Food Oils and Fats: Chemistry and Technology

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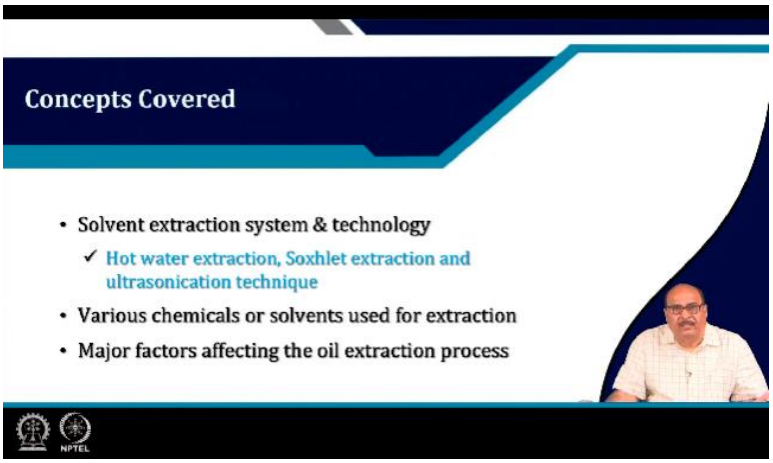
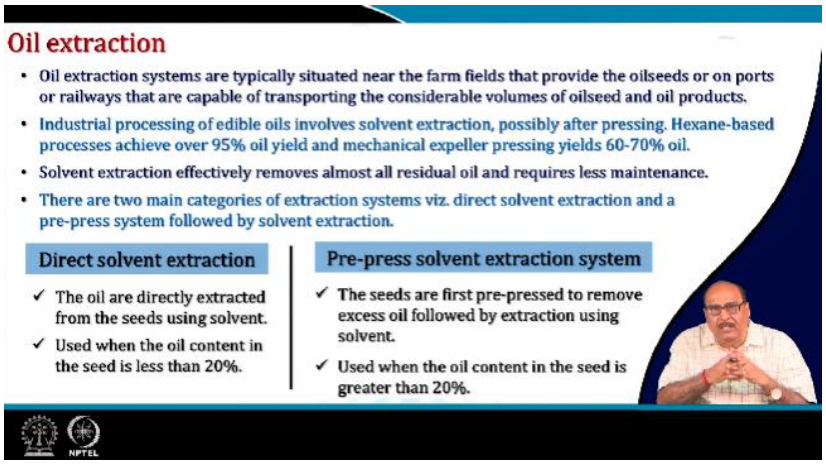
Module 05: Solvent Extraction of Edible Oils

Lecture 22: Oil Extraction Techniques and Factors Affecting

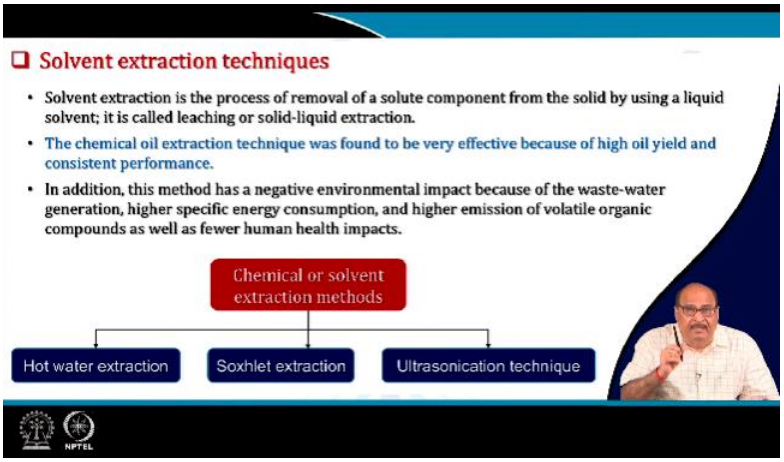
Hello everyone. Namaskar. Now, we are in lecture 22, and in this lecture, we will discuss oil extraction techniques and the factors affecting the extraction process.



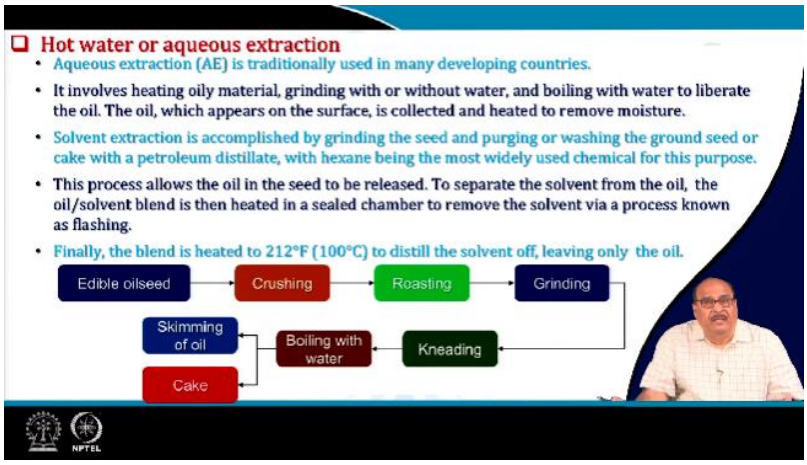
The concept we will cover in this lecture includes solvent extraction system and technology, hot water extraction, soxhlet extraction, and ultrasonication techniques. The various chemicals or solvents used for extraction and the major factors affecting the oil extraction.



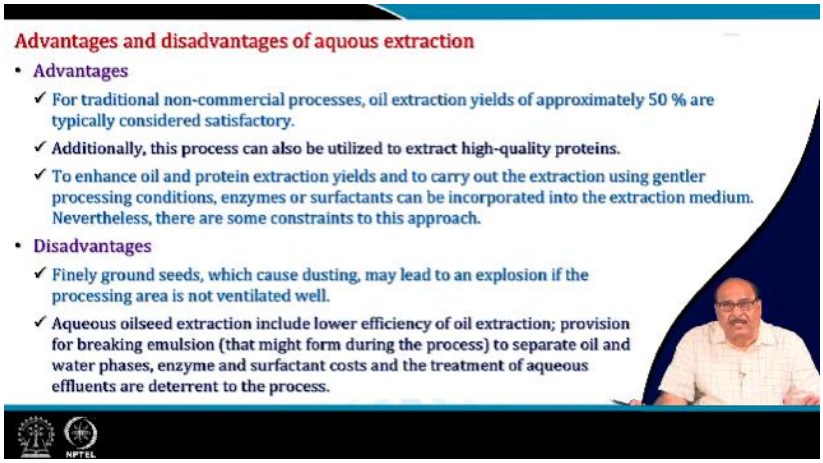
You know, the oil extraction systems are generally situated near the farm field that provides the oil seed or the ports or railways capable of transporting the considerable volume of oil seed and oil products. So that the factory or these systems are continuously working for the required period and there is no shortage of raw materials. Industrial processing of edible oil involves solvent extraction, possibly after pressing. Hexane-based processes achieve over 95 percent oil yield and mechanical expellers in the earlier classes. The general pressing result ranges from 60 to 70 percent oil. Solvent extraction effectively removes almost all residual oil and requires less maintenance. Two main categories of the extraction system are direct solvent extraction and a prepress system followed by solvent extraction. The material can be put directly for the solvent extraction, or, in some cases, where the oil content in the seed is more than 20 percent, the source is first pressed and then sent to the solvent extraction. So, direct solvent extraction is generally used where the oil content in the oil seed is less than 20 percent, and these oils are directly extracted from the source using solvent. Prepress solvent extraction is used when the oil content in the seed is more than 20 percent, and the seeds are pre-pressed to remove excess oil, followed by the extraction using a solvent.



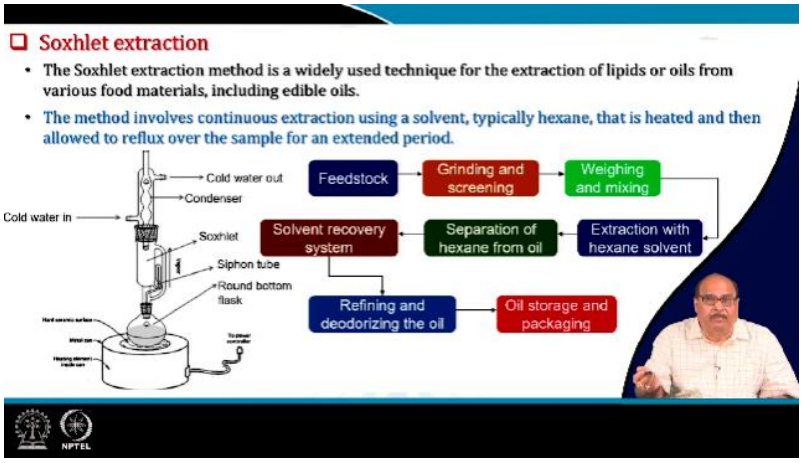
The solvent extraction technique removes a solute component from the solid using a liquid solvent called leaching or liquid extraction. In the earlier class, we discussed the various mass transfer operations. The chemical oil extraction techniques were very effective because of high oil yield and consistent performance. In addition, this method has a negative environmental impact because of the wastewater generation, higher specific energy consumption, higher emission of volatile organic compounds, and fewer human health impacts. Now, the chemical or solvent extraction methods are different. There are three methods that are popular and important here that is one is hot water extraction, charcoal extraction, and then ultrasonication technique that is ultrasonication assisted solvent extraction.



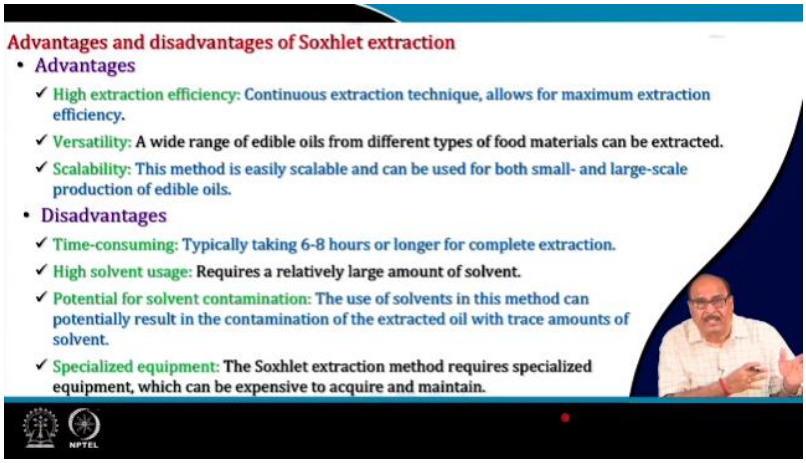
So, let us first discuss about the hot water or aqueous extraction. This is a traditionally used method that is the aqueous extraction is used traditionally in many developing countries. It involves heating oily material grinding with or without water and boiling with the water to liberate the oil. The oil which appears on the surface is collected and heated to remove the moisture this as simple as that. Solvent extraction is accomplished by grinding the seed and purging or washing the ground seed or cake with a petroleum distillate with hexane being the most widely used chemical for this purpose. This process allows the oil in the seed to be released to separate the solvent from the oil. The oil solvent blend is then heated in a sealed chamber to remove the solvent by a process known as flushing. And finally, the blend is heated to around 100°C to distill the solvent of leaving only the oil. And the steps in this are that is a edible oil seeds, it is crushed, roasted and ground after that is needed and then boiled with water and skimming of the oil and finally, the remaining material meal that is the cake is left.



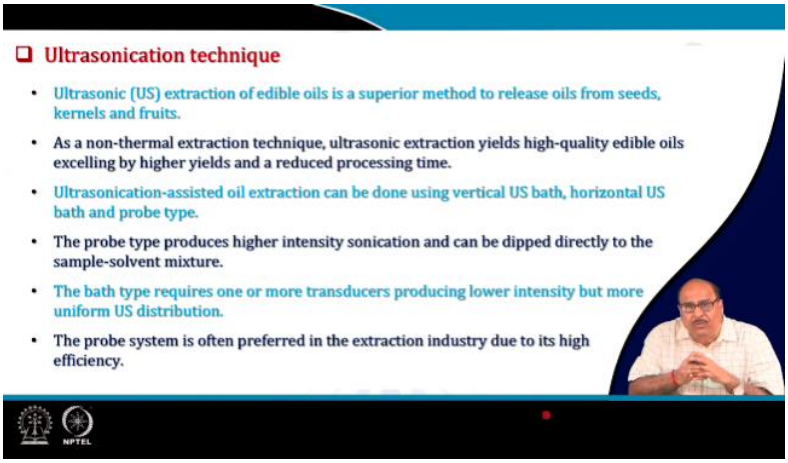
So, this method has both advantages and disadvantages. So, the advantages of the aqueous extraction method are that is these are the traditional non-commercial processes, oil extraction yields of approximately 5 percent are typically considered satisfactory in this case. Additionally, this process can also be utilized to extract the high quality protein that is the protein which is left meal which is left after the oil extraction, this quality of the protein is very good in this process. This process also is used to enhance the oil and protein extraction yields and to carry out the extraction using gentler processing conditions, enzymes or surfactants can be incorporated into the extraction medium. Nevertheless, there are some constraints to this approach. Examples of the water aqueous extraction process include you have to have very finely ground seed and which can cause dusting and this may lead to the explosion if the processing area is not properly ventilated. Also aqueous oil seed extraction inside include lower efficiency of oil extraction as I have seen earlier that is about only 50 percent that possible here ok. Then provision of breaking emulsion that might form during the process to separate the oil and water phases, enzyme and surfactant costs and the treatment of aqueous effluent these are some of the major deterrents to the process and major drawback to this process.



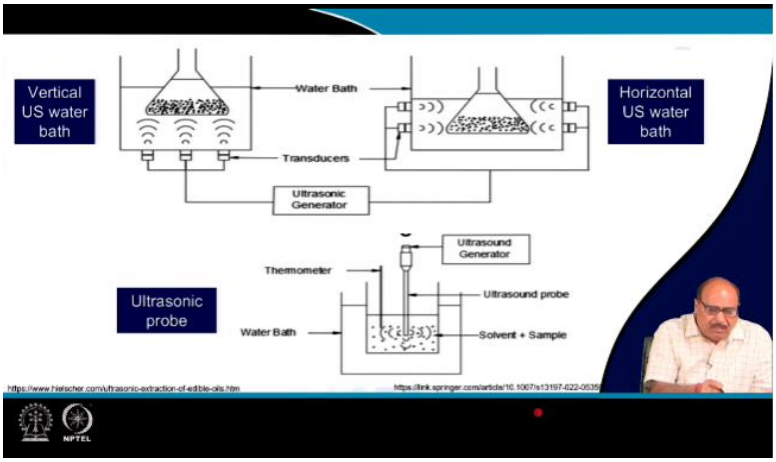
Then next very important process is the soxhlet extraction. This soxhlet extraction method is widely used technique for the extraction of liquids or oils from the various food materials including edible oil and it is one of the very popular method of oil determination even in the laboratory a testing laboratory, food testing laboratory ok. This method involves as you could see here in the figure continuous extraction using a solvent typically hexane that is heated and then allowed to reflux over the sample for an extended period of time. So, the feedstock oil seed it is ground and screen then weight a known weight of the material is taken then here in the extractor it is a in this round bottom flask where this solvent is put there and the material is put into the soxilate right. Then it is heated and once the heated solvent vapors come and in this soxilate in this sample is kept here and there is a direct contact between the sample and the solvent. And then the oil content which there in the sample in the oil seed it gets transferred into the solvent and then finally, solvent prizes here and then it is refluxed solvent again. And then this from where there is a also it is provided that direct siphoning system. So, siphon so from this soxilate the oil is transferred into the flask and finally, in this flask we get the solvent and oil mixture that is a miscella is obtained here.



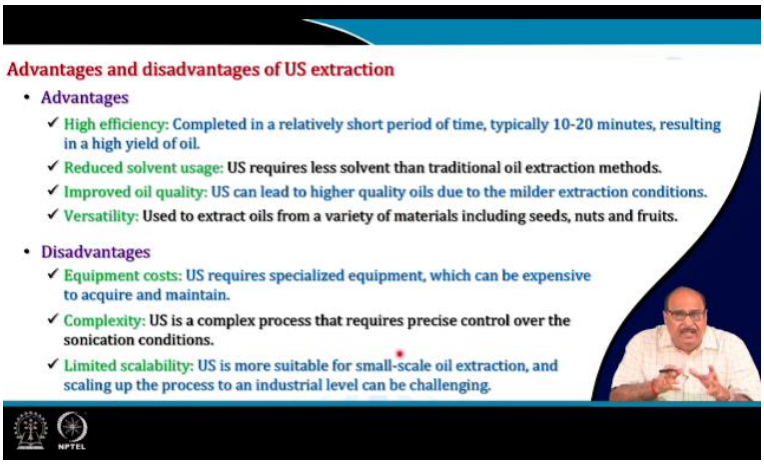
Then advantages of the Soxhlet extraction include, a high extraction efficiency that is because it is a continuous extraction technique it allows for the maximum extraction efficiency. It is a versatile process wide range of edible oils from different types of wood materials can be extracted in this apparatus. It has a good scalability the method can be easily scaled up and can be used for both small as well as large scale production of edible oils. However, the disadvantage of this process includes, time consuming process, typically takes for 6 to 8 hours or more than even longer time. It requires high solvent usage. There is a potential for solvent contamination that is use of solvent in this method can potentially result in the contamination of the extracted oil. This Soxhlet apparatus is expensive and many a times particularly large scale operations, it need maintenance. So, it is an expensive to acquire as well as maintain.



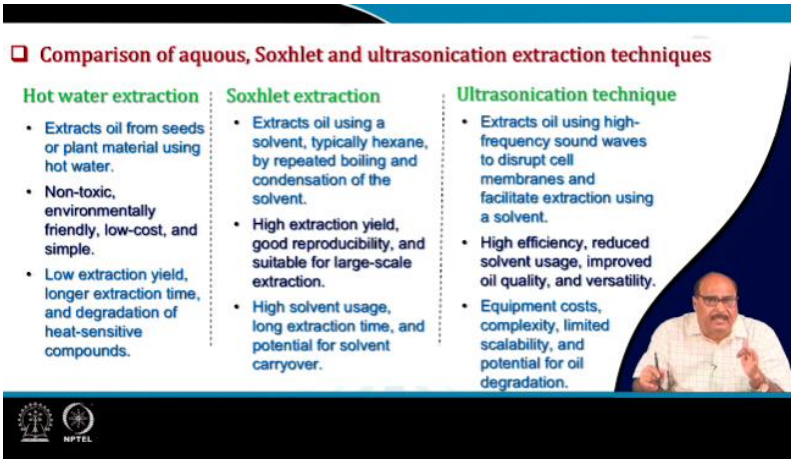
Then the next technique is the ultrasonication techniques. US extraction of edible oil is a superior method to release oil from the seed kernels and fruits. As a non-thermal extraction techniques ultrasonic extraction yields high quality edible oils excelling by higher yields and a reduced processing time. Ultrasonication assisted oil extraction can be done using vertical ultrasonic bath or horizontal ultrasonic bath and the probe type. The probe type produces higher intensity sonication and can be dipped directly to the sample solvent mixtures. The bath type requires one or more transducers producing lower intensity, but more uniform US distribution. The probe system is often preferred in the extraction industry due to its high efficiency.



In this figure, both the probe type as well as bath type are shown. Here it is a vertical US bath and horizontal US bath. In this case, there is an ultra transducer are put into the top that is one over that is the from the bottom these ultrasonic waves are created. And in the case of probe there is an ultrasound generation there is probe which is directly inserted into the solvent and sample. So, these are the different types of ultrasonic equipment.

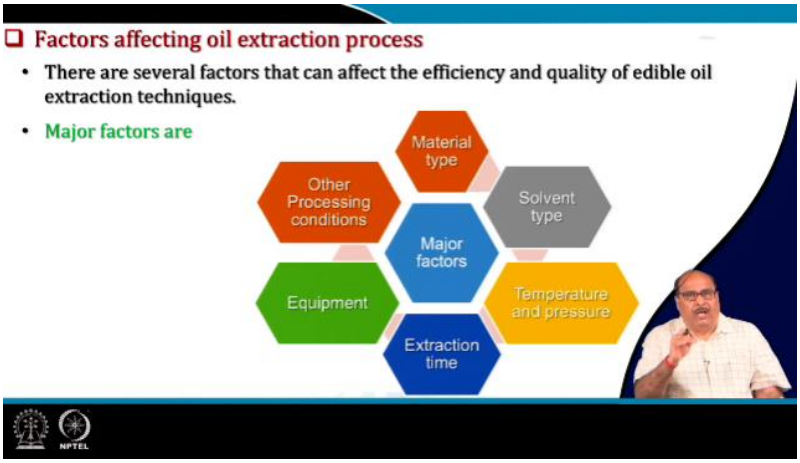


The advantages of this ultrasonic assisted extraction include high efficiency. So, very short time period of time typically this process can be completed in 10 to 20 minutes resulting in a high oil yield. There is a reduced solvent usage. The oilobtained by this process resulted better quality and there is high quality oil due to milder extraction conditions and versatility. The process is more versatile it can be used to extract oils from a variety of materials including seeds, nuts, fruits and so on. However, this process also has certain disadvantages like the equipment cost is one major factor disadvantage. US is a complex process that requires precise control over the sonication conditions. If the conditions are not properly maintained we can get a inferior quality of the oil. Limited scalability. US is a more suitable for a small scale oil extraction and the scaling up of the process in an industrial level can be challenging.

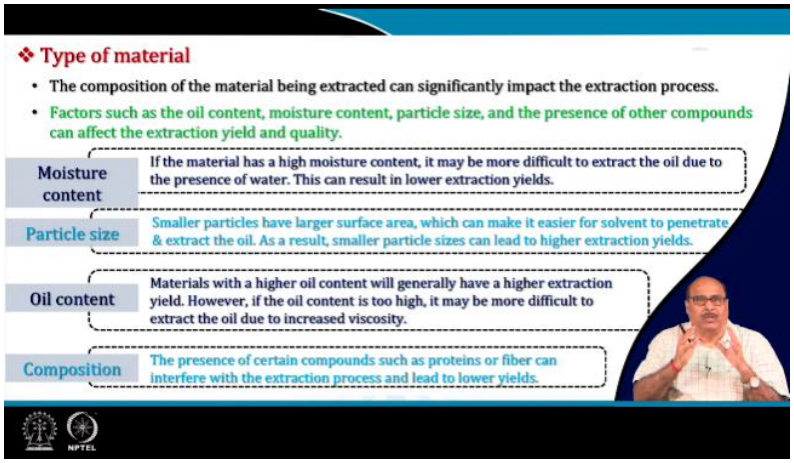


So, if we have a comparison between these three techniques that is hot water extraction this extracts oil from seeds or plant materials using hot water it is a non-toxic environmentally friendly low cost and simple. It however, gives low extraction yield it,

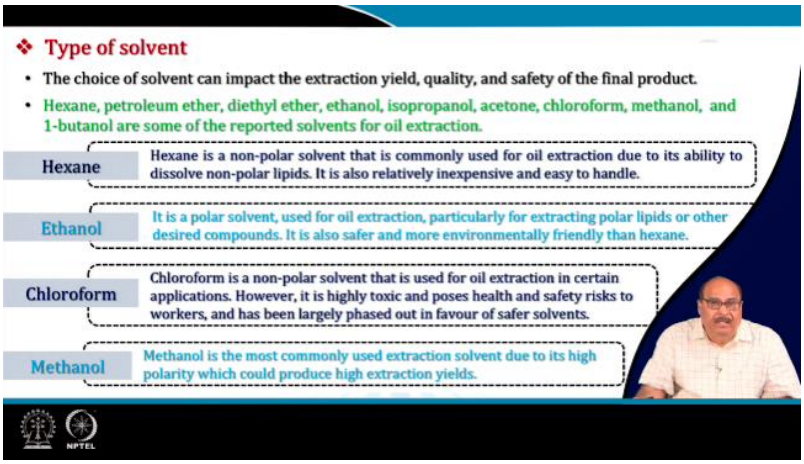
takes longer extraction time and degradation of the heat sensitive compounds. Soxhlet extraction, in this system, oil is extracted using a solvent typically exchange by repeated boiling and condensation of the solvent. This resulted in high extraction yield, good reproducibility and suitable for large scale extraction and the extraction technique. It requires high solvent usage, long extraction time and potential for solvent carry over. The ultrasonication technique extracts oil using high frequency sound waves to disrupt cell membrane and facilitate extraction using a solvent. It has a very good efficiency rather high efficiency reduced solvent usage improved oil quality and high versatility. Equipment costs, complexity, limited scalability and potential for oil degradation are some drawbacks of this techniques.



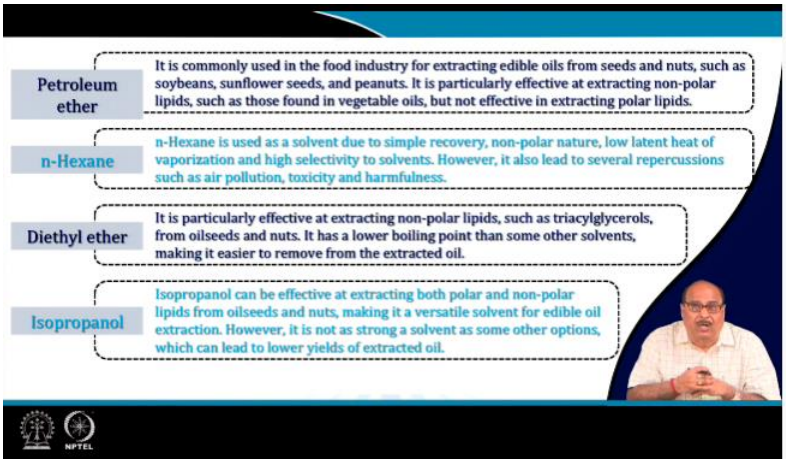
Now, let us see the factors affecting the oil extraction process. In any processes that various factors affect both the quality as well as quantity of the oil that is used by these methods. So, the major factors may include material type that is the type of the oil seed materials, the solvent type, the temperature and pressure, extraction time, equipment, other processing conditions etc.



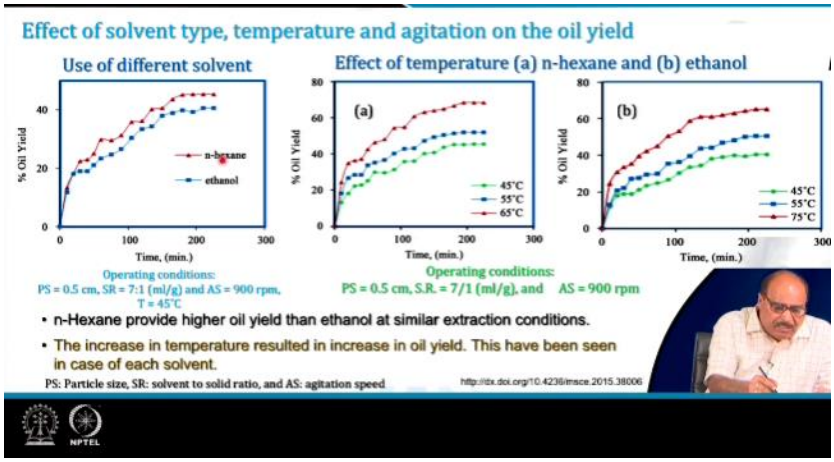
The type of the material that is oil seed whether it is a seed, fruit, leaf and all these things. So, the composition of the material being extracted can significantly impact the extraction process. Factors such as oil content, moisture content, particle size and the presence of other compounds can affect the extraction yield and as well as its quality. If the moisture content is high in the material, it may be more difficult to extract the oil due to the presence of water and this can result in a lower extraction yield. Similarly, the particle size has important influence, a smaller particle size has larger surface area which can make it easier for solvent to penetrate and extract the oil. As a result, a smaller particle size can lead to higher extraction yields. The oil content material with higher oil content will generally have a higher extraction yield. However, if the oil content is too high, it may be more difficult to extract the oil due to increased viscosity. Composition of the material is another important factor. The presence of certain compounds such as proteins or fibers can interfere with the extraction process and lead to lower extraction yields.



Then type of the solvent is very important consideration. The choice of the solvent can impact the extraction yield, quality and safety of the final products. Hexane, petroleum ether, diethyl ether, ethanol, isopropanol, acetone, chloroform, methanol and one butanols are some of the reported solvents for oil extraction. Hexane is a non-polar solvent that is commonly used for oil extraction due to its ability to dissolve non-polar lipids. It is also relatively expensive and easy to handle. Oil is a polar solvent, it is used for oil extraction particularly for extracting polar lipids or other desired compounds. It is also safer and more environmentally friendly than hexane. Chloroform is a non-polar solvent that is used for oil extraction in certain applications. However, it is highly toxic and possess health and safety risk to the workers and has been largely phased out in a favor of safer solvents. Methanol is the most commonly used extraction solvent due to its high polarity which could produce high extraction yields.

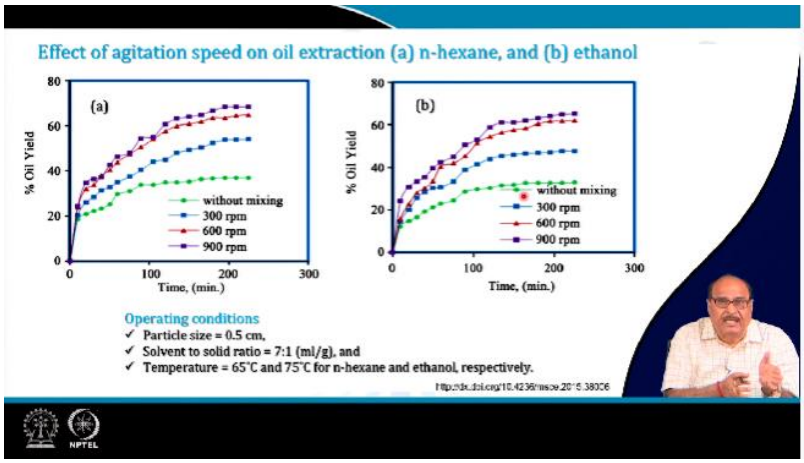


Petroleum ether is commonly used in food industry for extracting edible oils from hexane, from seeds and nuts such as soybeans, sunflower seeds, peanuts, etcetera. It is particularly effective at extracting non-polar lipids such as those found in vegetable oils, but not effective in extracting polar lipids. Diethyl ether is particularly effective in extracting non-polar lipids such as triacyl glycerol from oil seeds and nuts. It has a lower boiling point than some other solvents making it easier to remove from the extracted oil. Isopropanol can be effective at extracting both polar and non-polar lipids from oil seeds and nuts making it a versatile solvent for edible oil extraction. However, it is not as strong a solvent as some other options which can lead to lower yield of the extracted oils.

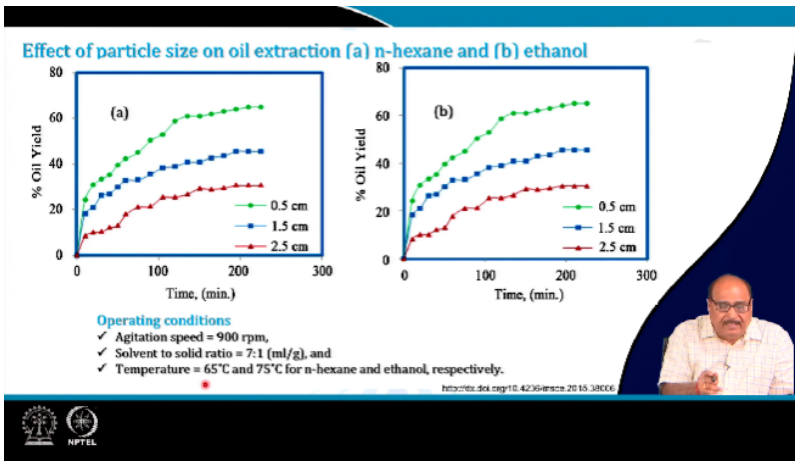


In this figure, the effect of solvent type, temperature and agitation and the oil yield are described. Here, n-hexane and ethanol are the two solvents. In the other figures, the effect of temperature and n-hexane as well as ethanol is given. The other operating condition that is particle size is 0.5 cm that is solvent ratio 7:1 and agitation speed is 900 rpm in both case. In the first case, the temperature is constant as 45°C. In the other two cases, that is the temperature is varied. So, you can see in as is can be easily seen in all the three figures that is n-hexane provides higher oil yield than ethanol at similar extraction conditions. The

increase in temperature resulted in increase in oil yield and this has been seen in case of each solvent in the figure you can see easily.

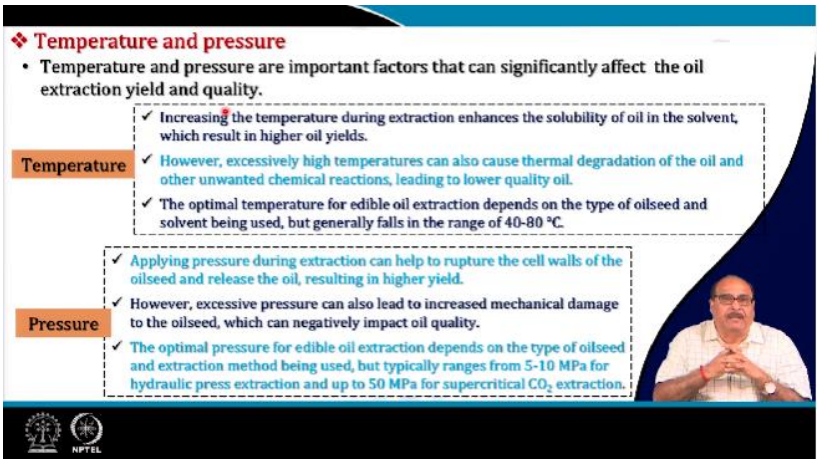


This is the effect of agitation speed on extraction of oil. Solvents used in the extraction are n-hexane and ethanol and the speed is varied from 300 to 900 rpm. In both the cases, the particle size is remaining the same like this 0.5 centimeter, solvent to solid ratio is 7:1 and temperature is normally 65°C and 75°C for n-hexane and ethanol respectively. And again the same trend that is by increasing the agitation speed that is oil extraction yield is increased and this solvent also having the here again that is it is a hexane is giving better recovery than the ethanol.

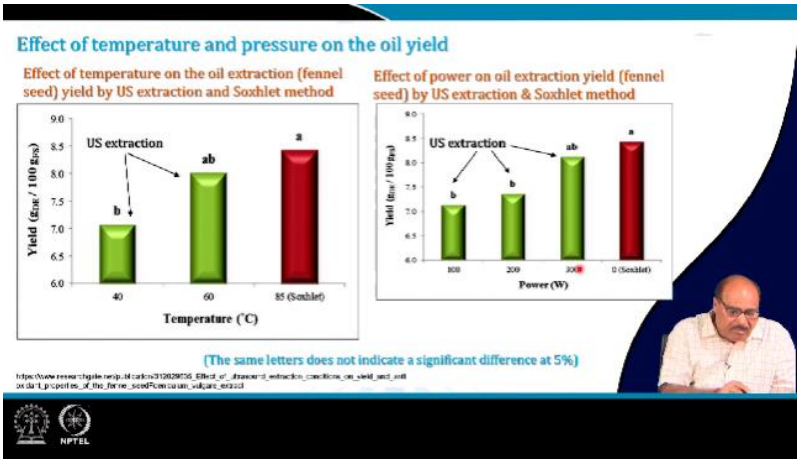


Similarly, that is the effect of particle size on oil extraction yield that is the particle size other conditions are same. The particle size is varying here from 0.2cm to 1.5 and 2.5 cm. A is the n-hexane and B is the ethanol and in this case, also you can see the same increase in the particle. Reducing the particle size that is 0.5 centimeter has better extraction. If you

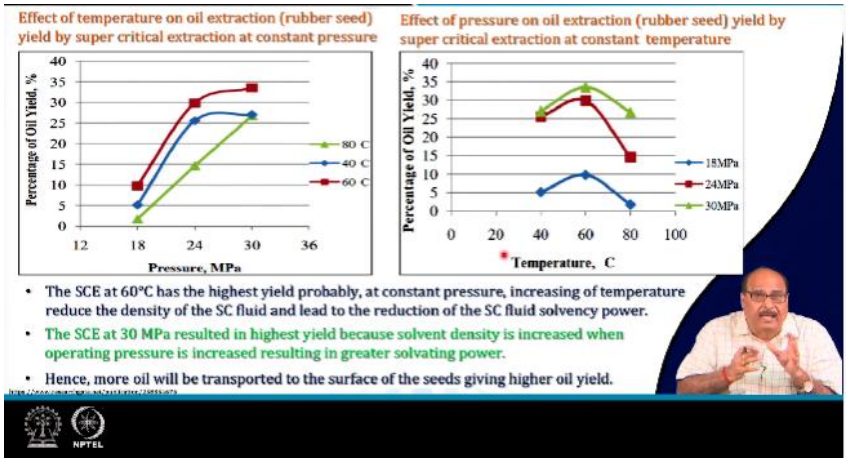
have lower particle size in the extraction ok, then for the longer time reducing the particle size increasing the time of extraction will give you a better oil yield.



Now the other factors are the temperature and pressure. Both this temperature and pressure of extraction are important factors and that can significantly affect the both oil extraction yield as well as quality of the extraction oil. So, temperature if you increase the temperature you have seen in the earlier slides that is the extraction enhances the solubility of the oil with the solvent and which result in the higher extraction yield. However, excessively high temperature can cause thermal degradation of the oil and other unwanted chemical reactions leading to lower quality. The optimal temperature for edible oil extraction depends on the type of the oil seed and the solvent being used, but generally it falls in the range of around 40 to 80°C for the common oil seed as well as common solvents. Then the pressure it again also has a very important influence applying pressure during extraction can help to rupture the cell walls of the oil seeds and release the oil resulting in higher yield. However, like temperature, the pressure also if you use excessive pressure it can lead to increased mechanical damage to the oil seed which can negatively impact the oil quality. The optimal pressure for edible oil extraction depends on the type of oil seed and extraction method being used, but it typically ranges from 5 to 10MPa for hydraulic press extraction and up to 50MPa for supercritical carbon dioxide extraction.

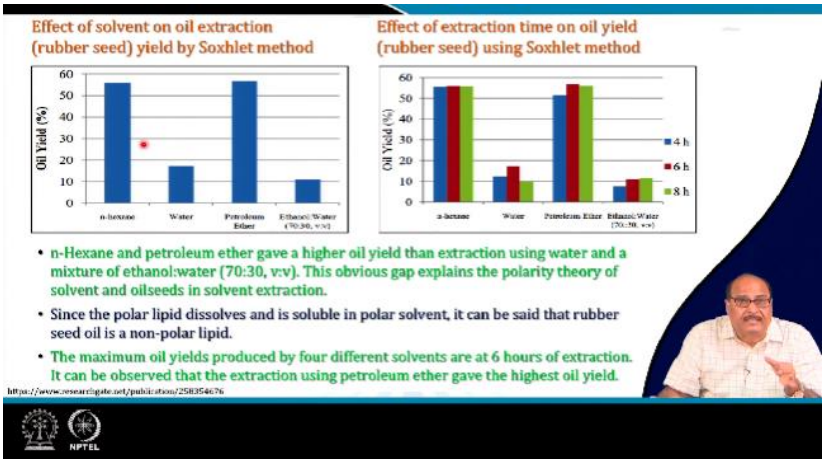


In this figure, the effect of temperature and pressure on oil yield are shown. And these green bars are the ultrasound extraction and the other one is the solvent extraction Soxhlet by Soxhlet apparatus. And this in the next case that is the effect of the power here the temperature is increased here in this case power is a power is 100 W, 200W, 300 W and the temperature is 40°C and 60°C. And you can see here again the both the power as well as a temperature they are having better effect that is increasing the power as well as increasing the temperature of the extraction increases the oil yield. And in this figure the same letter does not indicate any significant difference. In this case, ultrasonic extraction this 100 and 200 they are not having much significant difference, but at the 300 there is a significant difference.

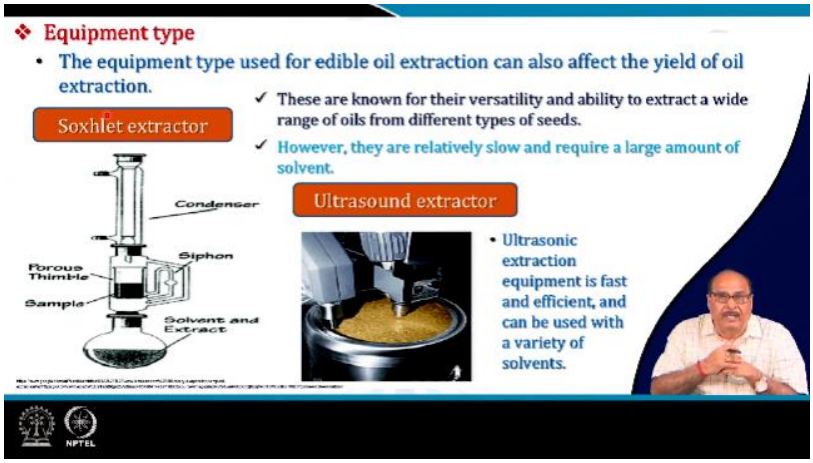


This figure here it is effect of temperature on oil extraction of a from rubber seed that is oil extraction yield by supercritical extraction at constant pressure that is the pressure is 15, 24, 30 MPa and the temperature is varied. And the other, the effect of oil extraction yield by supercritical extraction at constant temperature. The temperature is constant and the pressure is varied pressure is varied in this case from 80 Mpa, 18 Mpa to 30 Mpa. Here in

the first case, temperature is varied from 40 to 80°C. And you can see, in the figure, it indicates that the supercritical extraction at 60°C. It gives highest yield probably at constant pressure increasing a temperature reduces the density of the supercritical fluid and lead to the reduction in the super reduction of the supercritical fluid solvency power. The supercritical extraction at 30MPa resulted in higher yield because solvent density is increased when operating pressure is increased resulting in greater solvency power. Hence, more oil will be transported to the surface of the seed giving higher oil yield.

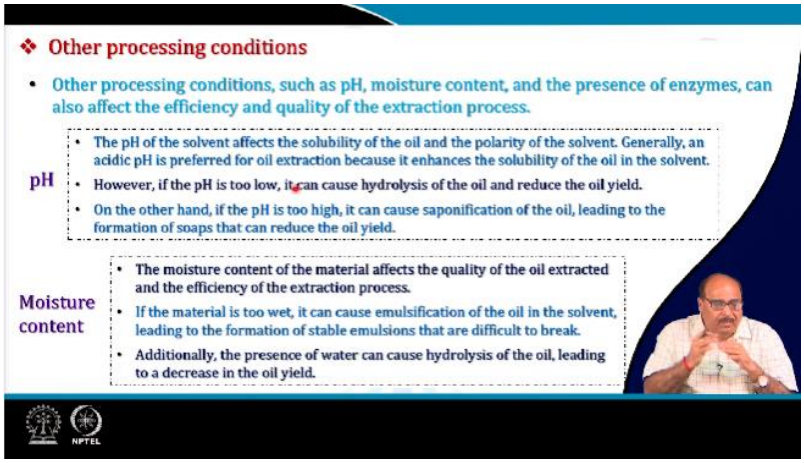


In this figure, the effect of solvent oil extraction in rubber seed both by the soxhlet method or the solvent extraction time on the oil yield are shown. So, here the n-hexane water, petroleum ether and ethanol water in the ratio of 70:30 is used in both. And in this case that is the time also is varied 4 hours, 6 hours and 8 hours. And you can see that is from the figure it is clearly indicated that n-hexane and petroleum ether gave a higher yield than extraction using water and mixture of ethanol water that is 70:30 volume by volume mixture. This obvious gap explains the polarity theory of the solvent and oil seeds in the solvent extraction that is even both mixture is not ethanol and water mixture also is not giving better whereas, n-hexane individually petroleum ether individually they are getting better extraction. So, polarity since the polar lipid dissolves and is insoluble in polar solvent it can since the polar lipid dissolves and is soluble in polar solvent it can be said that rubber seed is a non-polar lipid. The maximum oil yields produced by 4 different solvents are at 6 hours of extraction it can be observed that the extraction using petroleum ether gave the highest oil yield.

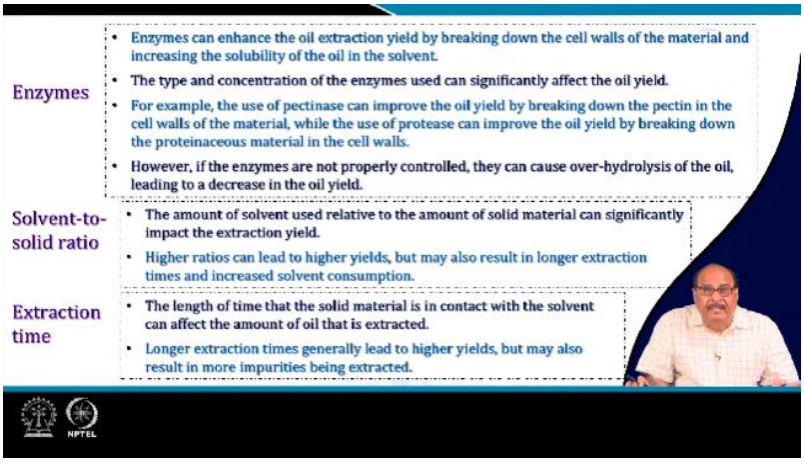


The equipment type again they influence the both oil yield as well as quality. The succulent apparatus these are known for their versatility and ability to extract a wide range of oils from different types of seeds. However, they are relatively slow and require a large amount of solvent. Ultrasonic extraction equipment is fast and efficient and can be used with a variety of solvents.

Rotary evaporators they are fast and efficient, but they may not be suitable for all types of seed and may require higher initial investment cost. You can see here in the rotary evaporator, it is the concentration that is vacuum concentration that is the mixture used and then under vacuum it is and the refluxed. So, this rotary evaporator of course, obviously, because of the vacuum it is maintained it is a fast and efficient.

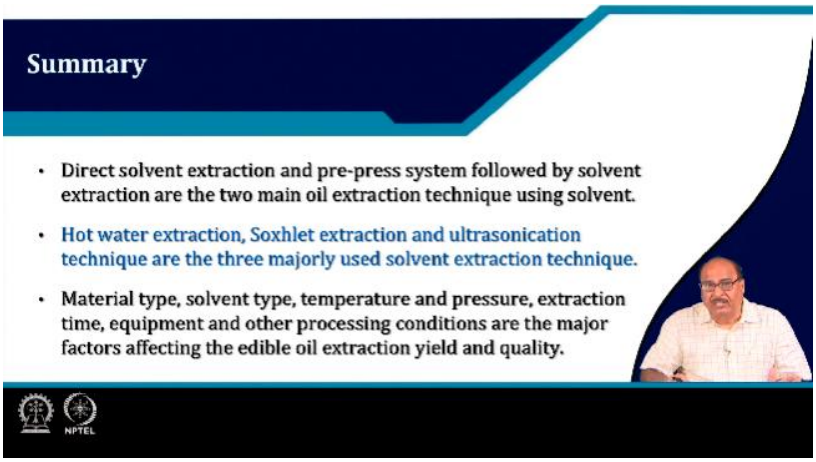


The other processing conditions such as pH, moisture content and the presence of enzymes can also affect the efficiency and quality of the extraction process. The pH of the solvent affects the solubility of the oil and the polarity of the solvent. Generally, an acidic pH is preferred for the oil extraction because it enhances the solubility of the oil in the solvent. However, if the pH is too low it can cause hydrolysis of the oil and reduce the oil yield. On the other hand, if the pH is too high it can cause saponification of the oil leading to the formation of soaps that can reduce the oil yield. Similarly, the moisture content of the material affects the quality of the extracted oil and the efficiency of the extraction process. If the material is too wet it can cause emulsification of the oil in the solvent leading to the formation of stable emulsion that are difficult to break. Additionally, the presence of water can cause hydrolysis of the oil leading to the decrease in oil yield as well as increase in the free fatty acids.



Enzymes can enhance the oil extraction yield by breaking down the cell walls of the materials and increasing the solubility of the oil in the solvent. The type and concentration of the enzyme used can significantly affect the oil yield. For example, the use of pectinases can improve the oil yield by breaking down the pectin in the cell wall of the material while the use of protease can improve the oil yield by breaking down the pectin material in the

cell wall. However, if the enzymes are not properly controlled they can cause over hydrolysis of the oil leading to the decrease in the oil yield. Solvent to solid ratio is another important factor. The amount of solvent used relative to the amount of solid material can significantly impact the extraction yield. Higher ratios can lead to higher yields, but may also result in the longer extraction times and increased solvent consumption. The length of the time that the seed material is in contact with the solvent can affect the amount of oil that is extracted. Longer extraction times generally lead to higher yields, but may also result in more impurities being extracted.



The direct solvent extraction and prepress system followed by solvent extraction are the two main oil extraction techniques using solvent. Hot water extraction, soxhlet extraction and ultrasonication techniques are the three majorly used solvent extraction techniques. Material type, solvent type, temperature, pressure, extraction time, equipment and other processing conditions are the major factors which affect the edible oil extraction yield as well as quality. So, it is very important that is during the extraction that is the process parameters should be properly controlled, that is the machines should be operated at proper conditions, so as to get better yield as well as better quality of the extracted oil.

So, these are the references that are used in this lecture. Thank you very much for your patience hearing.