Waste to energy conversion
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Lecture – 33
Tutorial on Fermentation

Good morning, now we will start discussion on a new module tutorial on fermentation. In the previous modules on fermentation we have discussed methanol synthesis in different types of micro organisms and different types of sugars particularly pentose and hexose sugars and how they are converted to ethanol.

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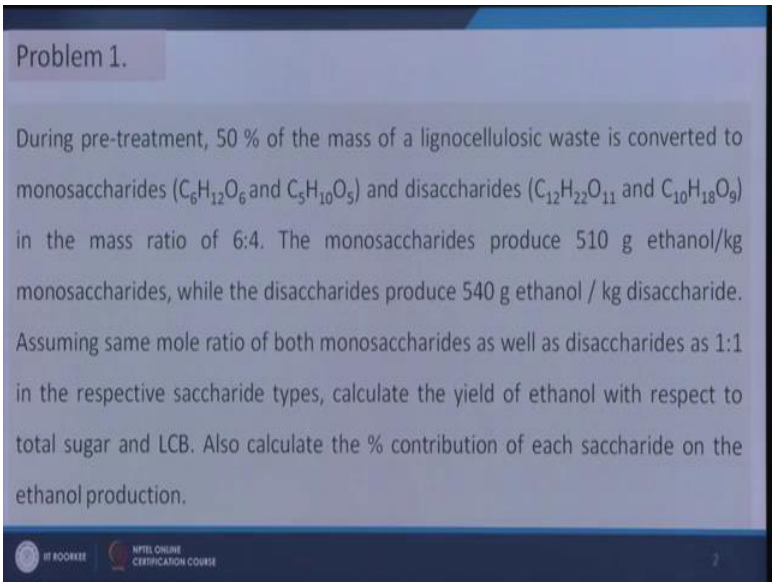

In this module, we will solve some numerical problems and the statement of the first problem is during the pre treatment 50 percent of the mass of a lignocellulosic waste is converted to monosaccharides that is C6H12O6 and C5H10O5 and disaccharides C12H22O11 and C10H18O9 in the mass ratio of 6 is to 4 the monosaccharides produce 510 gram ethanol per kg monosaccharides while the disaccharides produce 540 gram ethanol per kg disaccharide assume same mole ratio of both monosaccharides as well as disaccharides as one is to one in the respective saccharide types calculate the yield of ethanol with respect to total sugar and lignocellulosic biomass also calculate the percentage contribution of each saccharide on the ethanol production. So, this is the statement on the basis of which we have to solve it.

We have to calculate the yield of ethanol with respect to sugar and lignocellulosic biomass, as well as we have to find out the individual contributions of these monosaccharides and disaccharides towards ethanol production.

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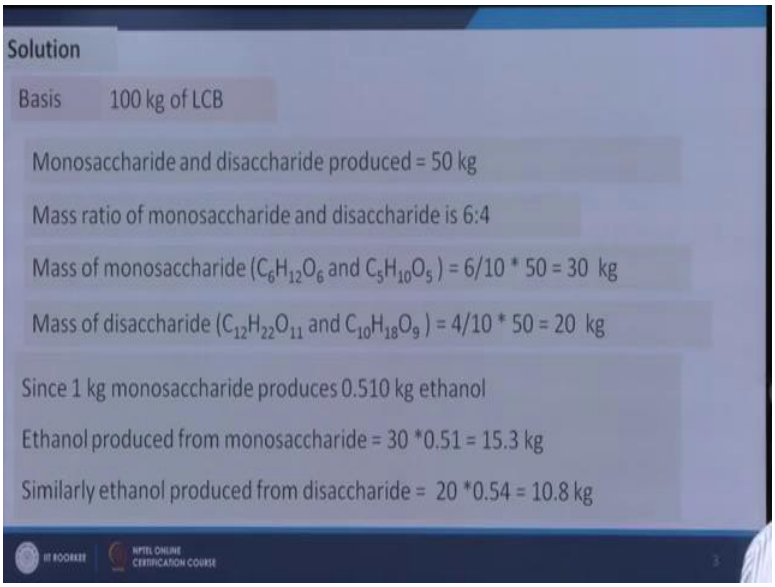

So, to solve these; what we will do we will take one basis first say 100 kg of LCB is our basis. So, if lignocellulosic biomass we have 100 kg. So, what is the conversion that is 50 percent of mass of lignocellulosic waste is converted to monosaccharide and disaccharides.

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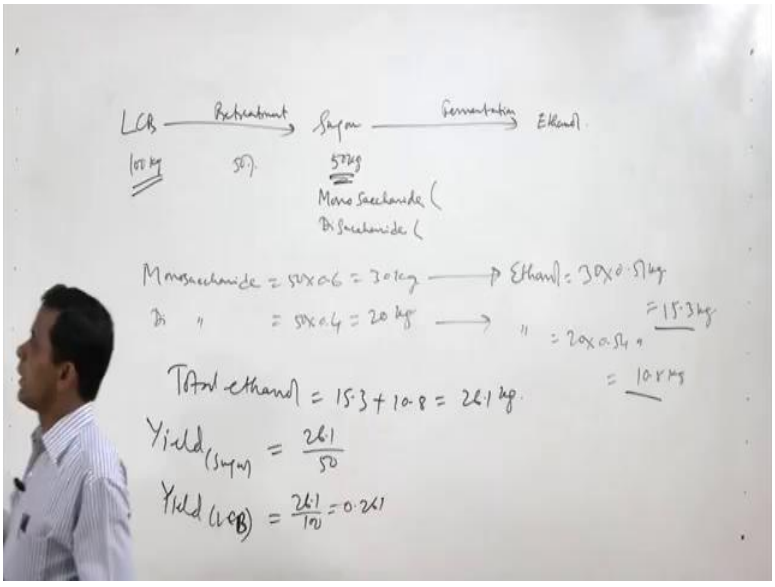

So, we have 1 LCB. So, we have pre treatment we are getting sugar we have fermentation it is giving ethanol. So, this is the process now we have 100 kg we will get 50 kg here 50 percent conversion and then we will see how much we are getting, now the sugar which we are getting we are getting monosaccharide as well as disaccharide. So, how much it is? 6 is to 4; the ratio is 6 is to 4, 6 monosaccharide and 4 disaccharide. So, 50 kg we are getting. So, how much monosaccharide is equal to 50 into 0.630 kg and disaccharide that is equal to 50 into 0.4 that is equal to 20 kg. So, 30 and 20 kg monosaccharide and disaccharides are produced then for the first part it is very easy because this is 510, it is 510 gram is produced from one kg of the monosaccharide. So, this will give us ethanol is equal to how much 0.51 kg into 30. So, 30 into 0.51 kg and this will give us ethanol is equal to 20 into 0.54 kg. So, in this case we are getting is equal to 15.3 and 10.8. So, 15.3 and 10.8, so total ethanol which we are getting in this case. So, total ethanol we are getting this plus this. So, how much it is it is coming equal to 26.1 kg.

So total ethanol 15.3 plus 10.8. So, 26.1 kg, first part is over, now we have to solve the second part then we will go to ethanol yield. So, what will be the yield we. So, we are getting this 26.1 kg of ethanol and what was our substrate if we want to get the yield with respect to sugar.

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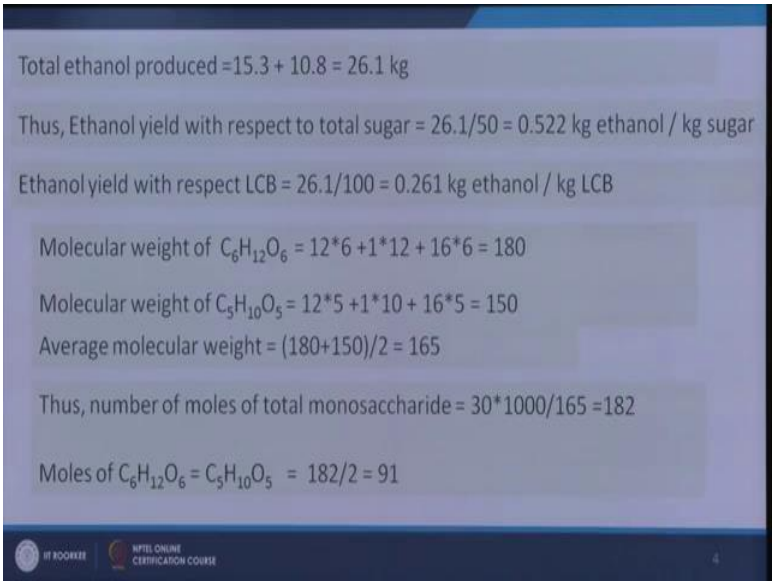

So, our 50 kg is our sugar and one 100 kg is our LCB. So, yield is equal to with respect to sugar that is equal to 26.1 divided by 50; 26.1 divided by 50 that is 0.522 kg ethanol per kg sugar, but with respect to your LCB yield, LCB lignocellulosic biomass that is equal to 26.1 divided by 100: 0.261 kg ethanol by kg LCB. So, these we are getting. So, this is the first part actually this over the second part we have to see the individual contribution of the different sugars present in the mixture on the ethanol production. So, we have 2 sugars monosaccharides and 2 disaccharides.

So, 2 monosaccharides we have C6H12O6 and C5H10O5 what is the condition one is to one molar ratio. So, we have to see how much mole average moles are present in monosaccharide. So, monosaccharides how much you have got monosaccharide is equal to 30 kg. So, molecular weight of these 2 glucose and xylose we will we will see the glucose molecular weight is equal to C6H12O6 whose 12 into 6 plus 1 into 12 plus 16 into 6. So, 180 and similarly for molecular weight of xylose C5H10O5 that is 12 into 5 plus 1 into 10 plus 6 into 5. So, 150, so this is 150 and 180, as mole ratio is one is to one present in the solution. So, average molecular weight will be 180 plus 150 divided by 2 1 is to 1 mole ratio. So, that is equal to 165. So, the number of moles of total monosaccharide is equal to how much we have 30 kg into one thousand this will be gram divided by 165 average molecular weight that is gram; so 165.

So, 182; 182 moles of monosaccharide are present in the solution 182 moles of monosaccharides are present in the solution then what will be the moles of C6H12O6 and C2C5H10O5 1 is to 1. So, divided by 2; 182 divided by 2; 91. So, 91 moles of is here glucose and 91 moles of xylose we are getting then what will be the mass of glucose molecular weight of glucose into moles that is 91 moles into 180 gram divided by 1000.

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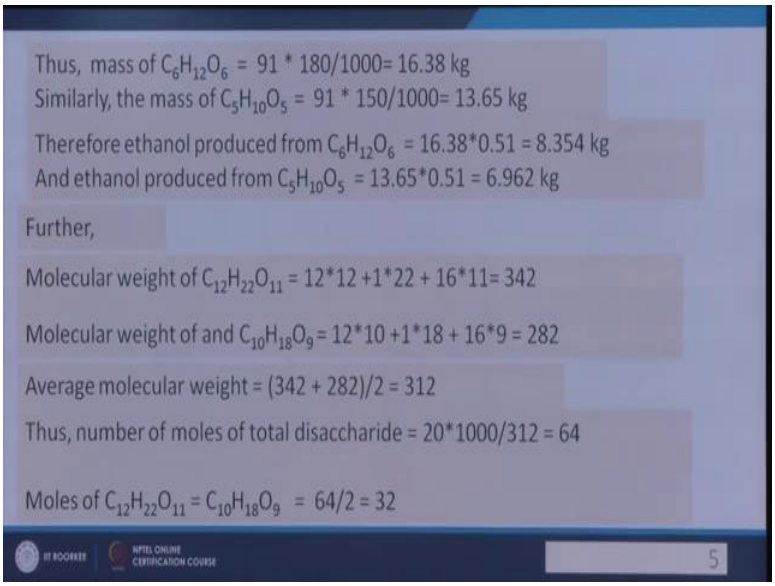

So, 16.38 kg, this is the mass of glucose present in the solution or that is that is produced after pretreatment after pretreatment we are getting this much of 16.38 kg of glucose and after pretreatment we are getting xylose as C5H10O5 that is equal to 91 into 150 divided by 1000. So, that is equal to 13.65 kg. So, these 2 sugars mono saccharides, we are getting then we will see the ethanol production. So, ethanol productions from these C6H12O6 will be 16.38 kg into point 5 one as it is given that 510 gram ethanol is produced per kg of the monosaccharides similarly first this also xylose also 30.65 into 0.51. So, it is becoming 6.962 kg.

So, these 2 different amount of alcohol is produced by 2 different monosaccharides similarly for disaccharide you will at first calculate the molecular weight. So, we have C12H22O11. So, 12 into 12 plus 22 into 1 plus 16 into 11, that is it is becoming 342 and the molecular weight of not and the molecular weight of C10H18O9 that is equal to 12 into 10 plus 1 into 18 plus 16 into 9. So, 282, again here the mole ratio is one is to one. So, average molecular weight in this case will be 342 plus 282 divided by 2 that is 312. So, how many moles we have only 20 kg. So, 20 kg into one thousand divided by 312 that is equal to 64 moles now.

So, how many moles of this cellobiose, and how many of these xylobiose? So, we will have to divided 64 by 2 because one is to 1 mole ratio. So, 64 by 2 that is equal to 32 both of these 2 disaccharides are having 32 moles each.

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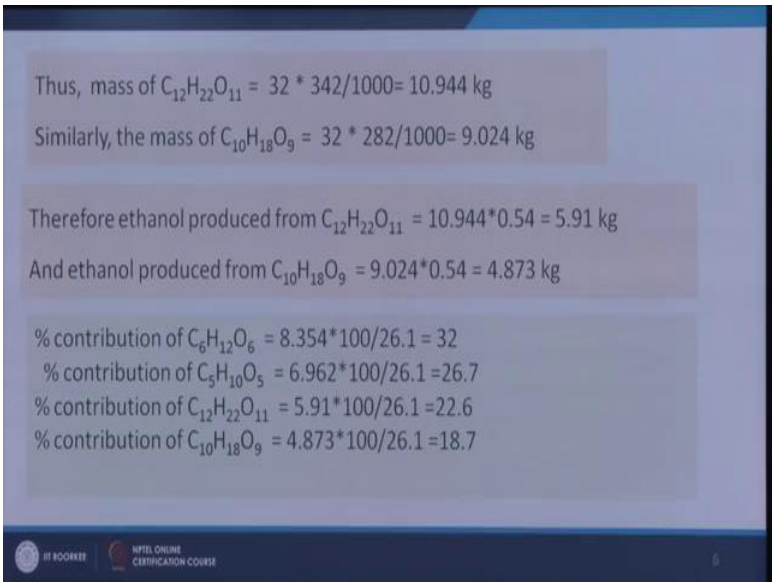

So, what will be the amount of this these one C12H22O11 cellobiose and xylobiose. So, 32 into 342 divided by one thousand. So, that is equal to 10.944 kg and for the xylobiose this is equal to 32 that is moles into molecular weight of xylobiose 282 divided by 1000 that is gram to kg conversion. So, 9.024, so this is the kg, now you see we have got 4 different saccharides 2 monosaccharides 2 disaccharides and these different saccharides produced different amount of alcohol. So, here this is the cellobiose production. So, the ethanol from the cellobiose will be 10.944 into 0.54. So, that is equal to 5.91 kg and similarly for xylobiose is equal to 9.024 into 0.54. So, that is equal to 4.873 kg. So, these are different amount of ethanol produced by these 2 disaccharides.

So, on percentage contribution basis C6H12O6 is giving us 8.3 how much it is giving it is giving us.

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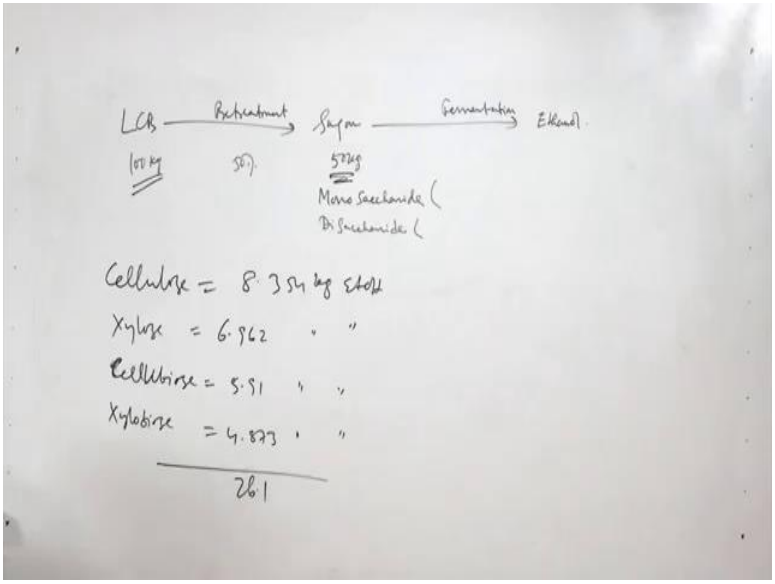

So, 8.354 kg and this is so cellulose giving 8.354 kg ethanol and xylose it is giving us 6.962; 6.962 kg ethanol and then cellobiose it is giving us this much of 5.91 kg 5.91 kg ethanol and xylosebiose it is giving us 4.873 kg, 4.873 kg of ethanol then will sum it of will get the total of this and then we will get the percentage of it.

So, the total is 26.1. So, in this case the contribution percentage contribution of glucose that is equal to 8.354 divided by 26.1. So, 8.354 divided by 26.1 into 100 xylose 6.962 divided by 26.1 onto 100 for these 5.91 by 26.1 into 100 and for xylobiose 4.873 by 26.1 into 100. So, we are getting the percentage. So, this is the percentage contribution of different sugars for the production of ethanol in this mixture.

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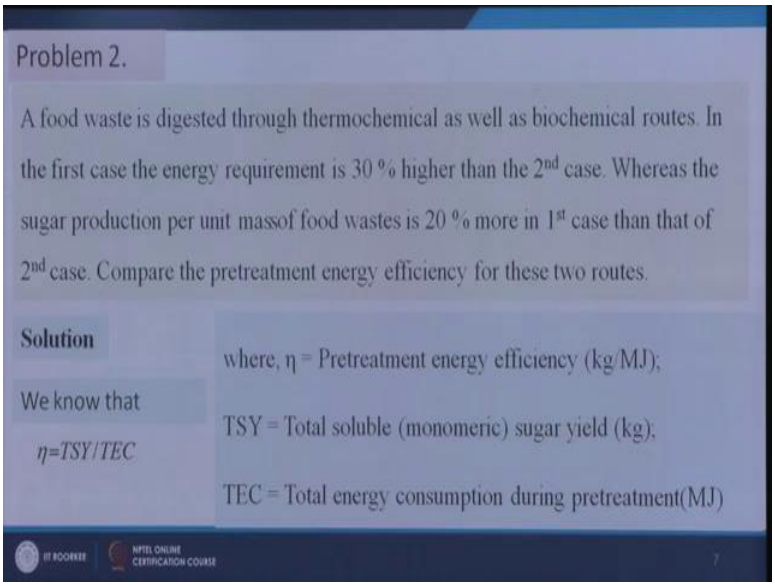

Next we will see the problem number 2. So, the statement is a food waste is digested through thermo chemical as well as biochemical routes in the first case the energy requirement is 30 percent higher than the second case whereas, the sugar production per unit mass of food waste is 20 percent more in first case than that of second case now we have to compare the compare the pretreatment energy efficiency for the 2 routes. So, what is the case in this in this case what is the situation we are delivery some pretreatment. So, we have some waste organic waste organic food wastage.

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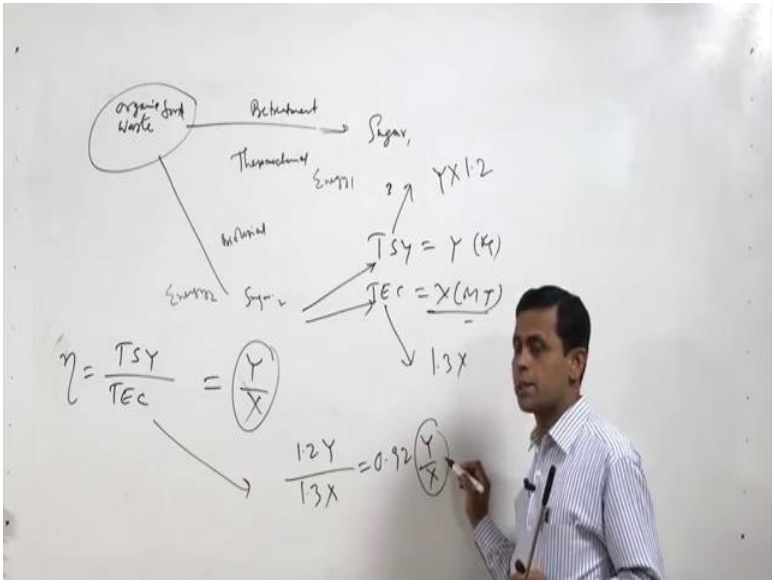

So, this food waste we are pre treating. So, pretreatment will give us sugar that will give us a sugar. So, we are following 2 routes thermo chemicals thermal and another is biological again we will get sugar and we need some energy here we will be recovering some energy one we will be recovering some energy here also energy 2 and we will be getting sugar one will be will be getting sugar 2. So, different sugar we will get now we have to calculate the energy efficiency. So, what is the definition of energy efficiency that is equal to energy efficiency is equal to as written here TSY by TEC; TSY by TEC, what is TSY and TEC? Total sugar yield divided by total energy consumption during pretreatment. So, TEC total energy consumption and total soluble sugar yield that is TSY. So, I have given here.

So, this is the pretreatment energy efficiency now for the first case say TSY is equal to Y that is sugar yield is equal to say Y, we are considering and X M mega joule is TEC is equal to X mega joule and this is equal to say kg is equal to kg, now the condition is that the first route fast route uses 320 percent, the first route uses 30 percent more energy and also produces 20 percent more sugar these are the conditions.

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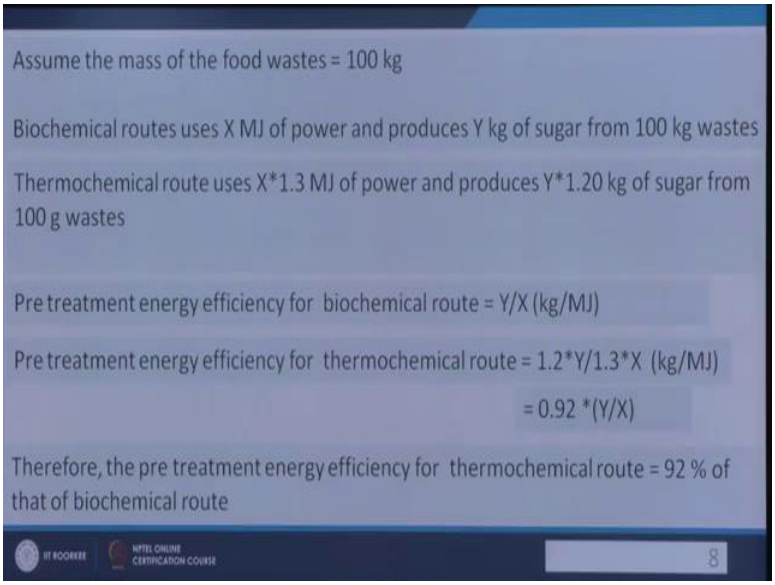

So, that will do the biochemical routes uses X mega joule of power and produces Y kg of sugar for 100 kg of waste this is you are assuming. So, this is the biochemical routes we are using Y kg we have sugar for producing and using X mega joule of electricity then what will be the what will be the efficiency the energy efficiency is equal to in this case

Y by X. So, Y by X, so for this case what will be the TSY in this case Y into 1.20 percent more sugar, so 1.2 into this Y and what will be the TCE that is 30 percent more energy. So, 1.3 into X then what will be the efficiency in this case it will becoming is equal to Y 1.2 Y divided by 1.3 X. So, that is equal to 0.92 Y by X and here this is equal to Y by X here equal to 0.92 Y by X.

So, 0.992 percent we can say. So, the pretreatment energy efficiency for thermo chemical route is equal to 92 percent of that of the biochemical route. So, this is the solution of this problem next we will come to problem number 3.

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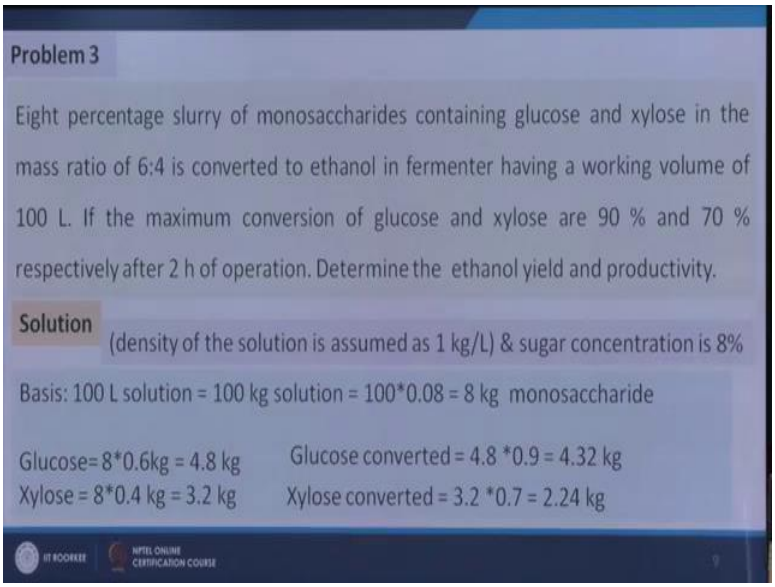

So, the statement is 8 percent slurry of monosaccharides containing glucose and xylose in the mass ratio of 6 is to 4 converted to ethanol in fermenter having a working volume of 100 liter if the maximum conversion of glucose and xylose are ninety percent and seventy percent respectively after 2 hours of operation determine the ethanol yield and productivity. So, we have to determine the ethanol yield and productivity. So, let us take one bases that is its say 100 liter of this 100 liter solution this is our basis. So, 100 kg solutions were assuming density equal to 1. So, 100 kg solution, so we have 8 percent slurry. So, that is the solid content that is that is the mono sugars monosaccharides percent 8 percent monosaccharides is percent monosaccharides is present is equal to 100 into 0.08 or 8 kg monosaccharide. So, 8 kg monosaccharide is present in it.

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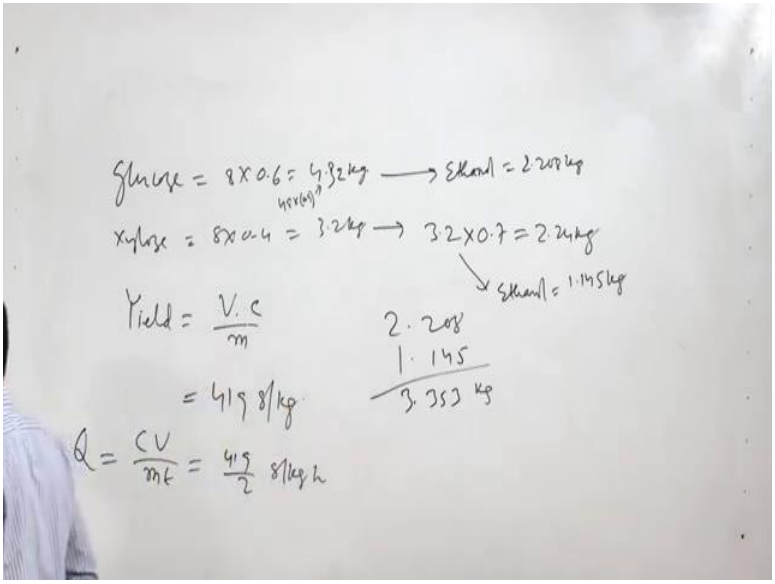

So, how many glucose glucose is equal to 6 is to 4. So, 8 into 0.6 and xylose 8 into 0.4 then we are getting 4.8 and 3.2 kg. So, that is 4.8 kg and that is 3.2 kg. So, this present in it, but now ninety percent glucose and seventy percent xylose are converted to ethanol after 2 hour of reaction after 2 hour of reaction the yield of ethanol is maximum.

So, with time the yield increases. So, maximum will get after 2 hour. So, in these case how much ethanol will get you see if we want to get the value of yield why is that yield is equal to yield is equal to V into C divided by m fine b is the volume in this case one 100 liter of the solution initially C is the ethanol concentration now will see how much ethanol concentration we are getting in this case and m is the substrate or sugar how much sugar we are using. So, m we can calculate here and then we have to calculate the value of C then we have to calculate the value of C then we can get the value of yield. So, now, for the calculation of C we have to see what type of reaction is going on and what will be the production of ethanol by these 2 sugar that is 4.8 kg and 3 point glucose and 3.2 kg of xylose.

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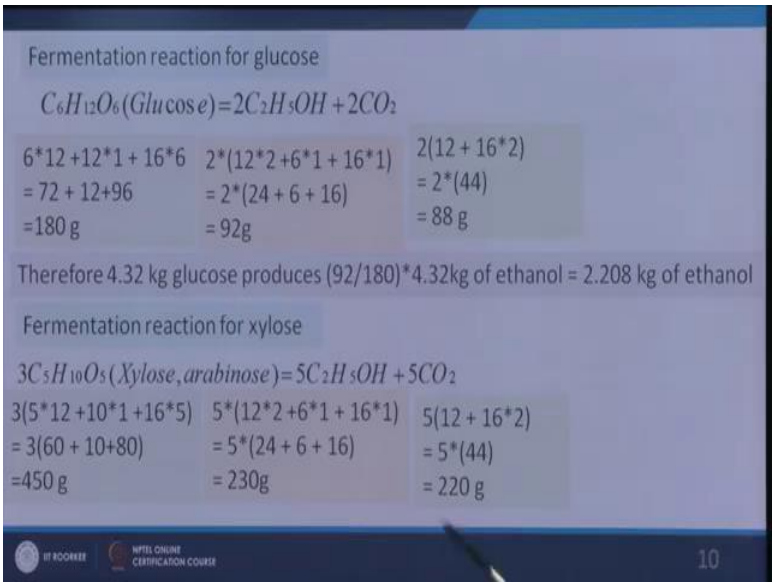

So, this is the reactions. So, C6H12O6 that reacts with micro organisms and gives 2C2H5OH plus 2CO2, so if we take the molecular weight of this glucose it is coming equal to 180 gram and where 2CH5OH the molecular weight is equal to 46 onto 2. So, 92 gram, so 180 gram glucose is giving us 92 gram of C2H5OH and 88 gram of CO2, this is the reactions it is going in the media. So, now, we have how much 4.32 that is 4.32 kg; 4.32 kg glucose we are getting. So, 4.32 kg of glucose will produce. So, 180 kg glucose produces 92 gram 180 gram glucose produces 92 gram ethanol. So, 4.32 kg glucose will produce 92 divided by 180 into 4.32 kg of ethanol.

So, that is equal to 2.208 kg of ethanol. So, glucose which is present in media that will produce 2.208 ethanol. So, this will produce ethanol equal to how much it is 2.208 kg 2.208 kg now if we consider the fermentation for the xylose the reaction is this one 3C5H10O5 that will give us 5C2H5OH plus 5CO2. So, if we take the mass of these. So, 3 into 60 plus 10 plus 80 that is 150 into 3 450 gram it is giving us 5 into 46 that is 230 gram. So, have here 3.2 kg the conversion xylose conversion will be seventy percent. So, these one will not be there this will be converted to 3.2 will become converted to 0.7. So, it will give us 2.24 kg. So, 2.24 kg so this is equal to 4.8 into 0.9. So, this is these one. So, here we are getting 2.24 kg. So, that is 2.24 kg xylose is converted. So, this 2.24 kg xylose will be producing how much of ethanol that is equal to 230 divided by 450 into 2.24 kg.

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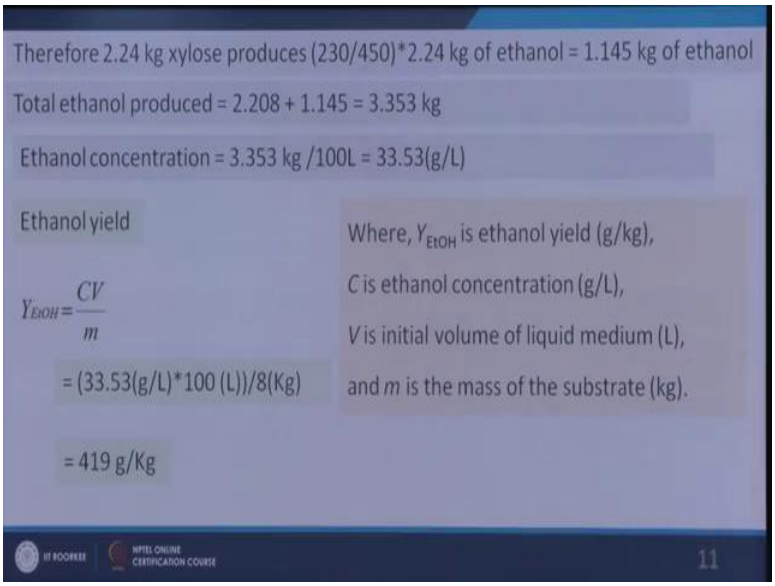

So, that is equal to 1.145 kg of ethanol. So, this will give us ethanol this will give us ethanol equal to 1.145 kg; 1.145 kg then what will do total ethanol equal to how much now we have got 2.208 from glucose and 1.145 from xylose. So, these 2 it is giving us a 3.353; so 3.353 kg. So, 3.353 kg total ethanol is produced by these 2 sugar now what is the ethanol concentration we have 100 liter of solution we are having 3.353 kg.

So, 3.353 divided by 100 that is equal to this is in kg per liter. So, multiple into 1000, so that will be gram per liter. So, 33 into 53 gram per liter, this is the concentration, now we have ethanol yield equal to C V M as we written. So, C is the concentration of ethanol 30 3 point 5 3 gram per liter into V, V is the one 100 liter solution volume and M is equal to 8 kg because 8 percent slurry is there. So, sugar is 8 percent. So, out of 100 into 0.8, 8 kg is there therefore, the yield is coming equal to 4.9 gram per kg. So, yield is equal to 419 gram per kg of sugar kg of sugar this is ethanol per kg of sugar. So, this is we are getting the yield the second question was the productivity. So, productivity is what productivity is equal to C V M by T. So, 419 divided by 2 gram per kg hour because it is given here in the statement after 2 hour we are getting maximum concentration of the ethanol.

So, we have to divide by 2 and this concentration here for the production of productivity that will be the maximum concentration. So, here we are getting maximum concentration as per the statement. So, this is 419 divided by 2 kg 2 gram per kg hour or if we can

multiply it into one thousand into 419 divided by 2 m g per kg sugar per hour. So, 2 0 9 5 0 0 m g per kg per hour, now, the problem is solved so up to these in this module.

Thank you very much for your patience.