Food Oils and Fats: Chemistry & Technology

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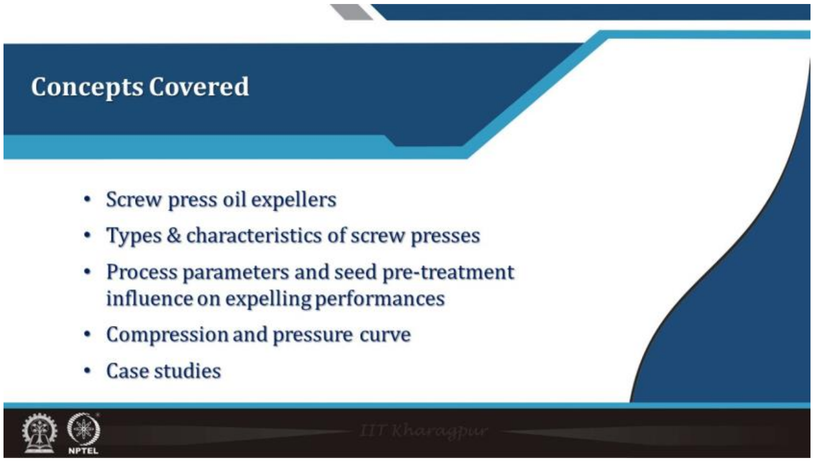
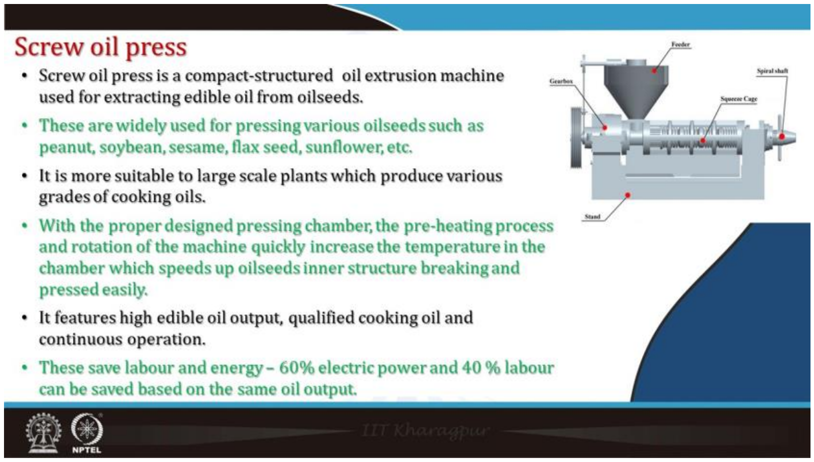
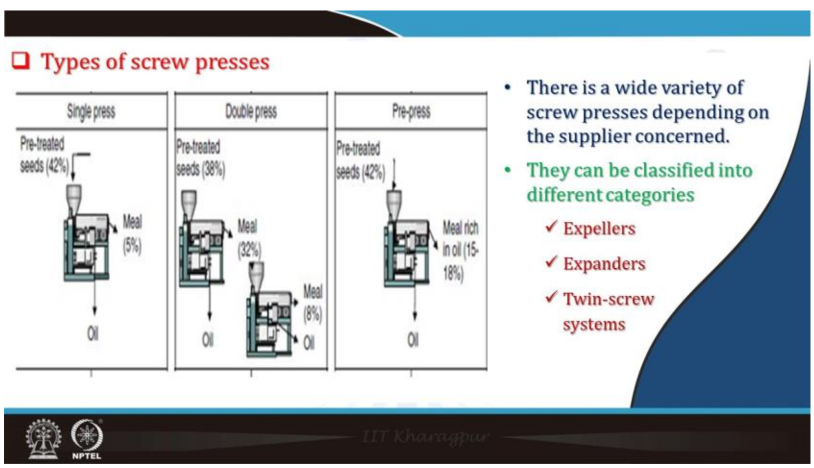
Hello everyone. Namaste. Now, today in this 19th lecture of this course, we will discuss about a screw expelling or screw pressing.



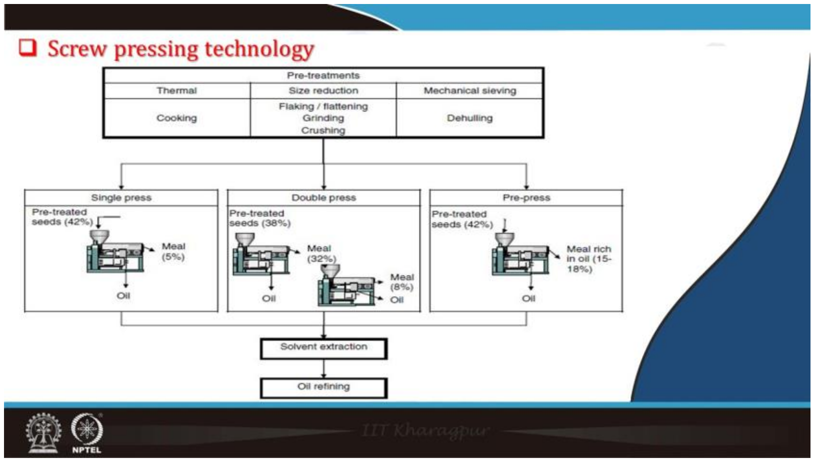
The various topics that we will cover in this lecture or themes include what are the screw press oil expellers, how do they work, what are the types and characteristics of screw presses, then influence of process parameters and seed pretreatment on expelling performances in the screw expellers, then also we will take up compression and pressure curve and its influence on expelling performance and finally, we will take one or two case studies to explain the matter.



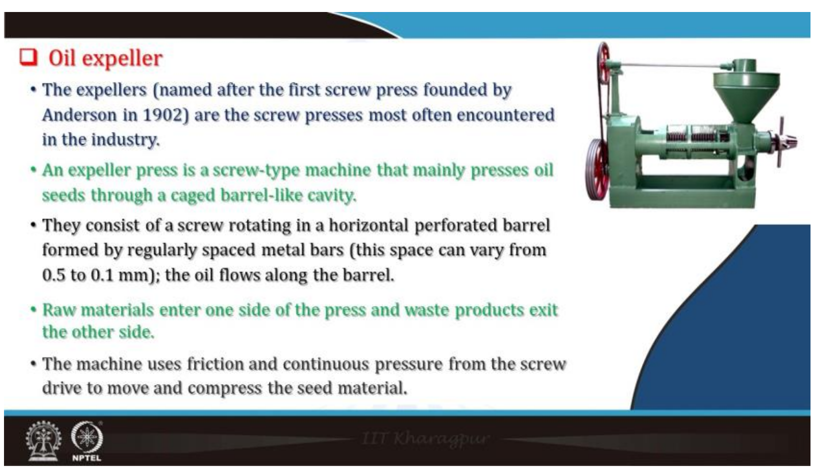
So, oil screw press or screw oil press, in the earlier class also I gave you a brief overview of what are the oil presses? These are compact structured oil extrusion machines which are used for extracting edible oil from oilseeds. Screw oil presses are widely used for pressing various oilseeds such as peanut, soybean, sesame, flax seed, sunflower, etc. It is more suitable for large-scale plants which produce various grades of cooking oils. With the properly designed pressing chambers, the preheating process and rotation of the machine quickly increase the temperature in the chamber which speeds up oilseed inner structure breaking and they are pressed easily which releases the oil easily. It features high edible oil output, qualified cooking oil, and continuous operations. These save labor and energy about 60 percent of the electric power and 40 percent of labor can be saved using these screw presses based on the same oil output.



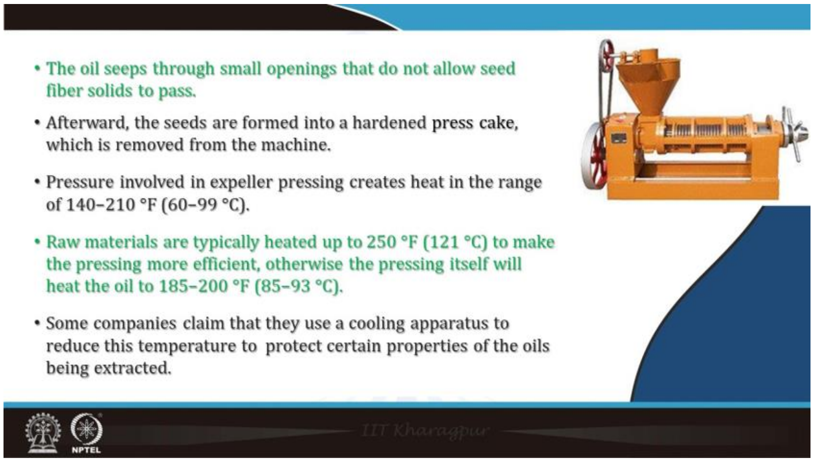
So, in this slide, I have shown you the different types of screw presses. They may be single-press screw, double-press, and pre-press, and depending upon the supplier concerned a wide variety of screw presses are available in the market. The different screw presses can be classified into different categories like expellers, expanders, and twin-screw systems.



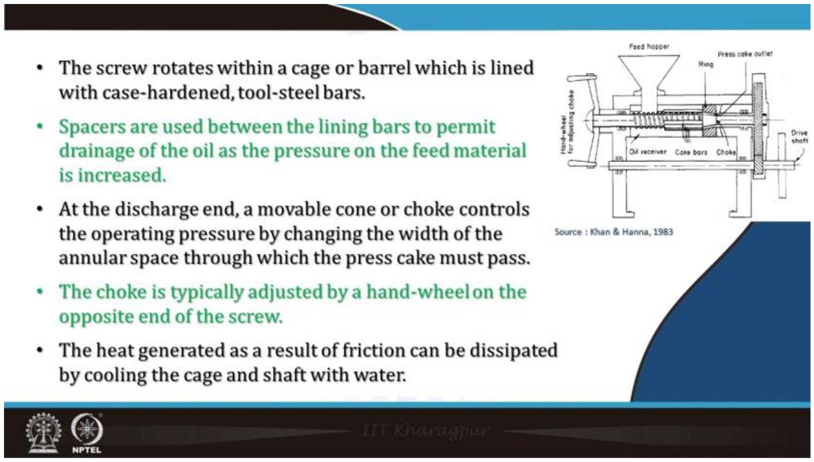
About the screw pressing technology, earlier also I told what are the different pretreatments. So, basically, the seeds are given pretreatments like thermal, size reduction, or mechanical sieving as the case may be depending upon the type of the seed, its characteristics, its oil content, moisture content, etc., and also what are the subprop that is the method which will be used whether it is going for direct spelling or it is going for pre-press solvent extraction or whatever this ok. So, they are normally in the thermal pretreatment it is cooking and then it is given for size reduction like flaking, flattening, grinding, crushing, etc., and then also in the mechanical pretreatment, it may be mechanical sieving like dehulling, etc. So, all these that are cooked, dehulled, conditioned, flaked, flattened, or crushed seeds are subjected to either single press here or in the double press or in the pre-press. This can be in the double press or single press they can be individually operated to get the maximum oil recovery or they can be used in the pre-press step in which the quantity of the oil in the meal is generally high that is around 15 to 18 percent. They are further subjected to solvent extraction and then oil which is obtained by this is sent to refining treatment. Details of refining, we will take up separately in the next class. So, you saw that three types of presses that is one is the expeller, the expander, then the twin screw expeller.



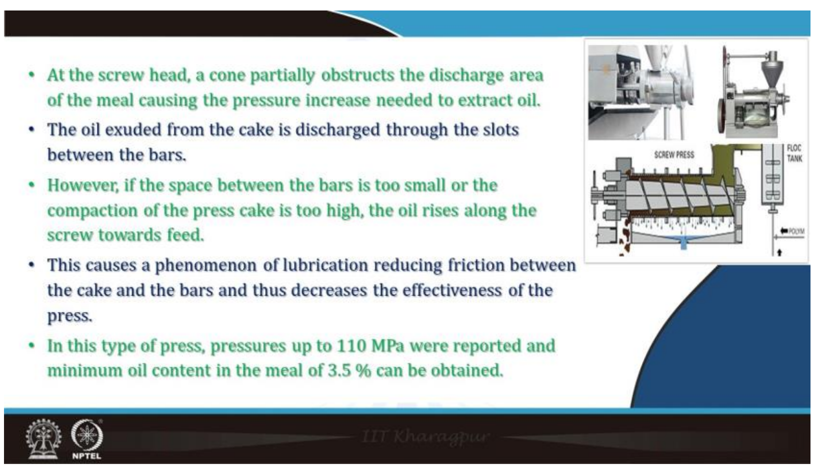
Then, let us talk about first about the expellers, oil expellers. These expellers named after the first screw press founded by Anderson in 1902 are the screw presses most often encountered in the industry. An expeller press is a screw-type machine that mainly presses oil seeds through a caged barrel-like cavity. They consist of a screw rotating in a horizontal perforated barrel formed by regularly spaced metal bars which are that thin spaces can vary from 0.5 to 0.1 mm that is the spacing that can be adjusted and the oil flows along this barrel. Raw material enters one side of the press as you can see here and then the waste product or which say that is more specifically the cake, as it cakes exits to the other side. The machine uses friction and continuous pressure from the screw drive to move and compress the seed material.



The oil seeps through the small openings that do not allow seed fiber solids to pass that is it is just only it allowed that the openings are it is just allowed to oil to pass fibers do not work they are retained on the seed. Afterwards, the seeds are formed into a hardened press cake which is removed from the machine from the other end. The pressure involved in expeller pressing creates heat in the range of around 60 to 99 degree Celsius. Raw materials are typically heated up to around 121 degree Celsius to make the pressing more efficient. Otherwise, the pressing itself will heat the oil to around 85 to 93 degree Celsius. Some companies claim that they use cooling apparatus to reduce this temperature to protect certain properties of the oil that is being extracted in this machine.

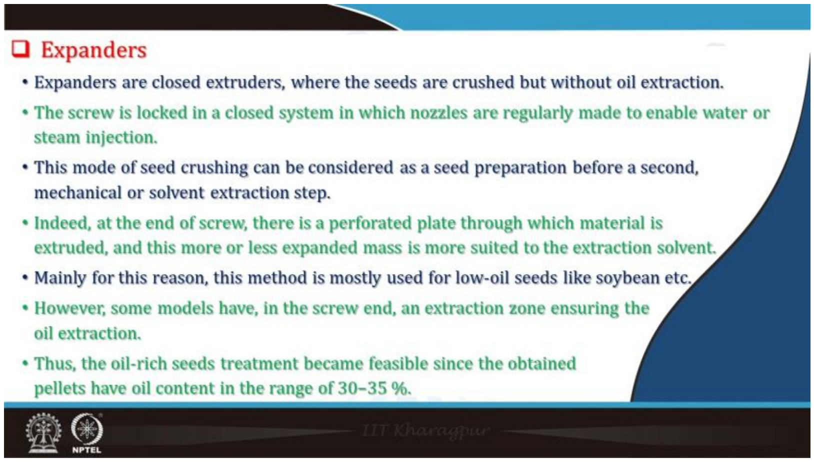


In the schematic figure here you can see that there is a feed hopper through this that is the seeds are conditioned and crushed seeds are fed to the that is expeller and here the screw there is a screw which you can see rotates within a cage barrel is lined with case-hardened tool steel bars. And the spacers are provided between the lining bars. They permit the drainage of the oil as the pressure on the feed material is increased. At the discharge end, there is a movable cone or choke mechanism which controls the operating pressure by changing the width of the annular space through which the press cake must pass. The choke is typically adjusted by a hand wheel on the opposite end of the screw, there is here. Then the heat generated as a result of friction can be dissipated by cooling the cage and shaft with water.



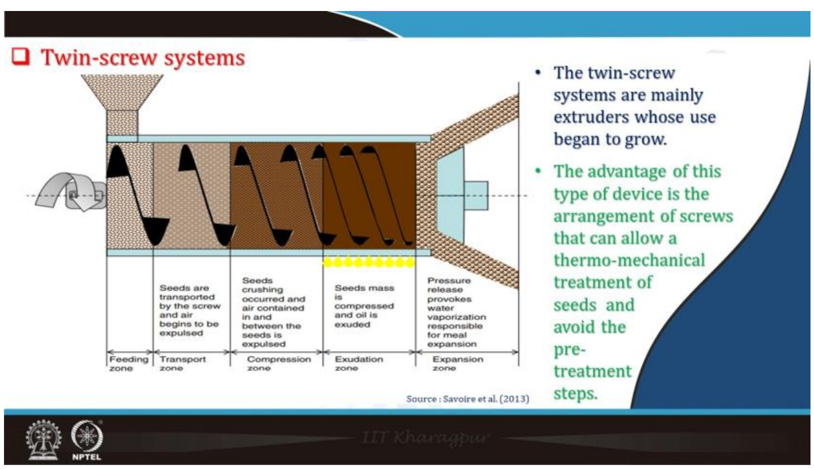
At the screw end, a cone partially obstructs the discharge area of the meal causing the pressure to increase, or which that is the pressure increase needed to extract the oil. The oil excluded from the cake is discharged through the slots between the bars. However, if the space between the bars is too small or the compaction of the press cake is too high the oil rises along the screw towards the feed. This causes a phenomenon of lubricating which reduces friction between the cake and the bar and therefore, it decreases the effectiveness of the press. In this type of press pressure up to 110 megapascals are reported and a minimum oil content in the meal to as low as 3.5 percent can be obtained.

And this if you can get 3.5 percent it is a very good oil explorer its efficiency can be considered very good.



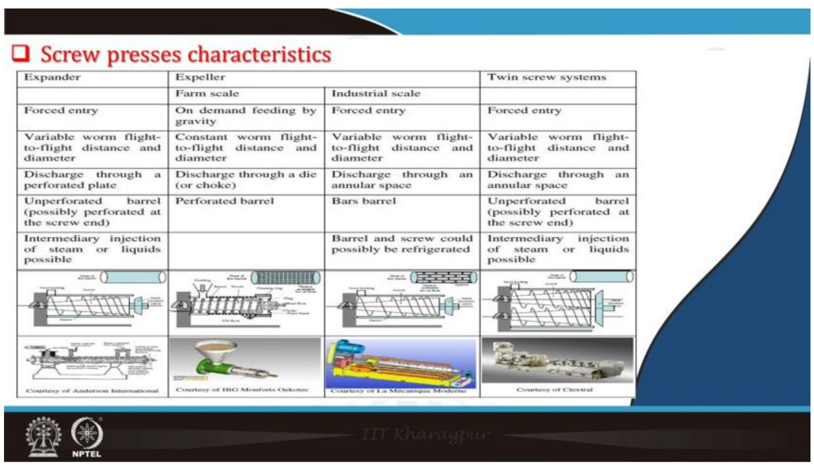
Then the other presses are the expanders. Expanders are closed extruders where the seeds are crushed but without oil extraction. The screw is locked in a closed system in which nozzles are regularly made to enable water or steam injection. This mode of seed crushing can be considered as a seed preparation before a second mechanical or solvent extraction step. So, expanders normally can be treated as a preparatory step.

Indeed, at the end of the screw, of course, there is a perforated plate through which material is extruded and this more or less expanded mass is suited for the extraction solvent that is better suited for the next step that is recovery of oil through solvent extraction. And mainly for this reason, this method is mostly used for low oil seeds, low oil containing oil seeds like soybean, etc. However, some models have in the screw end and extraction zone ensuring some extraction of oil. Whereas, oil seed treatment becomes feasible since the obtained pellets have oil content in the range of about 30 to 35 percent.



Now here it is the twin-screw system. It is shown here, that these twin-screw systems are mainly extruders which use begun to grow and now they are becoming more and more popular in oilseed processing. The advantage of this type of device is the arrangement of the screws that can allow a thermomechanical treatment of seeds and avoid the pretreatment steps. So, this can be used directly without any pretreatment to get the oil. You can see here in the screw that there is a feeding zone, there are the twin screws which rotate that is the, and then in the from the feeding zone the material when it rotates the screw it moves the material forward in the transport zone where the seeds are that is then pressed by the screw and the air begins to be expulsed that is air, it goes out from the cell at this stage when it is crushed.

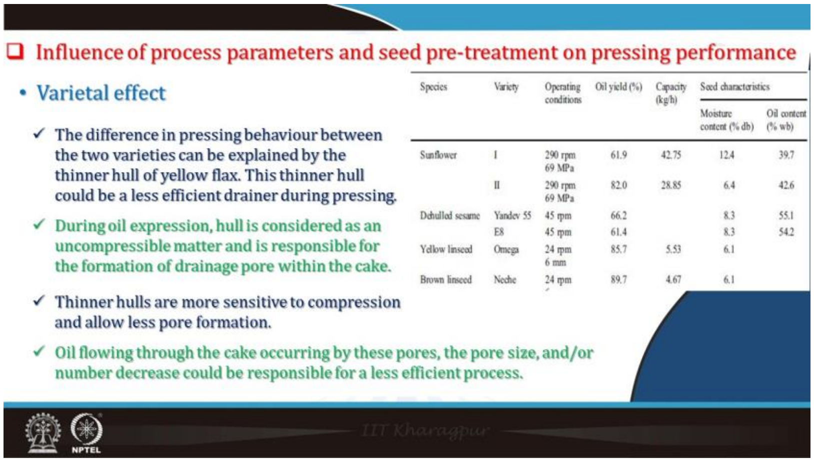
Then comes the compression zone where seed crushing occurs and air contained in this zone between the seeds is expulsed that is more air almost all air is expulsed. And then from here compression zone the seed is passed through the exudation zone and in this exudation zone it is actually as you can see here that is seed is compressed. More pressure is applied and the oil is exuded from the air. Then finally, it moves further to the expansion zone where press releases provoke the water vaporization which is responsible for the meal expansion and the air expansion. So, you get the meal as well as oil both in this case.



So, in this slide I have just tried to give you a comparison of the screw presses characteristics that is these three expanders, expellers, and twin-screw systems they are characteristics, etc. And so, you can see that expanders, they here the entry of the material is forced that there is a mechanical forced entry and there is a variable warm flight to flight distance between the diameter. Discharge is normally through a perforated plate and an unperforated barrel that is possibly perforated at the screw end is provided and it contains an intermediary injection of steam or liquid is possible here in this case.

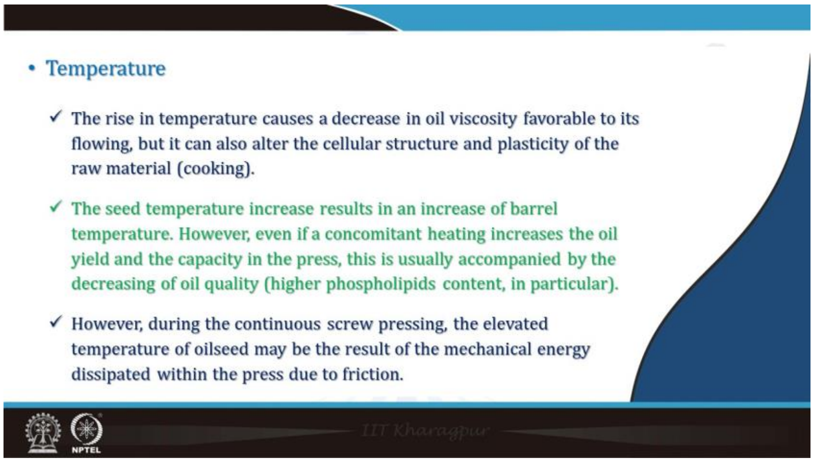
Then see the characteristics of the expellers. The expellers may be Farm scale expellers or industrial scale expellers and in the Farm scale expellers, the feeding is normally on demand by gravity whereas, on the industrial scale it is forced entry. Then the Farm scale expellers there is a constant warm flight to flight distance and diameter whereas, in the industrial scale there is a variable warm flight to flight distance and diameter that can be adjusted depending upon the type of the seal being pressed. Then in the Farm scale expellers, discharges through a die or choke in the industrial stage, it is discharged through an annular space. In the Farm scale expellers, they have the perforated barrel whereas, industrial scale expellers have bars barrel and the bars and barrel and screw could possibly be refrigerated here cooled here as per the requirement so that the oil and milk quality can be controlled.

In the twin-screw systems obviously, there is a forced entry of the material it has also a variable warm flight to flight distance and diameter in this case discharge is through an annular space you can see here and an unperforated barrel is used and their intermediary injection of steam or liquid is possible in this case. So, it was just a comparison between three types of presses.



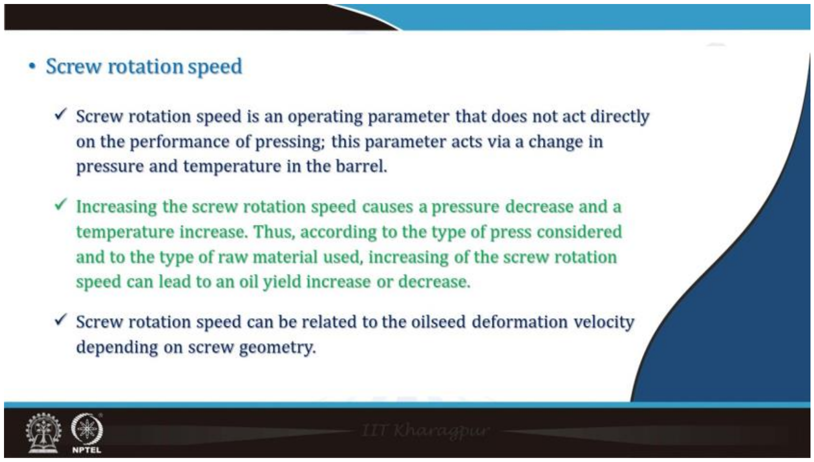
Now, let us see what are the influence of the process parameters and seed pretreatment or pressing performance of these expellers. So, different properties that is both the process parameters as well as what are the various pretreatments of the seed have a significant effect on the pressing performance. So, let us see one by one, first is the varietal effect. The difference in pressing behavior between the two varieties can be explained by the thinner hull of yellow flax and this thinner hull could be a less efficient drainer during the pressing. So, this is one example of how this different varieties these different varieties may be their hulls or husks, etc. There may be some differences etc. and because of this difference, there may be differences in the performance of the expression. During oil expression, the hull is considered an uncompressible matter and it is responsible for the formation of drainage pores within the cake. Thinner hulls are more sensitive to compression and allow less pore formation. Oil flowing through cake occurring by these pores, the pore size and the number decrease could be responsible for a less efficient process.

In this table, you can see that the species there are sunflower two species varieties one and two is taken, and in both 290 rpm of the speed at 69 megapascal pressure was used. And in this case, you can see in variety one the oil yield was 61 to 62 percent whereas, in variety two the oil yield was 82 percent. In the capacity also, in the variety one kg per hour it was around 43 kg per hour whereas, in the second variety 29 kg per hour. The difference you can see here in both the moisture content, in the first variety is around 12.4 percent in second variety is 6.4 percent and also the oil content, the first variety has oil content of around 40 percent, the variety two contains around 43 percent. Similarly, the dehulled sesame of two varieties Yandev55 and E8 and when they have expressed the same operating condition which is 45 rpm screw speed. In the Yandev variety, the oil yield was 66 percent whereas, in the E8 variety the oil yield was only 61 percent, while both have moisture content of about 8.3 percent. Oil content in those i.e. in the Yandev variety was 55, and in the E8 variety was 54 percent wet basis. Similarly, yellow linseed that they were subjected to two operating conditions which are omega variety at 24 rpm and 6 mm screw speed that is the oil yield was 85.7 percent, capacity 5.53 kg and moisture content was 6.1 percent. So, this shows that yes, the different varieties of the seed type of the seed that is their process parameters and pretreatment. The variety is one important parameter that needs to be considered.

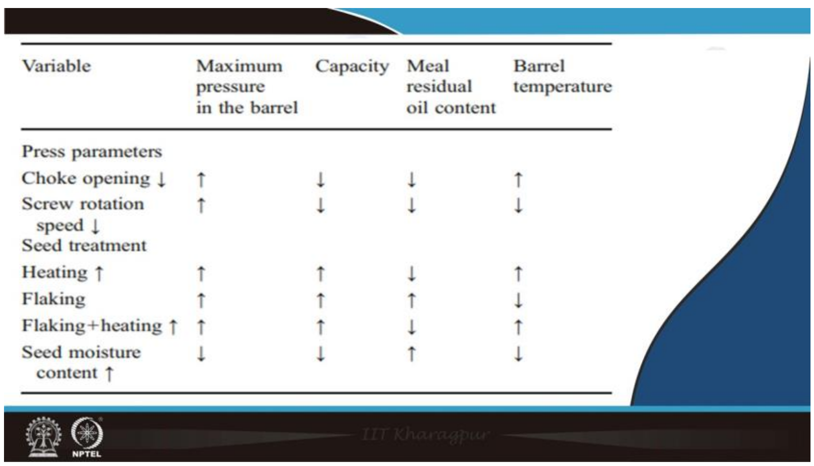


The temperature of the pressing inside the screw where when the pressure is increased obviously, the temperature will also get increased. So, the rise in temperature causes a decrease in oil viscosity which is favorable to its flow, but it can also alter the cellular structure and plasticity of the raw material. The seed temperature increases resulting in an increase of barrel temperature. However, concomitant heating increases the oil yield and the capacity of the press. This is usually accompanied by a decrease in oil quality. However, during the continuous screw pressing the elevated temperature of oilseed may be the result of the mechanical energy dissipated within the press due to friction. So, temperature has an important influence on the process efficiency.

Then screw rotation speed, rotation speed in the earlier table you saw the effect of this screw rotation speed also that it is an operating parameter that does not act directly on the performance of pressing. This parameter acts via a change in the pressure and temperature in the barrel because screw rotation speed will affect the pressure increase and thereby temperature increase temperature change in the barrel.



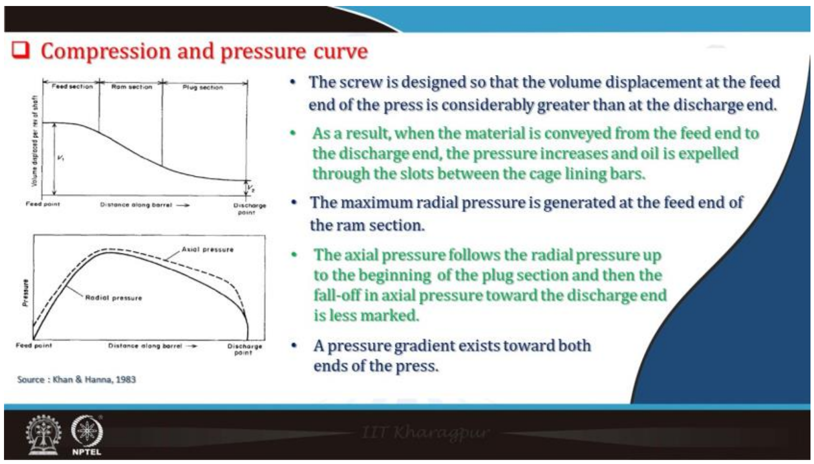
Increasing the screw rotation speed causes a pressure decrease and a temperature increase. Thus, according to the type of press considered and the type of raw material used, increasing the screw rotation speed can lead to an oil yield increase or decrease as the case may be. Screw rotation speed can be related to the oilseed deformation velocity depending upon the screw geometry.



Variable	Maximum pressure in the barrel	Capacity	Meal residual oil content	Barrel temperature
Press parameters				
Choke opening ↓	↑	↓	↓	↑
Screw rotation speed ↓	↑	↓	↓	↓
Seed treatment				
Heating ↑	↑	↑	↓	↑
Flaking	↑	↑	↑	↓
Flaking+heating ↑	↑	↑	↓	↑
Seed moisture content ↑	↓	↓	↑	↓

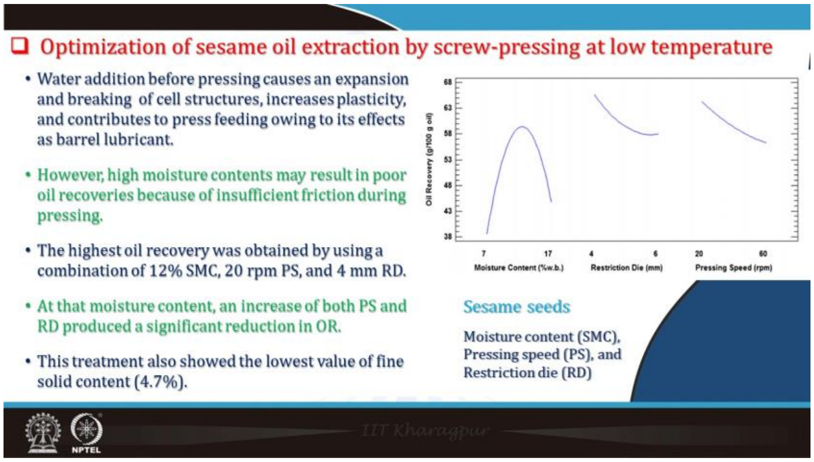
Here I have just given you a comparison that is how the various parameters both press parameters as well as seed treatment influence the properties explaining efficiency. So, if you see the press parameter like choke opening, if the choke opening is lower down or is reduced then maximum pressure in the barrel will increase. The barrel temperature will increase. However, the meal residual oil content as well as the capacity of the expeller will decrease if the choke opening is reduced.

Now, if the screw rotation speed is reduced, what influence it will have? It will increase the maximum pressure in the barrel, but it will cause a reduction in the oil capacity meal residual oil content as well as in the barrel temperature. Now, the seed treatment like heating, if you give more heat treatment, it will result in maximum pressure in the barrel that is it will increase the maximum pressure in the barrel as well as capacity, but it will reduce the residual oil content in the meal that means there is more and more oil is extracted and it will result into the more increase in the temperature obviously, that is why you are getting better recovery here if the heating of the seed during the pre-treatment process is increased. Then the flaking, flaking plus heating, if it is flaked and then heat and if the heating is increased it will cause an increase in the maximum pressure in the barrel, it will also cause an increase in the capacity and increase in the temperature and it will reduce the residual oil content in the meal. Seed moisture content, if it increases increasing the seed moisture content will cause a reduction in the barrel pressure, reduction in the capacity, and reduction in the barrel temperature, and all these influences will obviously, result in more oil content in the meal there is less efficiency and less extraction of the oil.



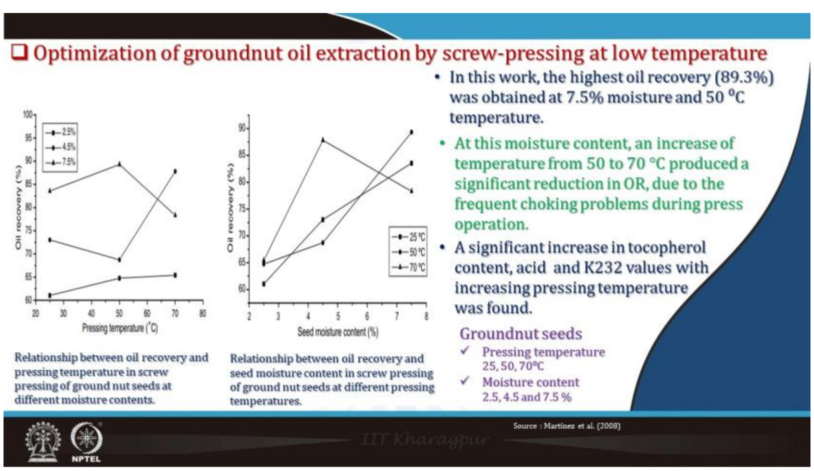
Then see here, the compression and pressure curve. So, you know that the in the screw spelling the screw is designed, so that the volume displacement at the end that is the feed end of the press is considerably greater than that at the discharge end. As a result, when the material is conveyed from the feed end to the discharge end the pressure increases. You can see that from the feed end when it is going to the discharge first the pressure increases and oil is expelled through the slots between the cage lining barrel. The maximum radial pressure is the radial pressure which is increasing and then it reaches to maximum which is followed by axial pressure.

The maximum radial pressure is generated at the feed end of the ram section. This is the ram section you can see here in this is the feed section of the screw then the ram section and then the plug section. As it goes that is to the discharge point the volume displacement will be less, here this volume displacement is more in the feed section. The axial pressure follows the radial pressure up to the beginning of the plug section and then the fall-off in the axial pressure towards the discharge end is less marked as you can see here in this figure. A pressure gradient exists towards both the end of the press. So, this is the compression and pressure curve obviously, if you get more pressure, it influences what I have already given you. So, it will result in more oil recovery. This is the feed point, discharge point, and distance along the barrel in this figure.

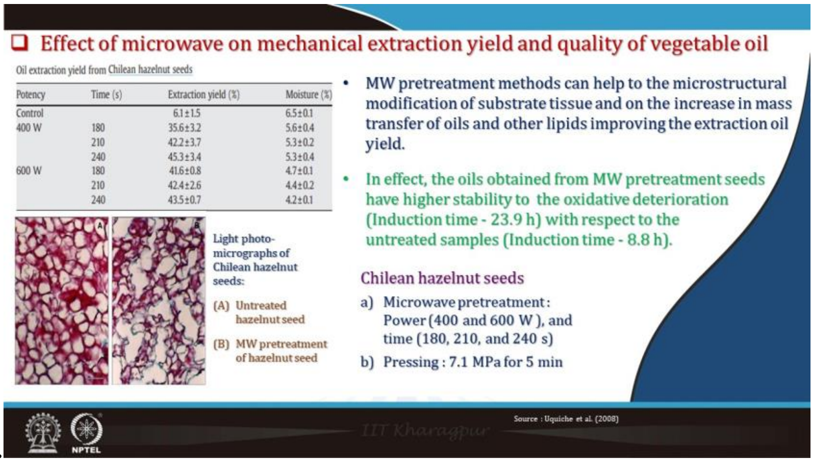


Then a case study, you see the optimization of the sesame oil extraction by screw pressing at low temperature. The effect of moisture content, restriction dye, and pressing speed is shown on the oil recovery. The moisture content is known as seed moisture content SMC. It was used from 7 to 17 percent, restriction dye (RD) was used at 4 and 6 mm, and pressing speed was 20 and 60 rpm that is PS. So, the salient finding that the experiment was conducted and then it was found that water addition before pressing causes an expansion and breaking of cell structure that increases plasticity and contributes to press feeding owing to its effects on barrel lubricants. However, the high moisture content may result in poor oil recoveries because of insufficient friction during the pressing. You can see here that if the up to certain moisture content the oil recovery increases and beyond which it decreases. The highest oil recovery was obtained by using a combination of 12 percent seed moisture content approximately you can see here 20 rpm pressing speed and 4 mm restriction dye.

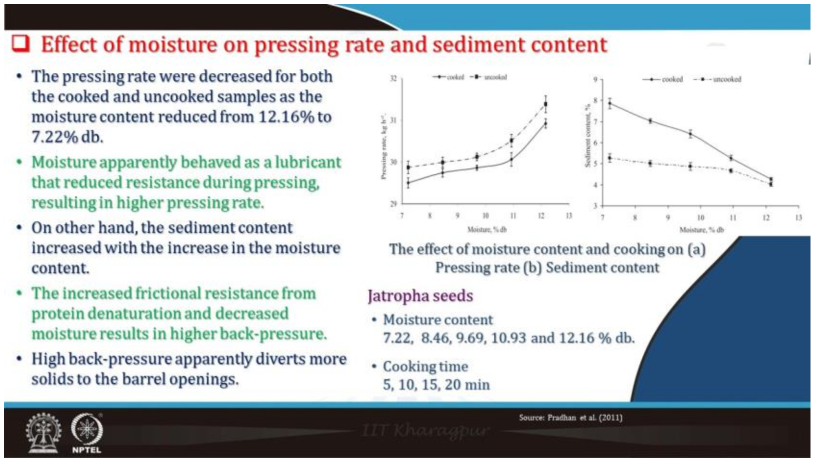
At the moisture content, an increase in both the PS and the RD. that is the pressing speed as well as restriction dye produced a significant reduction in the oil recovery. This treatment also showed the lowest value of the fine solid content in the oil which is about 4.7 percent or so.



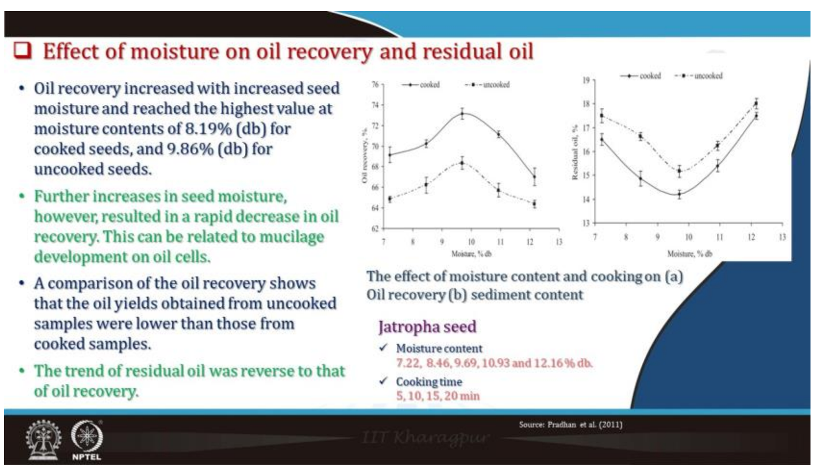
Another case study. In this work, the highest oil recovery as you can see here in the pressing temperature is basically not sesame, but groundnut alright that is only written here. So, the relationship between oil recovery and pressing temperature, and the second graph shows the relationship between oil recovery and seed moisture content. So, groundnut seeds were pressed at temperature 25, 50, and 70 degree Celsius and the moisture content of the seeds were about 2.5, 4.5, and 7.5 percent. At moisture content that is about 7.5 percent moisture content and 50 degree Celsius temperature. An increase the temperature from up to 70 degree Celsius produced a significant reduction in oil recovery. And this might be mainly due to the frequent choking problems during press operations. A significant increase in tocopherol content and acid and K232 values with increasing pressing temperatures was also reported.



Then effect of another case study is the effect of microwaves on mechanical extraction yield and quality of vegetable oil. You can see here that it was basically, Chilean hazelnut seeds the microwave treatment pretreatment was given power 400 and 600 watts, and time was 180, 210, and 240 seconds, and pressing was done at 7.1 megapascal for 5 minutes. In the figure here, in A and B, you can see it is a light photomicrograph of Chilean hazelnut seeds, A is the untreated seed and B the second one is the microwave pretreatment of the seed. There is a clear-cut difference that can be seen and both these have significant effects on the oil recovery. That is microwave pretreatment method can help with the microstructural modification of substrate tissues and the increase in mass transfer of the oil and other liquids improving the extraction oil yield. In effect, the oil obtained from microwave pretreatment seeds has higher stability to the oxidative deterioration that is incubation time is about 23.9 almost 24 hours with respect to the untreated sample which had an induction time of around 9 hours.

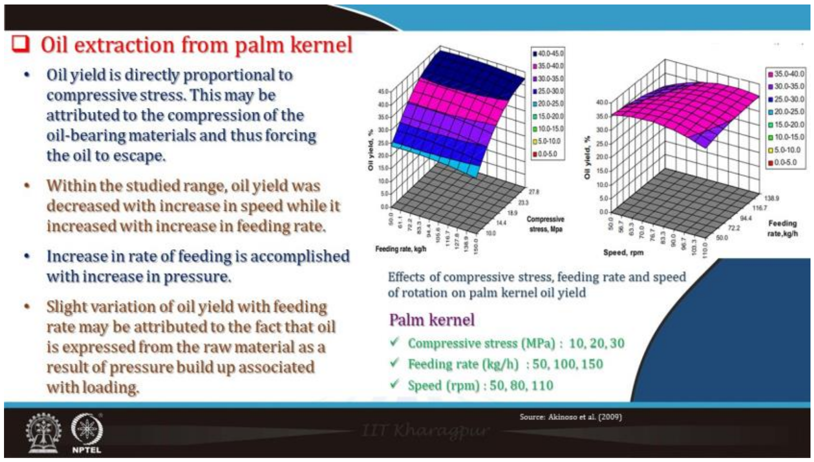


The effect of moisture on pressing rate and sediment content. It was a Jatropha seed, moisture content was about 7, 8, 9, 10, and 12 percent approximately and the cooking time was 5, 10, 15, and 20 minutes it was an experimental by Prasad et al. It was reported and you can see that with an increase in the moisture content that is up to 12 percent, there is a pressing rate also increases and both these have the influence on the sediment content in the oil, both in the cooked and uncooked. The pressing rate was decreased for both the cooked and uncooked samples as the moisture content reduced from 12.16 percent to around 7 percent or so it is decreased. Moisture behaved as a lubricant that reduced the resistance during pressing resulting in a higher pressing rate. On the other hand, the sediment content increased with the increase in moisture content. The increased frictional resistance from protein denaturation and decreased moisture results in higher back pressure. High back pressure diverts more seeds or more solids to the barrel opening.

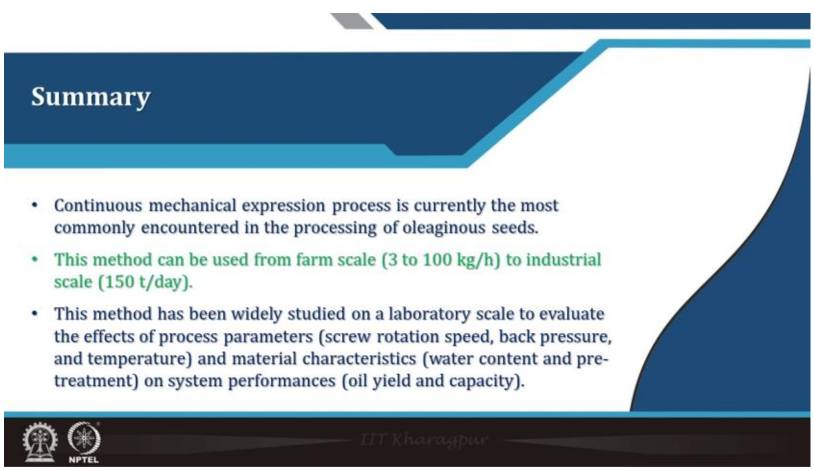


Similarly, in this, you can say the effect of the same experiment is the effect of moisture content on oil recovery and the effect of moisture content on the residual oil in the meal both in the case of cooked and uncooked seeds. The oil recovery increased with increased seed moisture and reached the highest value at a moisture content of around 8 percent dry basis for cooked seeds and almost 9.86 or 10 percent dry basis for uncooked seeds.

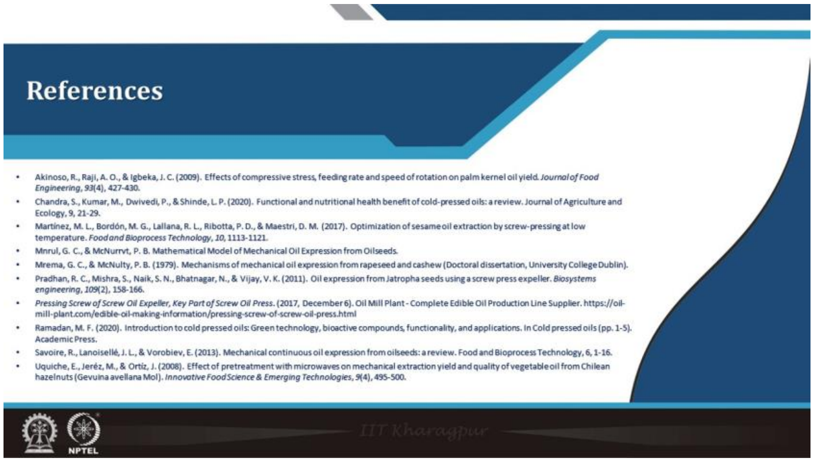
Further increase in seed moisture, however, resulted in a rapid decrease in oil recovery this can be related to the mucilage development on oil cells. A comparison of the oil recovery shows that the oil yields obtained from the uncooked samples were lower than those from the cooked samples and the trend of residual oil was reversed so that of the oil recovery.



In the oil extraction from the palm kernel, you can see that compressive stress was used about 10, 20, and 30 megapascals. The feeding rate was 50, 100, and 150 kg per hour, and screw speed (rpm) was 50, 80, and 110 rpm, and these are the response surface graph showing the effect of feed rate and compressive stress on the oil yield as well as speed and feeding rate on the oil yield. Oil yield, as you can see from this graph, the oil yield is directly proportional to the compressive stress. This may be attributed to the compression of the oil-bearing materials thus forcing the oil to escape. Within the studied range oil yield decreased with an increase in speed while it increased with an increase in the feeding rate. An increase in the rate of feeding is accomplished with an increase in pressure. Slight variation of oil yield with feeding rate may be attributed to the fact that oil is expressed from the raw material as a result of pressure buildup associated with loading.



So, finally, I would summarize this lecture by saying that yes, the continuous mechanical expression process is currently the most commonly encountered in the processing of oil seeds or oleaginous seeds. This method can be used from the farm scale where there are machines that can handle 3 to 100 kg per hour to the industrial scale that is which can use even 150 tons per day. This method has been widely studied on a laboratory scale to evaluate the effect of process parameters like screw to rotation speed, back pressure and temperature, material characteristics, water content, and pretreatment type of the seed performance, oil yield, and capacity.



So, these are the references that are used in this lecture.

Thank you very much for your patience here. Thank you.