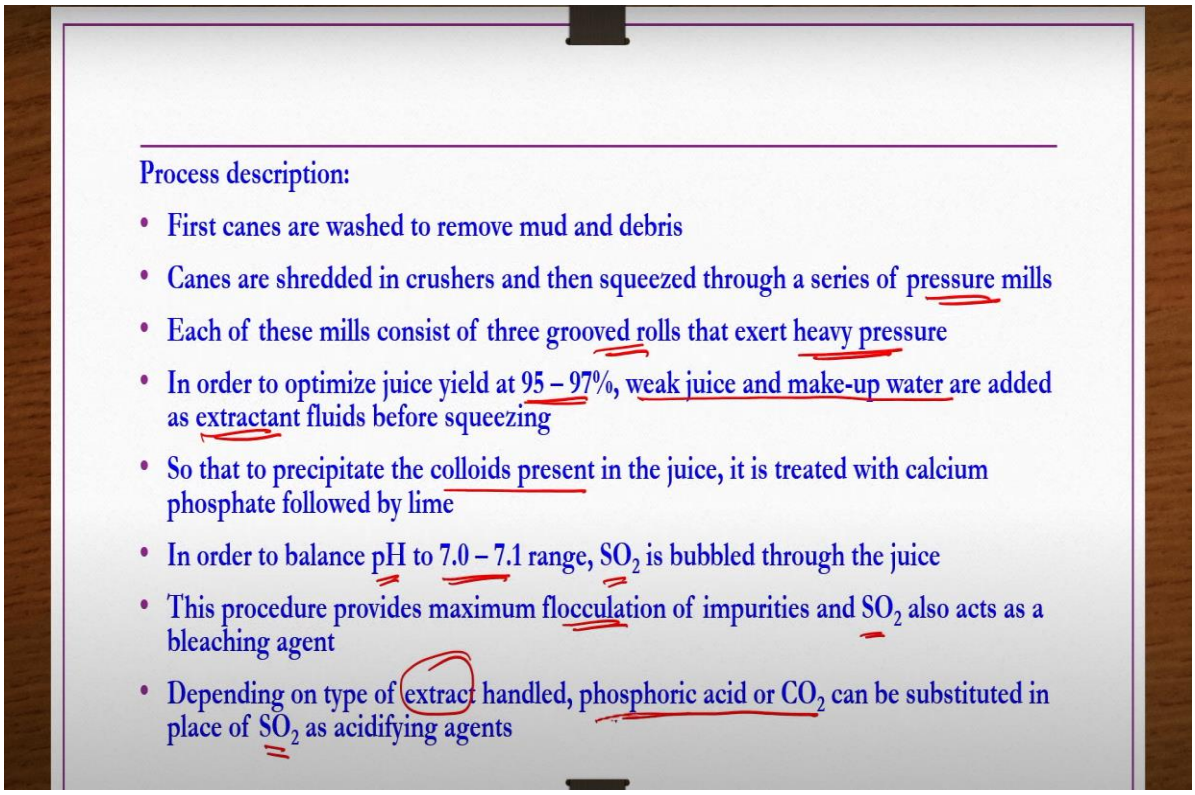

So, the steps whatever involved in the discussion of this flow sheet for the preparation of crystal sugar, those steps are provided here again for the understanding point of view. First canes are washed to remove mud and debris, etc. Canes are shredded in crushers and then squeezed through a series of pressure mills. Each of these mills consists of 3 grooved rolls that exert heavy pressure that is the reason they are known as the pressure mills. In order to optimize juice yield up to 95 to 97%, weak juice and make up water are added as extractant fluids before squeezing so that to precipitate the colloids present in the juice it is treated with calcium phosphate followed by lime.

Further in order to maintain the balance between 7 to 7.1 range, SO2 is bubbled through the juice. This procedure provides maximum flocculation of impurities and SO2 also acts as a bleaching agent. Depending on type of extract handled phosphoric acid or CO2 can be substituted in place of SO2 as acidifying agent, okay? It depends on what type of extract are you handling that is extract in the sense whatever the juice that you got, what is the

quality of the juice based on that one, you know within the continuous crystallizer you can use phosphoric acid or CO2 in place of SO2.

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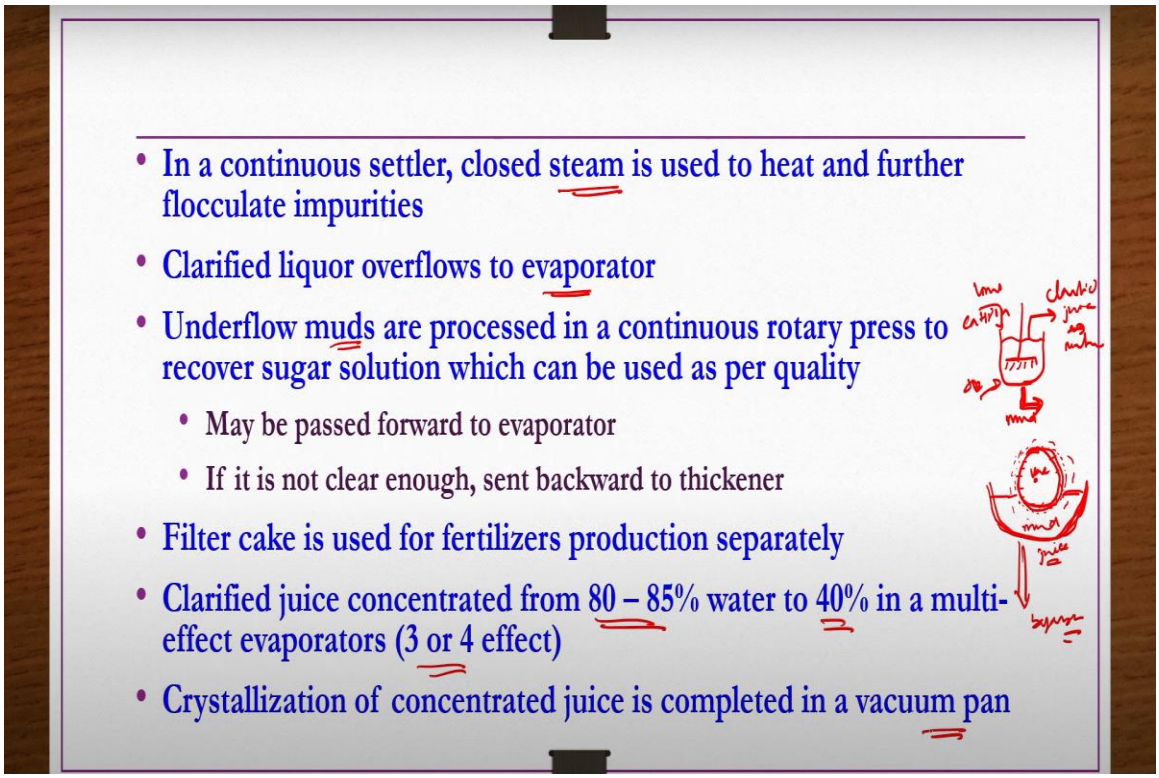

In this continuous settler, closed steam is used to heat and further flocculate impurities, clarified liquor overflows to the evaporator, underflow muds or whatever are there, they are processed in a continuous rotary press to recover sugar solution which can be used as per quality. In the flow chart at the bottom of the, you know, at the bottom of the continuous settler there is a provision for collection of mud after getting this clear liquid, after removing clear liquid or clarified juice is sent to the multiple effective operator that is what we have seen. At the bottom or from the bottom of this continuous settler or thickener you can get the mud that would be processed through a rotary drum filter. Rotary drum filter you have a drum which is actually perforated one, perforated drum is there. To this drum you can have or this drum is covered with a filter cloth and this drum is inserted in a container in which whichever the material that you are going to filter it. Now here in this

case this mud is there, right? And then at the center of the drum you apply vacuum or through the interior of the drum you apply the vacuum.

So then what happens in the mud if it has still, you know, juice is there which is of high quality or required quality that would be sucked in and then collected as a filtrate whereas the mud whatever is there that is taken as a wastage or as a kind of a, you know, baggases, impurities, etc. This juice that you collect through the interior of the rotary drum by applying the vacuum, you check its quality. If its quality is good enough, then you can send it to the triple effect or multiple effective operators for the further concentration or otherwise it can be sent back to the continuous thickener. This recovered sugar solution whatever is there that may be passed forward to the evaporator if it is having sufficient concentration to be further concentrated in a evaporator. Otherwise, if it is not clear enough, then it is sent back to the thickener so that more extraction process or more recovery of the sugar solution may be taking place.

Filter cake that is formed on the surface of the drum that is used for fertilizers production separately. Clarified juice concentrated which is from the continuous thickener is still having 80 to 85% of water and then that would be reduced to 40% in multiple effect

evaporators. You can use 3 or 4 effect evaporators in general. Crystallization of concentrated juice is completed by a vacuum pan crystallizer, okay?

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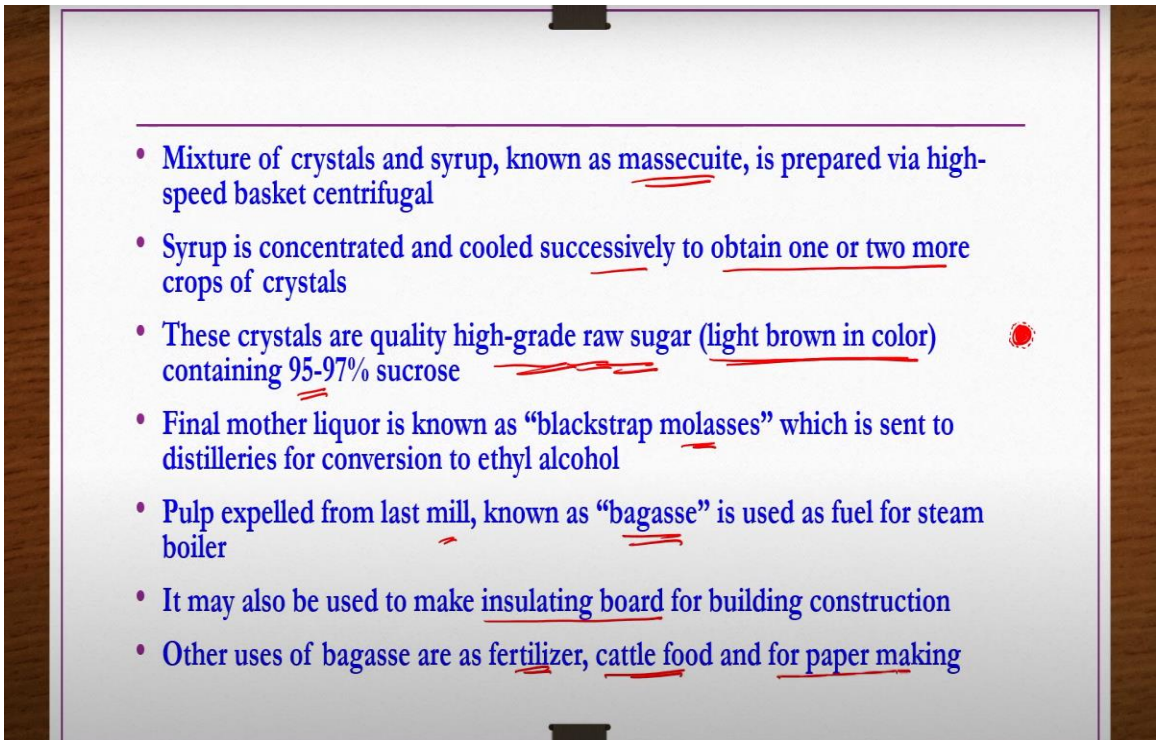

Mixture of crystals and syrup known as massecuite is prepared by a high speed basket centrifugal so that to remove if at all syrup is still there along with the crystals. So that recovered syrup is concentrated and cooled successively to obtain 1 or 2 or more crops of crystals. These crystals are quality high grade raw sugar. In some plants, you may get the refined sugar. Here probably maybe you may be getting raw sugar. Raw sugar is nothing but which is in light brown in color. Why this light brown in color is there? Because these sugar crystals whatever are there, they may be covered with a layer of molasses. Because of the layering by the molasses, the sugar looks little brown and then it need to be refined if you wanted to have refined sugar that we are going to discuss in the next class.

However, this high grade raw sugar though it is raw sugar, it contains 95 to 97% sucrose. Final mother liquor is known as blackstrap molasses which is sent to distilleries for conversion to ethyl alcohol or maybe sent to the fermentation industries to recover more

products from it. Pulp expelled from last mill is known as the bagasse. It is used as fuel for the steam boiler within the plant itself or as a solid fuel it is used in general. It may also be used to make insulating board for building constructions.It is having other applications like as fertilizers, cattle, food and for paper making. So, this is all about the production of sugar in sugar industries.

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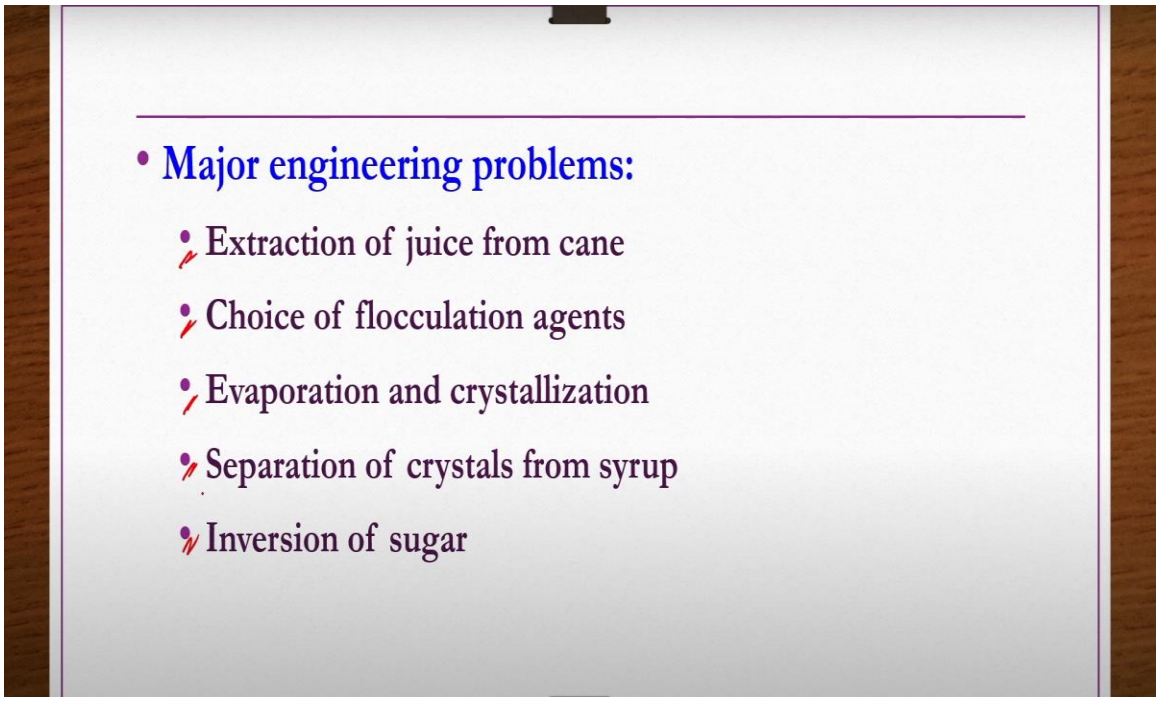

Now, we have to list out what are the major engineering problems. First important step is the extraction. If you are not able to extract juice as much as possible, it is not going to be economical or process is not going to be economical. You have to extract as maximum as possible, not as much as possible, as maximum as possible and then extraction is expected to be up to 95 to 97% at least. Then after the extraction continuous thickener is there. So, in that one you are using different types of agents, flocculating agents, etc. are used. What kind of agents one should use something like that and then after that evaporation is there.

If evaporation is not proper, then subsequent crystallization will also be a problem, right? So, evaporation, crystallization and then inversion also if you do not handle it properly, store it properly, then this disaccharide sucrose may be inverted to the monosaccharide, D-

glucose, D-fractose, etc. So, these many issues are there. So, one has to give some attention to handle such kind of problems as well. So, we are going to discuss such major engineering problems associated with sugar industries now. Major engineering problems associated with the sugar industries, extraction of juice from cane, choice of flocculation agents, evaporation and crystallization, separation of crystals from syrup, inversion of sugar. So, we see individual of these points and then what are the important things to be considered in this one.

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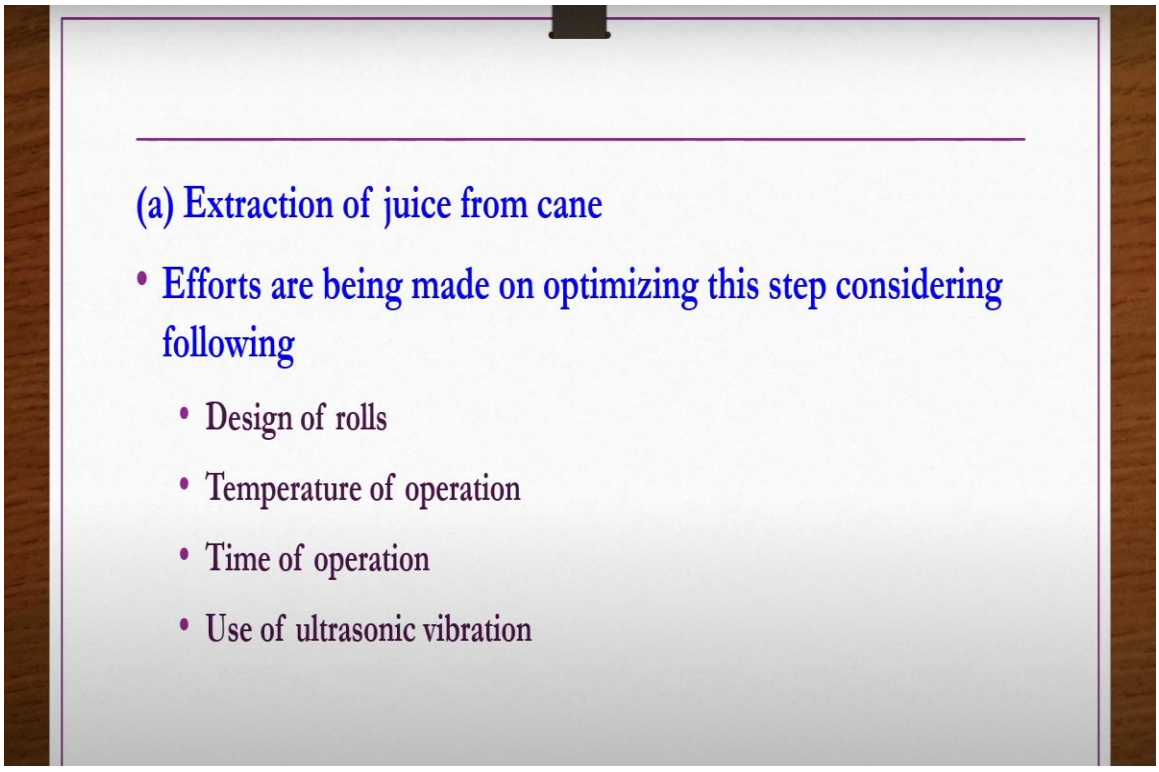

So, let us say extraction of juice. Here, efforts are being made on optimizing this step considering the following steps, primarily the design of rolls, the size of the rolls, then the corrugated bars, their size, at what distance they are placed on the rolls, etc. What should be the pressure that roll should be exerting on the canes, all those things are coming under design calculations of pressure mills, right? So, design of pressure mills is one essential thing. Then at what temperature you want to do the extraction of the juice from the sugar cane, for how many hours or what is the duration of the extraction, all these things should

be considered, right? Then use of ultrasonic vibration is also one of the option people try to improve for extraction of juice from the cane, okay?

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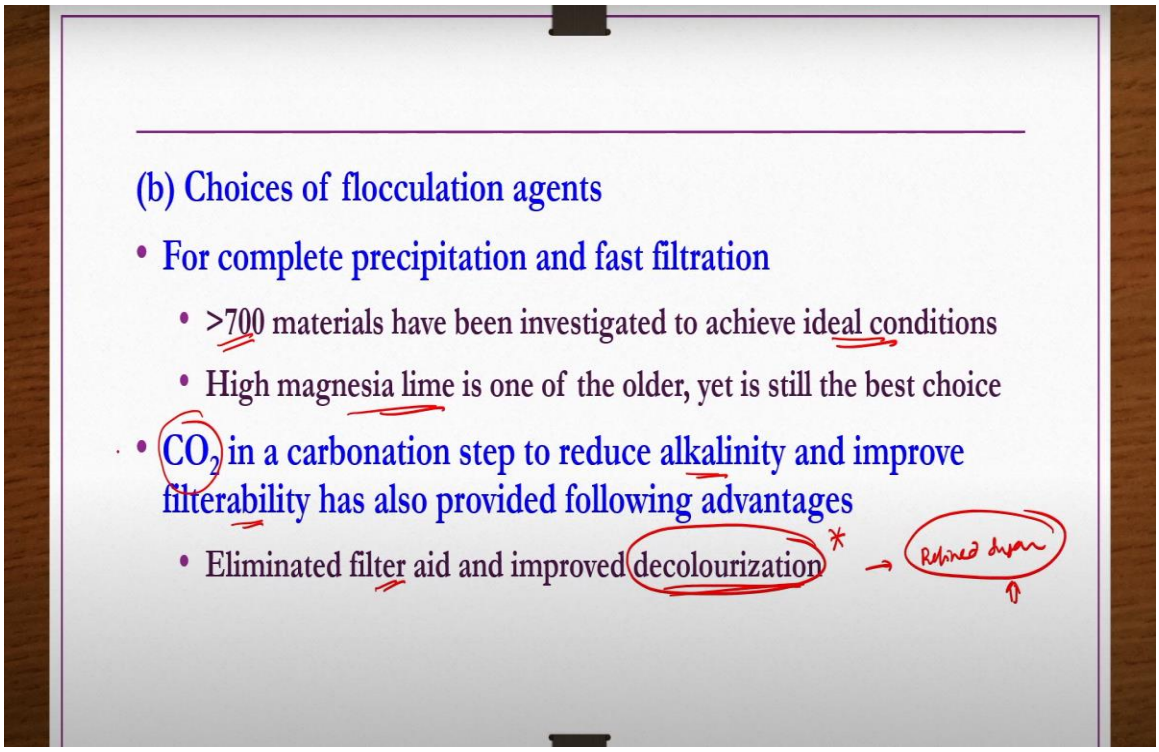

Then next one is choices of flocculation agents. For complete precipitation and fast filtration in this process, more than 700 materials have been investigated to achieve ideal conditions, not one or two or one or two dozens or something like that, more than 700 materials have been investigated, out of which high magnesia lime is still found to be the best one even today. Further, CO2 in a carbonation step to reduce alkalinity and improve filterability has also provided several advantages. What are they? Eliminated the requirement of filter aid, improved the decolorization. In the refined sugar making, we are going to see this refined sugar making in next class where decolorization is one of the important things. So, if you are able to do the decolorization during the production of raw sugar itself, so the load on the refined sugar plant is going to be reduced or refined sugar

production steps the load would be reduced, okay? So, that is achievable if you are using CO2 in carbonation step to produce alkalinity and improve filterability.

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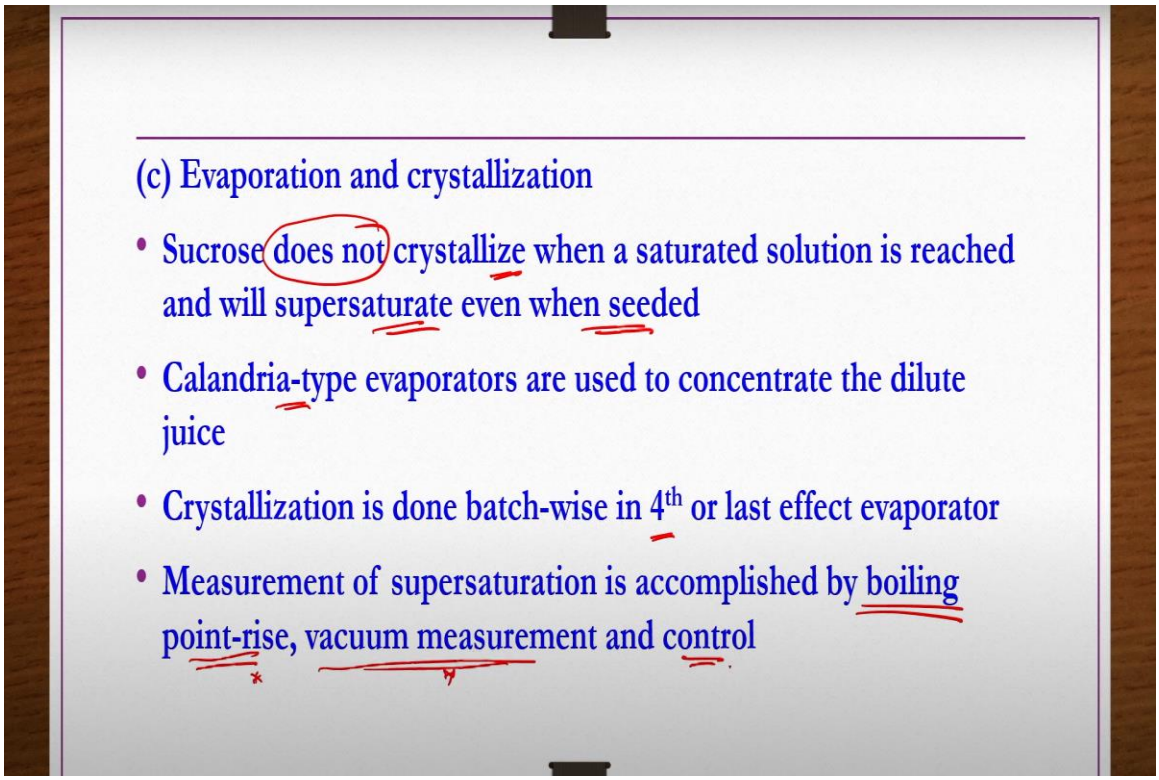

Third problem is evaporation and crystallization. Sucrose does not crystallize when a saturated solution is reached and will super saturate even when seeded, right? So, because of that one, calandria type evaporators are used to concentrate the dilute juice. How these vacuum pan evaporators, etc., operate, those things also we are going to see, then you can understand what are these calandria type evaporators, etc., maybe in the next class we will discuss about it. Crystallization is done batch wise in fourth or last effect evaporator. Measurement of super saturation is accomplished by boiling point rise, vacuum measurement and by control. How do you measure the super saturation? For that purpose, these things are important, okay?

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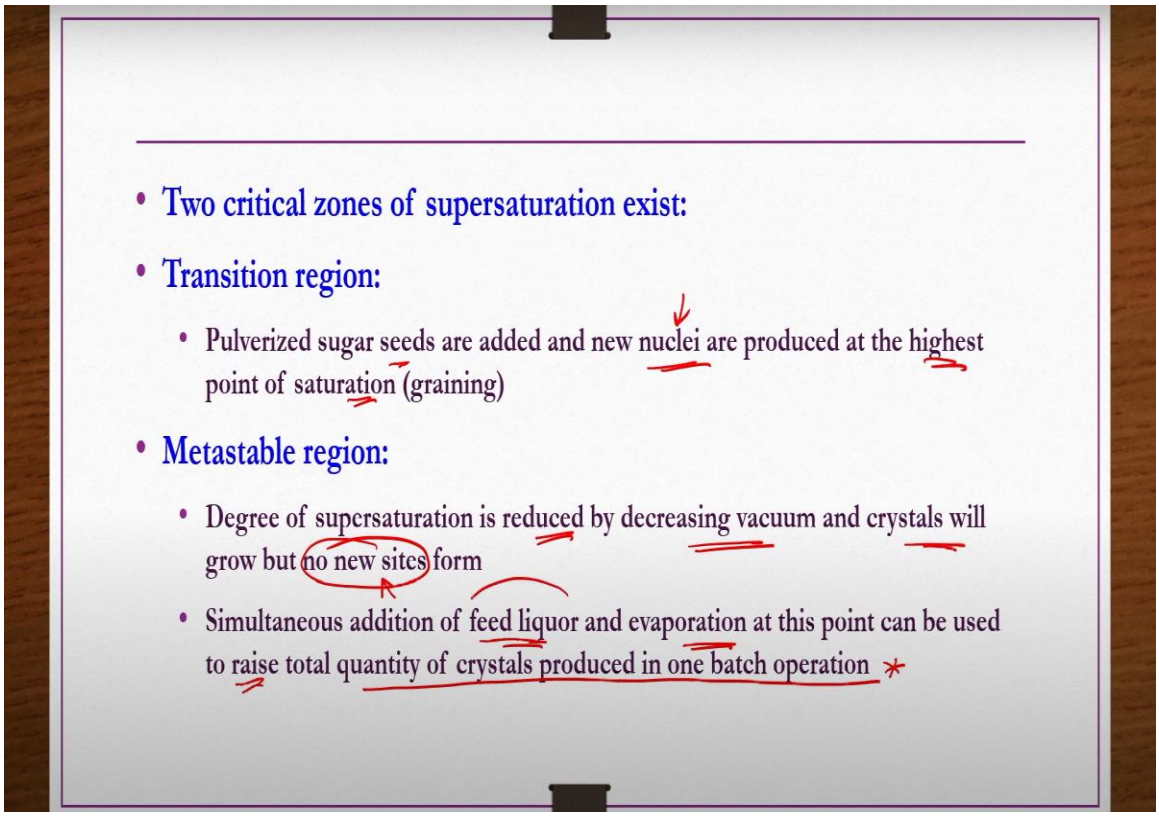

Now, in this one, 2 critical zones are possible that is 2 critical zones of super saturation exist. The first one is the transition zone where pulverized sugar seeds are added and new nuclei are produced at the highest point of saturation which is known as the graining, okay? Other one is the metastable region in which degree of super saturation is reduced by decreasing vacuum and crystals will grow, but no new sites form. Here new nuclei is forming here, but new sites are not forming, okay? Simultaneous addition of feed liquor and evaporation at this point can be used to raise the total quantity of crystals produced in one batch operation. This is very much addition because of this thing addition or the feed liquor is added, okay?

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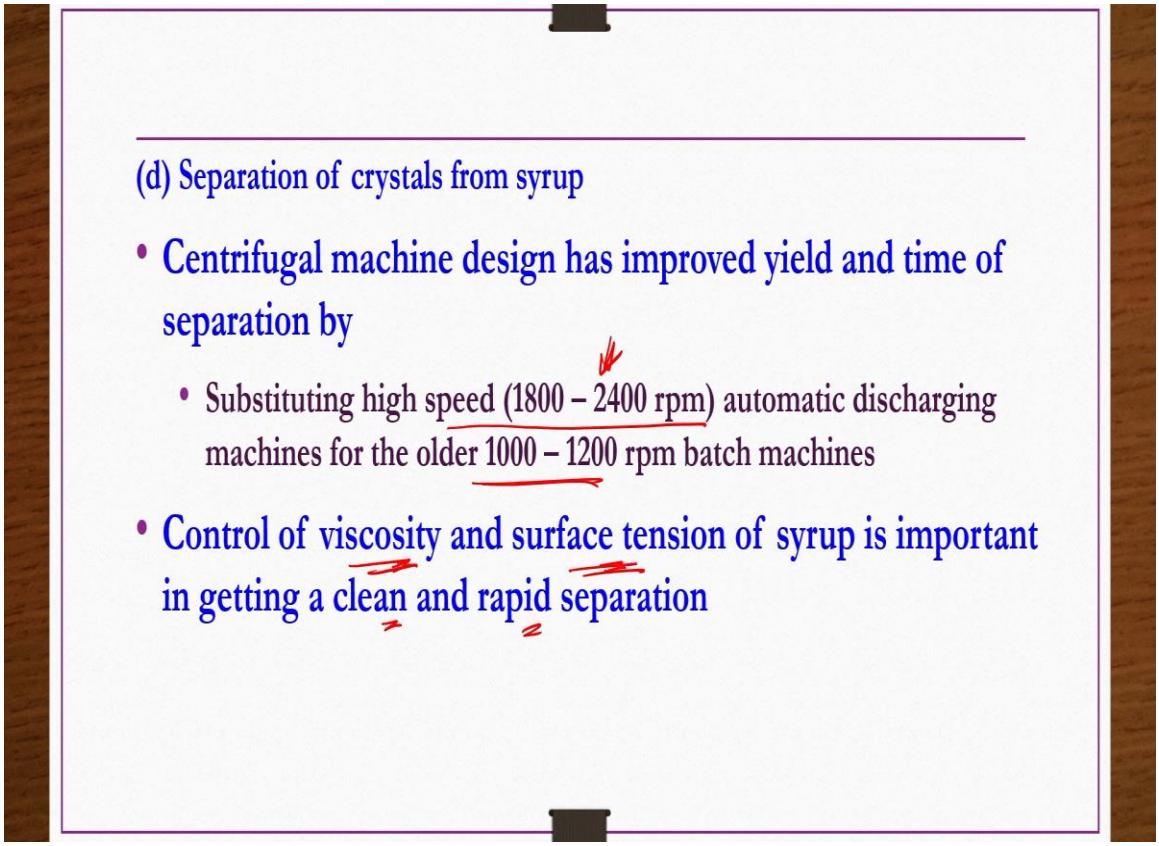

Separation of crystals from syrup, if you are not recovering the syrup solution properly from the crystals, then what is going to happen over the period of time after a few days or maybe few weeks rather having the crystalline sugar, you may be having the syrup juice in the cans. That is the reason separation of crystals from syrup is very much essential. Centrifugal machine design has improved yield and time of separation by substituting high speed automatic discharging machines for the older ones. Older ones are having only 1000 to 1200 RPM batch machines. Nowadays, we are having continuous centrifugal machines operating at 1800 to 2400 RPM. In this process, control of viscosity and surface tension of syrup is important so that to get a clean and then rapid separation, what is that value of

viscosity, what is that value of surface tension one has to keep measuring and then required one has to be controlled.

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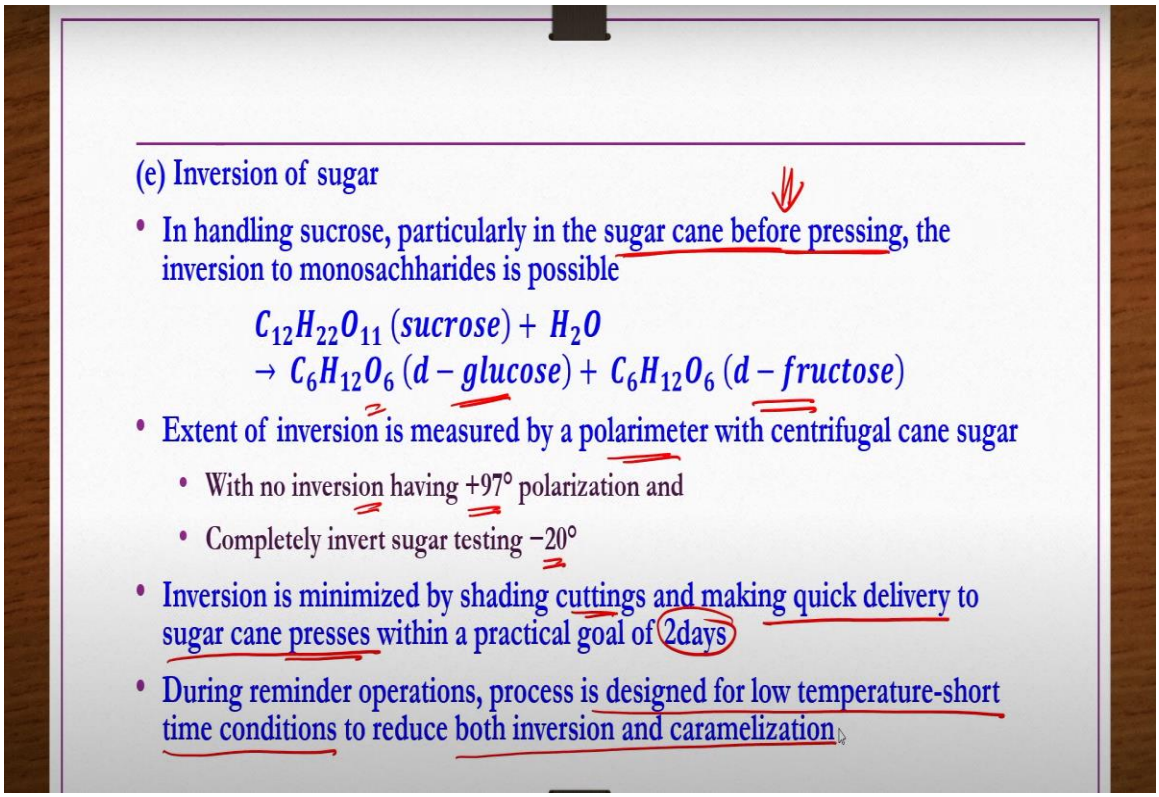

Finally, inversion of sugar is the last engineering problem. In handling sucrose especially in the sugarcane before pressing itself, the inversion to monosaccharide is possible. If you do not use the sugarcane at the earliest possible time in the sugar industry to produce the sugar, what will happen? This disaccharide sucrose or sugar which is present in the sugarcane that may be undergoing inversion reaction to produce monosaccharides D-glucose or D-fructose which we do not want. Extent of inversion is measured by a polarimeter with centrifugal cane sugar with no inversion. If there is no inversion taking place, then it will be having plus 97 degrees polarization that is to the right. If completely inversion has taken place, then polarization angle would be minus 20 degrees that is to the left.

Inversion is minimized by shading cuttings and making quick delivery to sugarcane process within a practical goal of 2 days. Within 2 days, the sugarcane once they are cut from the sugar cultivating field within 2 days, they should be sent to the high pressure mills so that to extract the sugar in disaccharide form otherwise inversion of the disaccharides may take place and then you may be producing glucose and fructose rather producing the sucrose. During remainder operations, process is designed for low temperature, short time conditions to reduce both inversion and caramelization.

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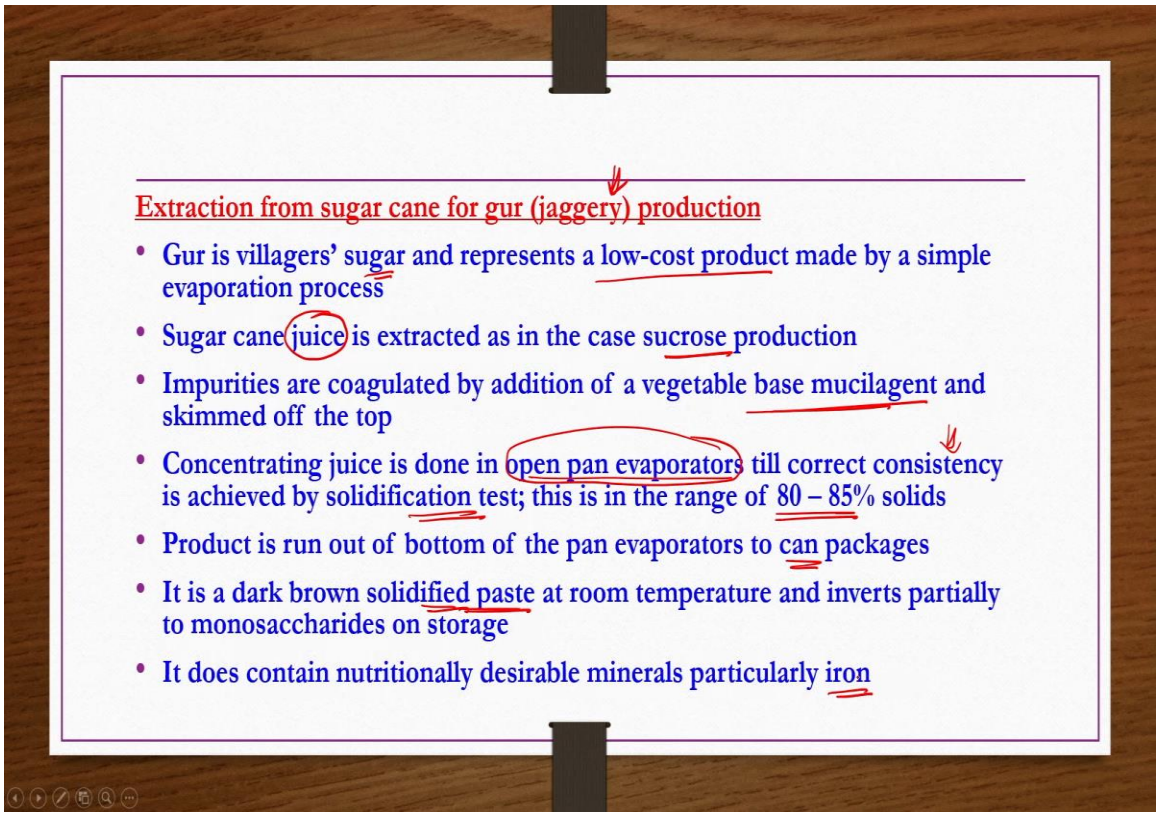

Next is extraction from sugarcane for gur or jaggery production. Gur is villages sugar and represents a low cost product made by a simple evaporation process.This is having nutrients like iron, etc. So, then it is more energy full compared to the sugar or it is more useful or good for health compared to the sugar. Sugarcane juice is extracted as in the case of sucrose production as well. The production or extraction of the juice up to the step it is seen. After that impurities are coagulated by addition of vegetable based mucilagent and skimmed off the top. Once removing the impurities has already been done, then

concentrating of the juice is done in open pan evaporators until the correct consistency is achieved by solidification test.

This is in the range of 80 to 85% solids. What do you mean by correct consistency is achieved by the solidification in some kind of solvent? These are being the concentrated juice has been released so that to check whether how it is dispersing if it is not dispersing quickly that means it is solidified like that. Product is run out of bottom of the pan evaporators to can packages. It is a dark brown solidified paste at room temperature and inverts partially to monosaccharides on storage. It does contain nutritionally desirable minerals particularly iron. So, it is good for the health.

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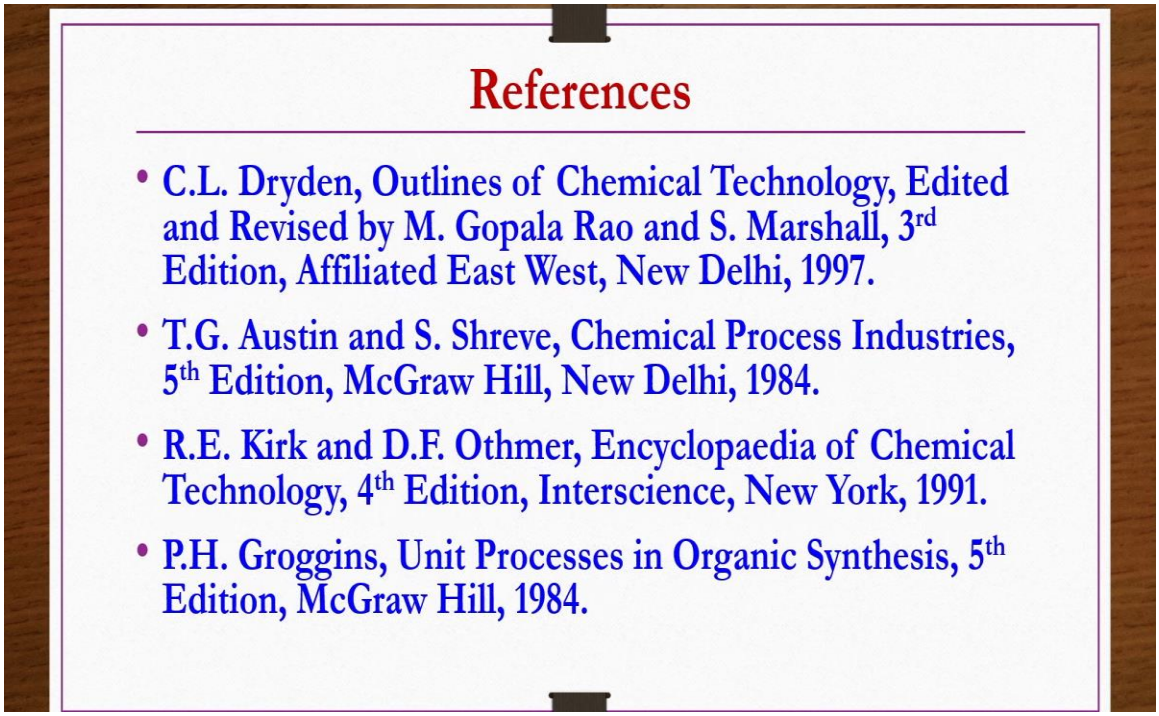

References for today's lecture are provided here. Outlines of Chemical Technology by Dryden edited and revised by Gopala rao and Marshall third edition. Chemical Process Industries by Austin and Shreve fifth edition. Encyclopedia of Chemical Technology, Kirk and Othmer fourth edition. Unit processes in organic synthesis by Groggins fifth edition. Thank you.