Novel Technologies for Food Processing and Shelf Life Extension
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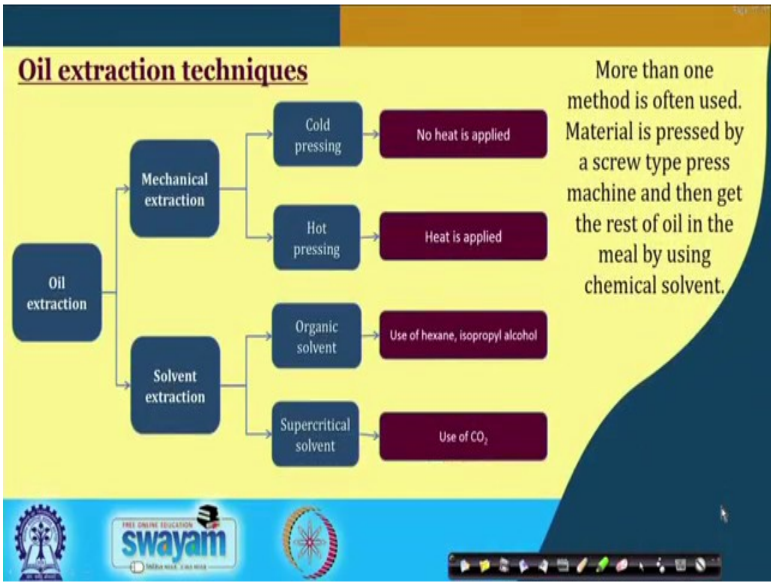
Lecture – 30
Extraction of Oil (Part 1- Mechanical Expression)

This topic of extraction of oil will be taken up in two parts. In the part-1, the mechanical extraction of oil and in the 2nd part, solvent extraction will be studied.

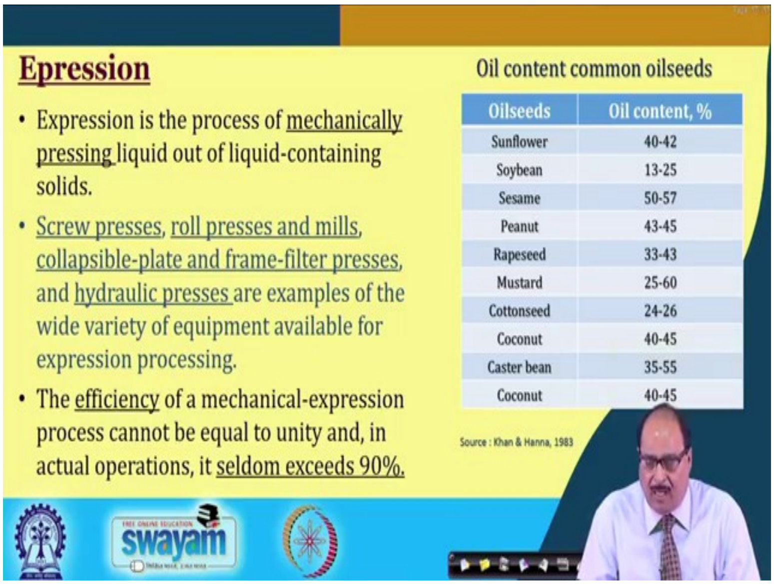
In the last class, fats and oils or food lipids have been introduced. They are not found free in nature, rather they are present either in animal cells in the adipose tissues or in the seeds and fruits of plants and other plant materials.



So, either from plant or animal sources, these oils and fats are extracted using appropriate technologies. So, this part of the lecture will focus on the different methods of extracting oil from oil bearing plant materials like oilseeds, fruits, nuts, etc. Generally for the extraction of oil from the oil seeds two operations are used. One is the mechanical expression, and another is the solvent extraction. In the mechanical process, there are processes which apply heat; there are processes which do not apply much heat. And accordingly the processes are known as cold pressing or hot pressing.

In the solvent extraction method, organic solvents like hexane, isopropyl alcohol, benzene, etc. or even more safe or green solvents like supercritical carbon dioxide can be used for extraction purposes.

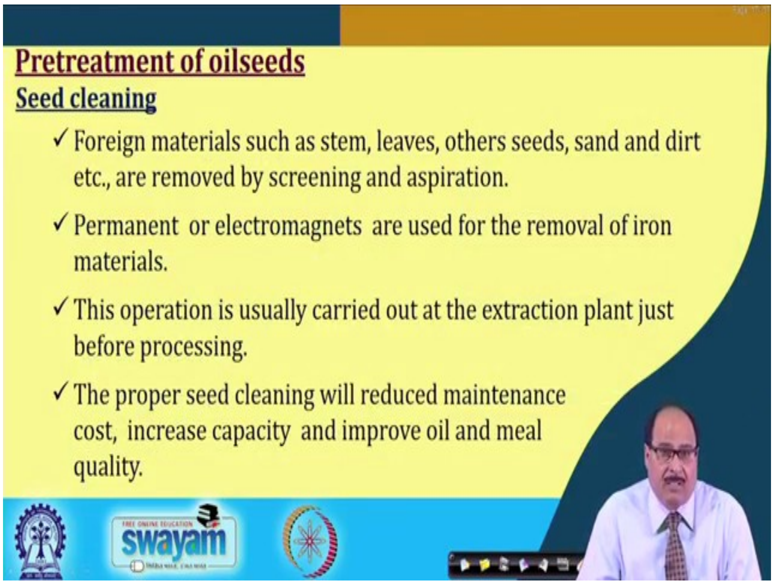
Invariably, it has been seen that by the industry the combinations of methods are used for extracting the oil, because the objective is to get the maximum oil from the oilseed without any significant reduction in the quality of the oil as well as in the quality of the left residue which is called meal. So, accordingly process parameters are optimized and suitable technologies, equipments and machineries are used for this purpose.



In table, the oil content of some of the major oil seeds like sunflower oil, soya bean oil, peanut, rapeseed, etc. are indicated. Some of the materials like mustard or even sunflower oil etc. contain oil to the tune of even as high as 45 to 50 or 60 %.

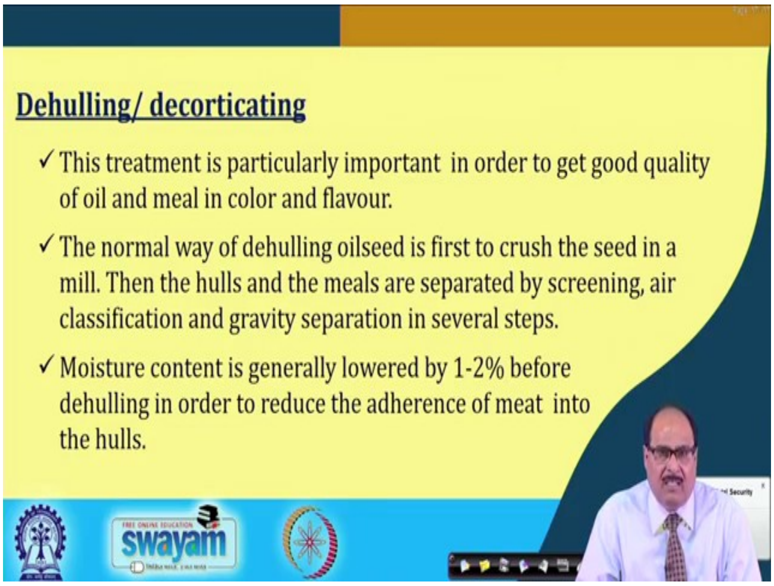
Expression is the process of mechanically pressing liquid out of liquid containing solids. And different presses like screw press, roller presses and mills, collapsible-plate and frame-filter presses, hydraulic presses, etc. are examples of the wide variety of equipment, which are available for expression of liquids from solid materials or i.e. the liquid solid extraction.

The efficiency of a mechanical-expression process cannot be unity, and in actual operations, it seldom exceeds 90 %. If one can get 90 % extraction, that process can be considered to be a very good mechanical extraction process.



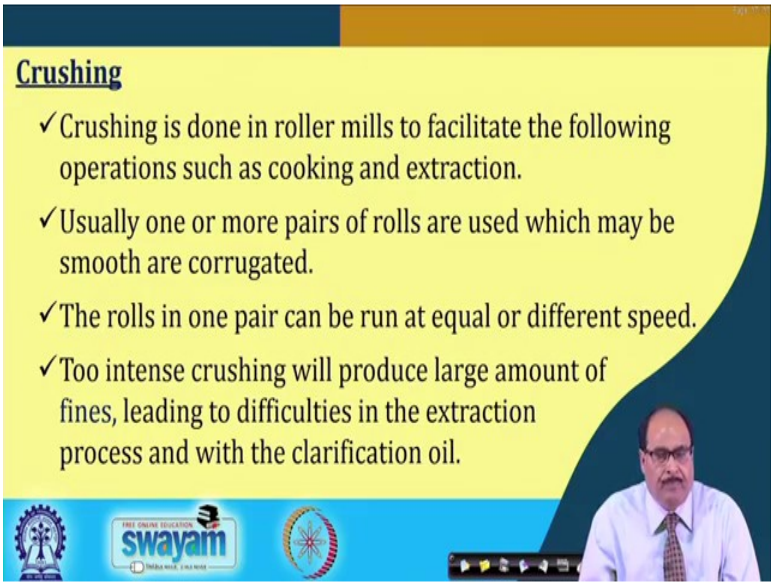
The oilseeds need to be given various pretreatment before subjecting to the actual extraction process. The main objective of these pretreatment is to get the best quality and maximum yield of the oil as well as meal.

So, the first treatment is seed cleaning in which the foreign materials such as stems, leaves, other seeds, sand, dirt, etc. are removed by screening and aspiration. Permanent or electromagnets are used sometimes to remove the iron particles. This operation is usually carried out at the extraction plant just before processing. And the proper seed cleaning will reduce the maintenance cost; it will increase the capacity of the plant and will improve both the oil and meal quality.

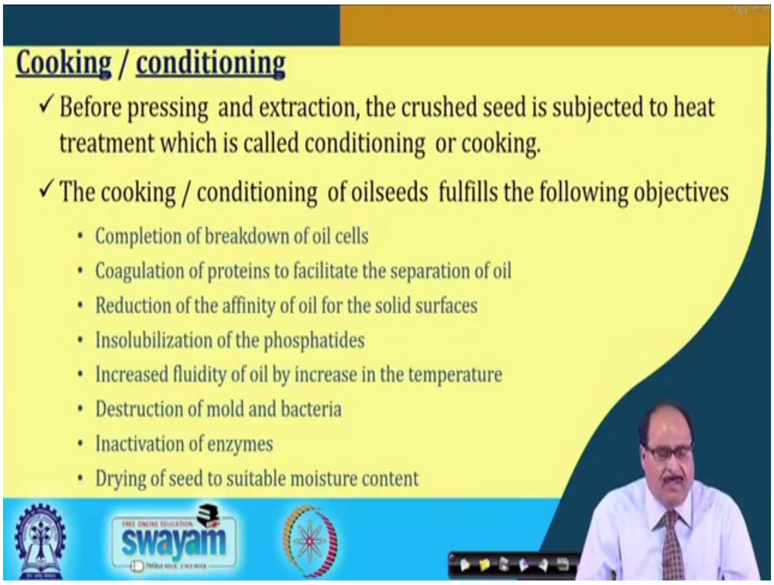


After the cleaning, the seeds are dehulled and decorticated i.e. outer husk or fibrous materials of the seed or seed coat is removed. And this treatment is particularly important in order to get good quality of oil and meal in terms of colour and flavour. The normal way of decorticating oilseed is first to crush the seed in a mill. Then the hulls and the meals are separated by screening, air classification and gravity separation in several steps as the case may be.

Generally moisture content is lowered by 1 to 2 % before dehulling just to reduce the adherence of the meat with the hulls. So, the seed coat loosens and its removal becomes easy; the dehulling or decorticating operations become easier.

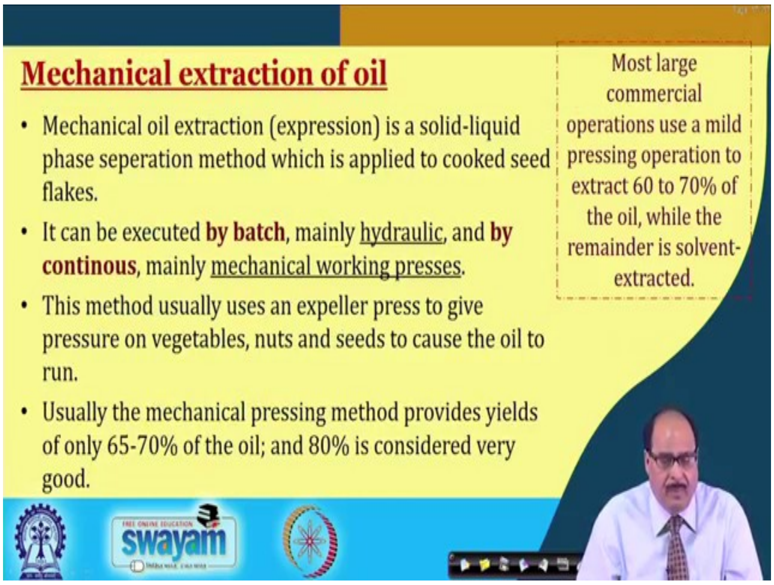


After the dehulling or decorticating, next pretreatment is the crushing. It is done in roller mills to facilitate the operations such as cooking and extraction. Usually one or more pairs of rolls are used which may be smooth or corrugated. The rolls in one pair can be run at equal or different speed. So, depending on the nature of the seed, seed coat, hulls, etc. present or the amount of the pressure or other factors or energy required to dehull the seed, the rolls can be operated. But, one thing important here is to note that too intense crushing should be avoided, since it will produce large amount of fines; a large amount of fines will lead to difficulties in the extraction process. Because if the crushing is done very fine, then during the pressing or other treatment this may form a solid cake and it may adversely affect the flow of the oil from the material. And also if there are too much fines, they may go into the oil which will increase the clarification or refining cost.



The next pretreatment is cooking or conditioning. So, before the extraction process, the crushed seed is subjected to heat treatment and this process is called conditioning or cooking. Cooking serves the following objectives:

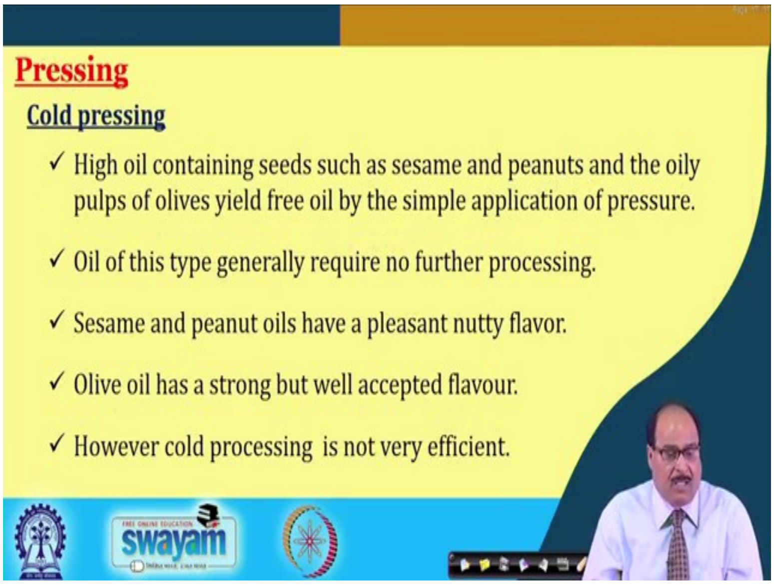
- Completion of breakdown of oil cells
- Coagulation of proteins to facilitate the separation of oil
- Reduction of the affinity of oil for the solid surfaces
- Insolubilization of the phosphatides
- Increased fluidity of oil by increase in the temperature
- Destruction of mold and bacteria
- Inactivation of enzymes
- Drying of seed to suitable moisture content



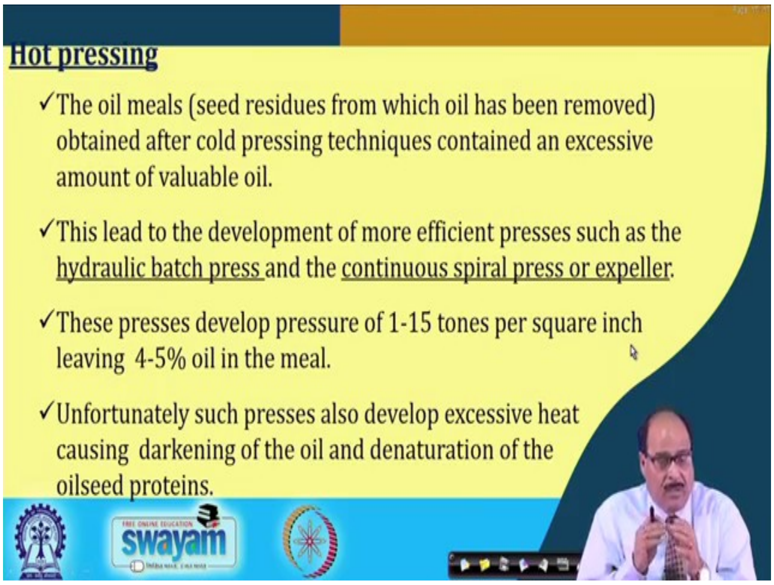
After these pretreatments, the prepared oilseeds are crushed, cooked and conditioned oilseeds are subjected to mechanical extraction process. So, the mechanical extraction process or expression is a solid-liquid phase separation method which is applied to cooked seed flakes. It may be executed in batch, mainly by hydraulic presses or in continuous operation by mechanical working presses.

This method usually uses an expeller press to give pressure on vegetables, nuts and seeds to cause the oil to run in the continuous method. Depending upon the process conditions, pressing results into the maximum yield of 65 to 70 or 80 %.

So, the large amount of 20 to 30 % oil remains in the meal. Generally, a part of the oil that may be 60, 70 % is removed by pressing operation and the remaining using solvent extraction method. This is called pre-press solvent extraction method.

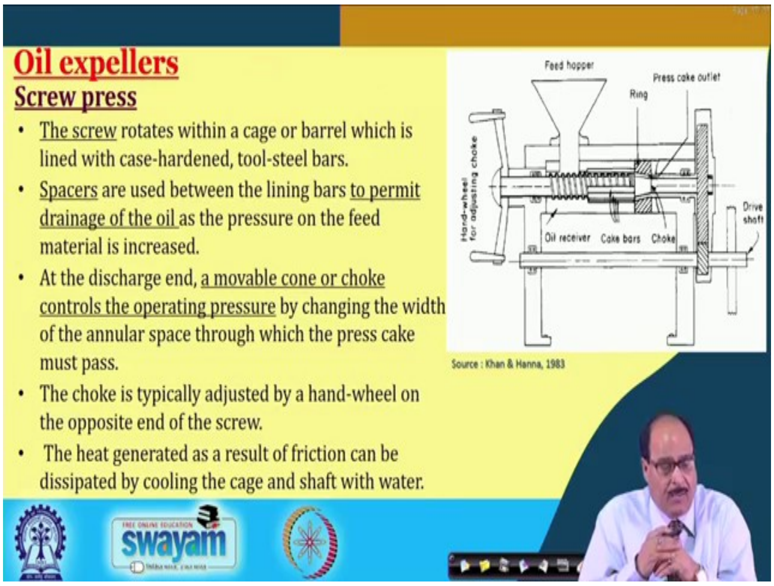


There are two methods of pressing: Cold pressing and hot pressing. Cold pressing is generally used for high oil containing soft seeds like sesame, peanut, olive, palm, etc. In this, the fat content is generally high and the tissue is comparatively softer. So, just by application of simple pressure, the oil cells get broken and the oil is released. And oil of this type generally require no further processing, they are used as virgin oil. Sesame and peanut oils etc. have very pleasant nutty flavor. Olive oil has a strong but well accepted flavour. However, cold pressing is not very efficient and large amount of valuable oil remains in the oilseed meal.



So, to overcome this or to get more oil yield, hot pressing methods are developed. The oilseed meals (seed residues from which oil has been removed) obtained after cold pressing techniques contain an excessive amount of valuable oil and this leads to the development of more efficient presses such as the hydraulic batch press, and continuous spiral press or expellers.

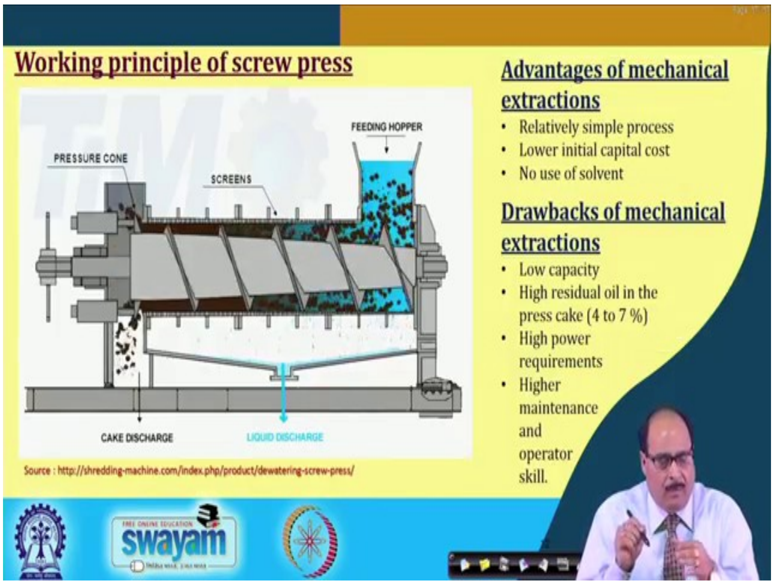
These presses develop pressure of about 1 to 15 tons per square inch, and under these conditions, comparatively more yield of oil is obtained; only about 4-5 % of the oil remains in the meal. But, unfortunately such presses also develop excessive heat and which causes darkening of the oil as well as denaturation of the oilseed proteins.



Oil expellers

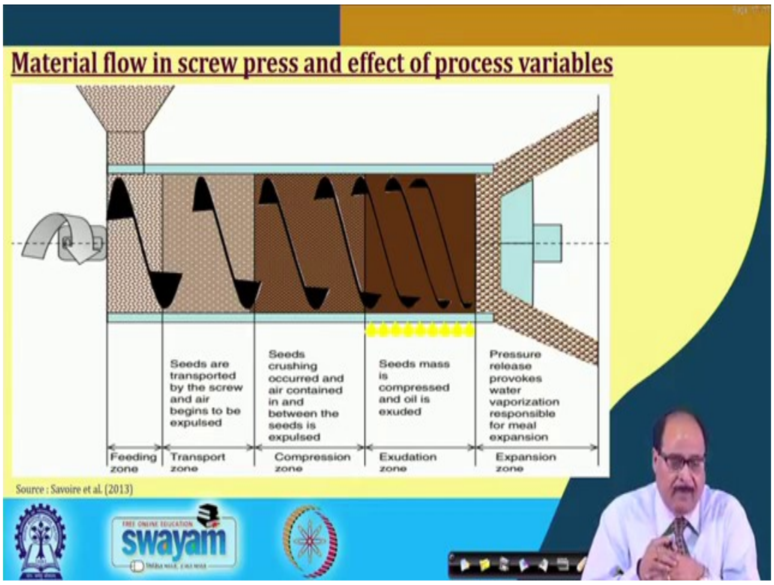
Screw press:

The screw rotates within a case or barrel which is lined with case-hardened, tool-steel bars. Spacers are provided which permit the drainage of oils as the pressure on the feed material is increased. At the discharge end, a movable cone or choke controls the operating pressure by changing the width of the annular space through which the press cake passes. The choke is typically adjusted by a hand-wheel on the opposite side of the screw so as to get the desired pressure generated. The heat generated as a result of the friction right can be dissipated by cooling the cage and shaft with the water.



Working principle of screw press: The material is fed from the top through the feeding hopper (see Fig.) and as it passes through the screw where the screens are provided, the oil cells rupture. The screw geometry is designed in such a manner that as it moves towards the end, its pitch increases and more and more pressure develops in the space between the screw and the barrel frame. So, more the pressure develops, more the extraction of oil. Oil is collected at the base provided. At the end of the screw, there is the cake discharge. Depending upon the oil cakes, even 2-3 times it can be recycled to get the maximum recovery. By the choke arrangement, one can adjust the pressure.

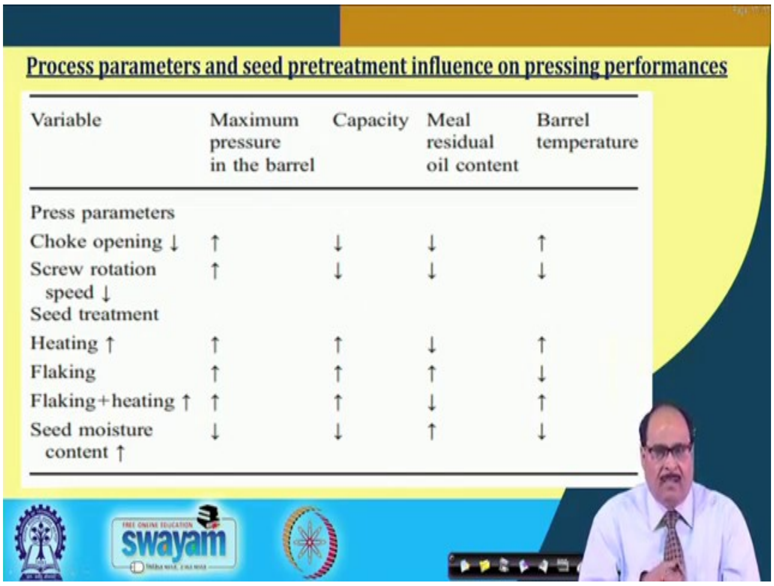
The mechanical extraction process is advantageous, because it is a relatively simple process. It has lower initial capital cost and there is no use of solvent. However, it has some drawbacks as well. Like it has low capacity, high residual oil content in the press cake, high power requirement and high maintenance cost for the operation.



Material flow in screw press and effect of process variables:

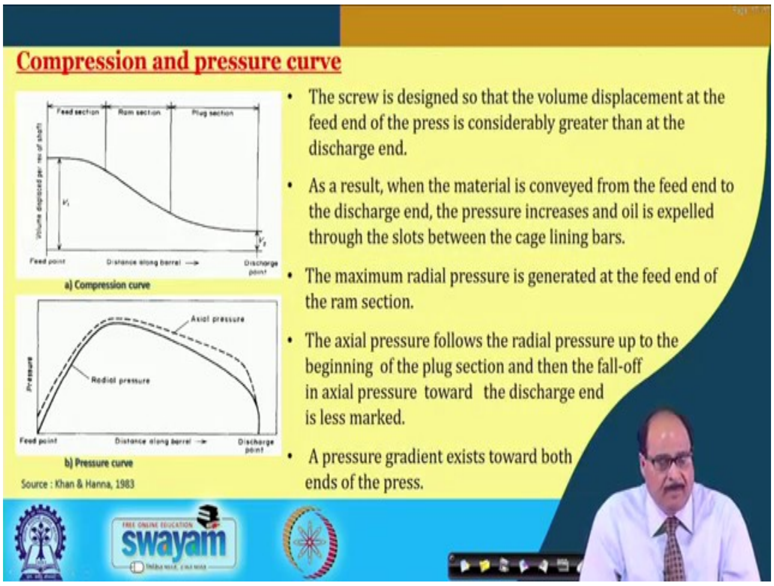
This figure shows the movement of the material in screw press and effect of process variables.

In the feeding zone, the material comes and then moves towards the transport zone, where the seeds are transported by the screw, and air begins to be expulsed from the seeds. Then seed crushing occurs and air content in between the seeds is expulsed. Finally, the seed mass is compressed and the oil is excluded from the material. And then it goes out as the pressure release provokes water vaporization, which is responsible for the meal expansion.



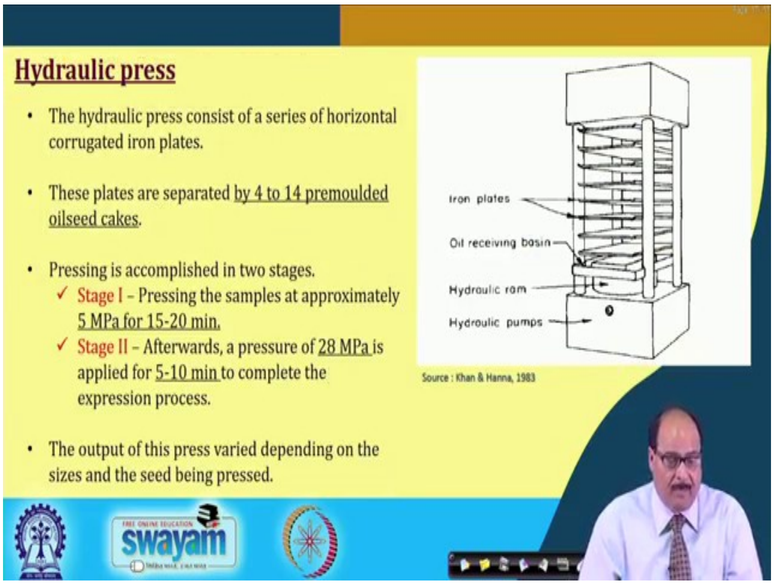
Variable	Maximum pressure in the barrel	Capacity	Meal residual oil content	Barrel temperature
Press parameters				
Choke opening ↓	↑	↓	↓	↑
Screw rotation speed ↓	↑	↓	↓	↓
Seed treatment				
Heating ↑	↑	↑	↓	↑
Flaking	↑	↑	↑	↓
Flaking+heating ↑	↑	↑	↓	↑
Seed moisture content ↑	↓	↓	↑	↓

In this table, the influence of different variables like press parameters, choke opening, screw rotation speed, seed treatment, heating, flaking, etc. on the generation of the pressure in the barrel, capacity, meal residue oil content or barrel temperature etc. is shown. They all significantly influence the oil quality and oil yield.



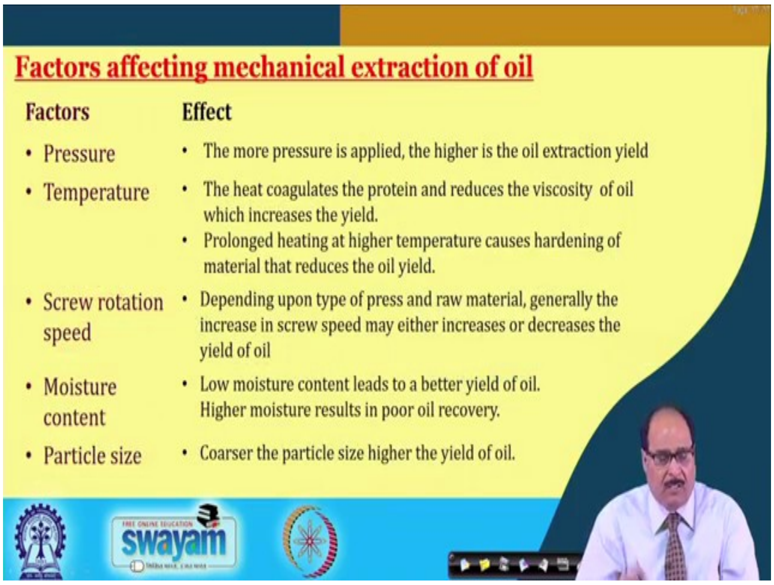
Compression and pressure curve: It was reported that the screw is designed (see Fig.), so that the volume displacement at the feed end is considerably greater than that at the discharge end. As a result, when the material is conveyed from the feed end to the discharge end, the pressure increases and oil is expelled through the slots between the cage lining bars. The maximum radial pressure is generated at the feed end of the ram section.

The axial pressure (see Fig.) follows the radial pressure up to the beginning of the plug-section and then the fall-off in axial pressure towards the discharge of the end is less marked. A pressure gradient, therefore exist towards the end of the process. And it is the pressure gradient more towards the discharge end which results in the rather more expression or more extraction of the oil.



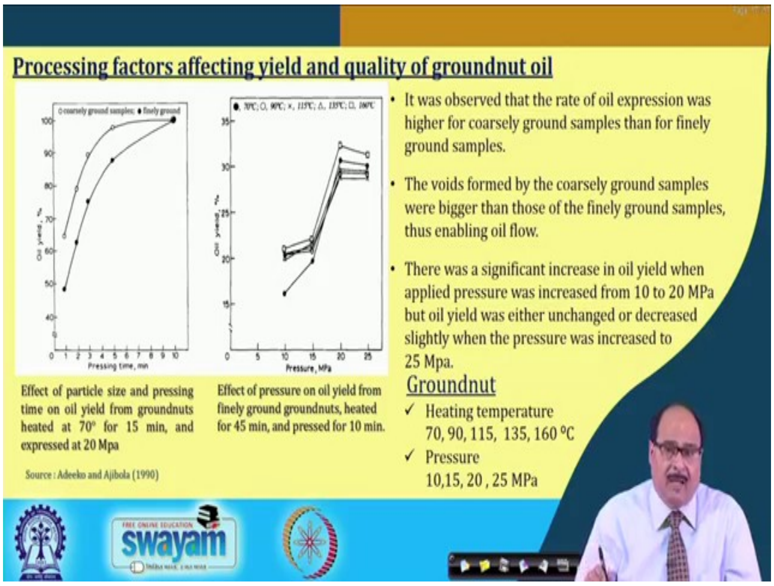
Another type of batch pressing is the hydraulic press. The hydraulic press consists of a series of horizontal corrugated iron plates; these plates are separated by 4 to 14 premoulded oilseed cakes.

The pressing is accomplished in two stages i.e. first pressing the sample at approximately 5 MPa for 15 to 20 min, which is followed by a pressure of 28 MPa for 5 to 10 min. Initially by simple application of the pressure, the molecular diffusion theory holds good, but when the oil content in the seed becomes less, it becomes difficult to get extracted. May be towards the later part of the extraction, little higher pressure is required for some time. Therefore, output of this press vary depending upon the size and seed being pressed.



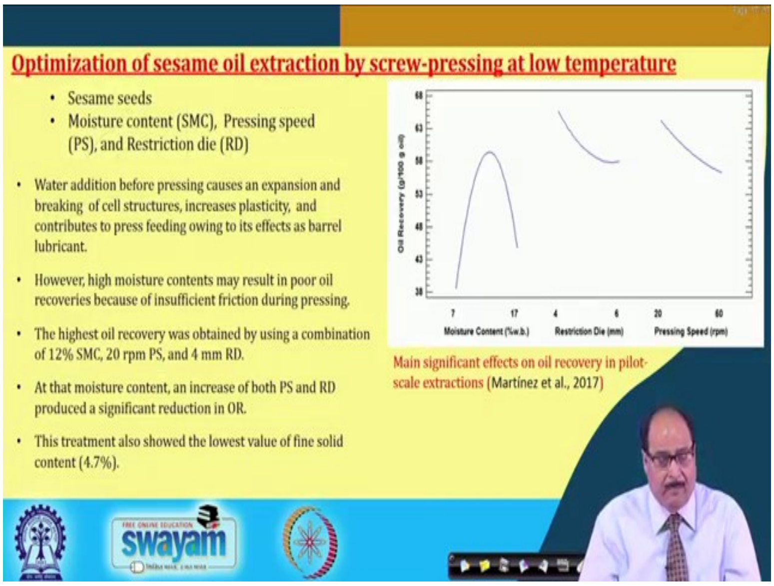
Factors affecting the mechanical extraction process of the oil and yield: Particularly if the more pressure is applied, the higher is the oil extraction yield. The heat coagulates the protein, reduces the viscosity of the oil, which increases the yield. Prolonged heating at higher temperature, however causes hardening of the material that reduces the yield. So, excessive heating should be avoided.

Depending upon the type of the press and the raw material, generally the increase in screw speed may either increase or decrease the yield of the oil. Low moisture content leads to a better oil yield. Higher moisture content, however results in poor oil recovery. Coarser the particle size, higher will be the yield of the oil.



Processing factors affecting yield and quality of groundnut oil:

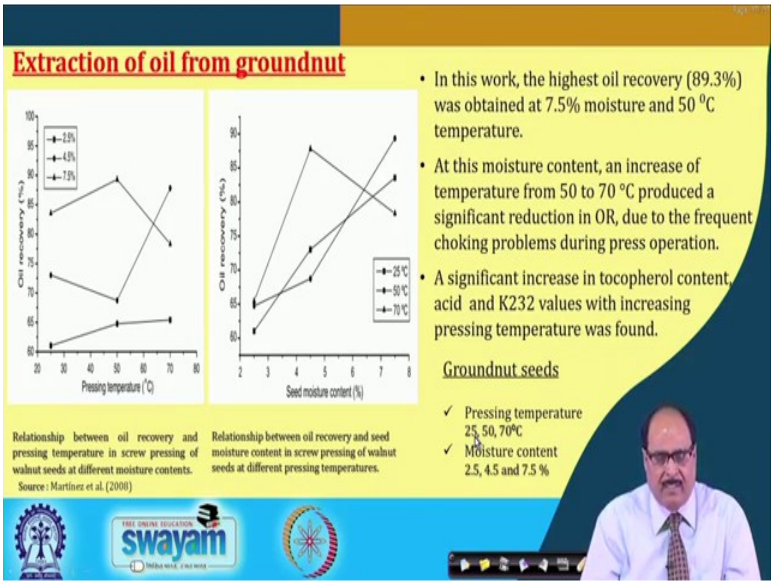
In one of the studies reported on the groundnut oil extraction, where the heating temperature varied from 70 to 160 ºC and pressure from 10 to 25 MPa, the result showed that the rate of oil expression was higher for the coarsely ground samples than that of the finely ground sample (see Fig.). The voids formed by coarsely ground samples are bigger than those in the finely ground samples and these bigger voids enable the easy flow of the oil. There was a significant increase in oil yield, when the applied pressure was increased from 10 to 20 MPa, but oil yield was either unchanged or decreased slightly, when the pressure was increased more than 25 MPa. So, there is a limitation of pressure here one should decide or optimize the amount of pressure required. Because, if too much pressure is applied for a longer duration of time, it might result into the compression of the oilseed yield which may adversely affect the yield.



Optimization of sesame oil extraction by screw-pressing at low temperature:

Several researchers have optimized the sesame oil extraction process by screw pressing at low temperature. They have varied moisture content, pressing speed, and restriction die. And the results indicated that water addition before pressing causes an expansion, and breaking of cell structure, it increases the plasticity and contributes to press feeding owing to its effects as that of lubricant.

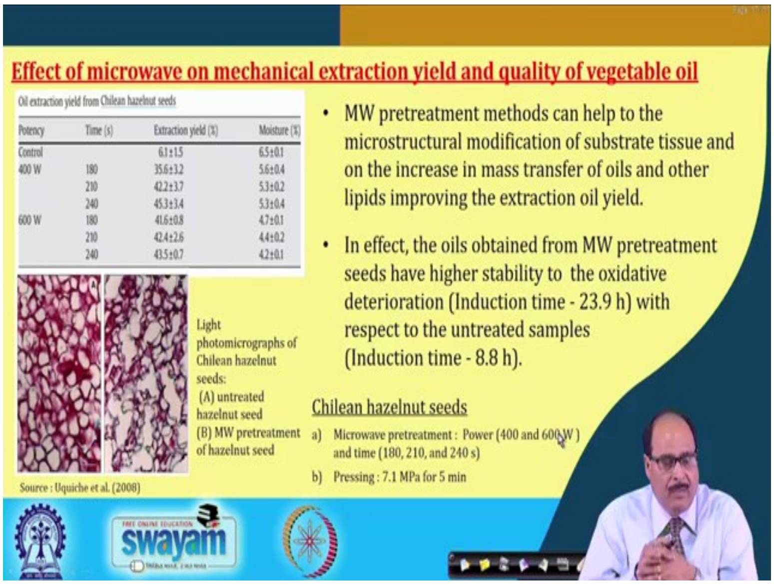
However, high moisture content may result in poor oil recoveries because of the insufficient frictions generated during pressing. The highest oil recovery was obtained by using a combination of about 12 % seed moisture content, 20 rpm pressing speed, and 4 mm restriction die. At that moisture content, an increase in both the pressing speed as well as restriction die resulted in a significant reduction in oil recovery. And the treatment also showed the lowest value of fine solid content (4.7%).



Extraction of oil from groundnut:

Pressing temperature were 25, 50 and 70 ºC and moisture content were 2.5, 4.5 and 7.5 %. Its effect on seed moisture content, pressing temperature and oil recovery was studied.

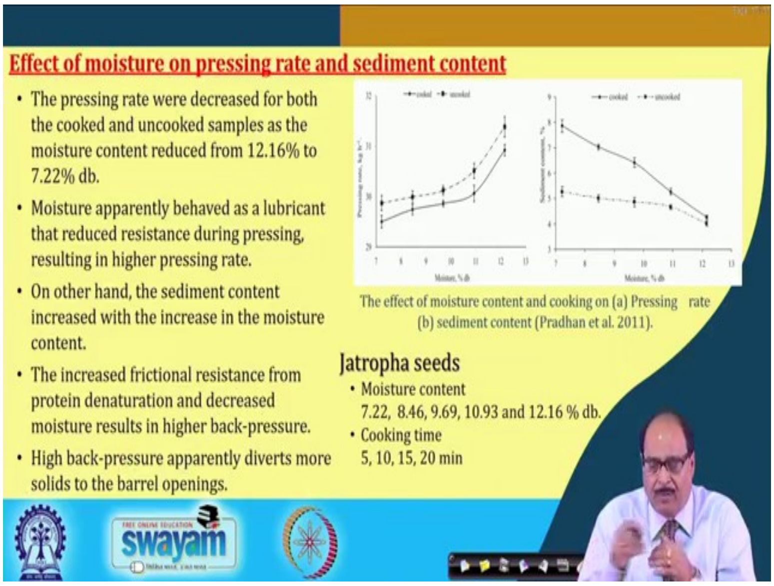
The highest oil recovery may be 89 % (see Fig.) was obtained at 7.5 % moisture content and 50 ºC temperature. And at this moisture content, an increase of the temperature from 50 to 70 ºC produced a significant reduction in oil recovery and the reason might be the frequent choking problems during the press operations.



Effect of microwave on mechanical extraction yield and quality of vegetable oil:

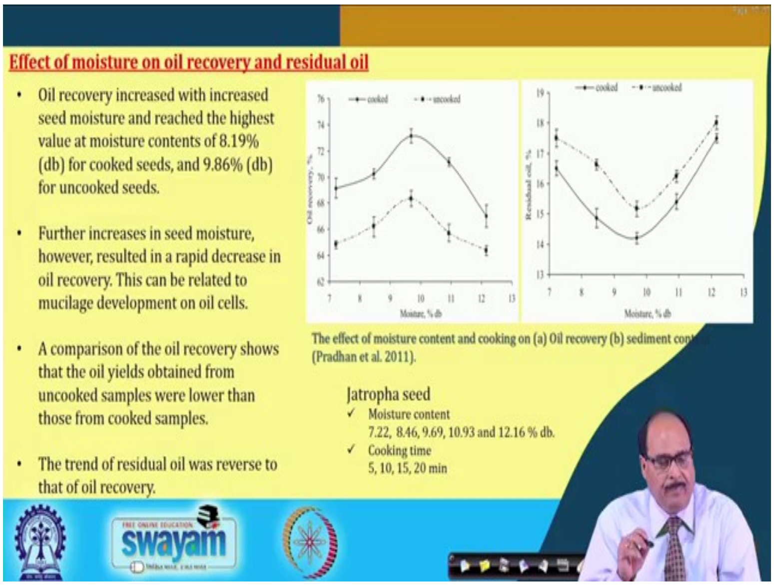
The microwave power were 400 and 600 watt for 180 to 240 sec. It was a microwave treatment followed by pressing at 7.1 MPa for 5 min. The results are shown in the table; the effect of both power level and time on the extraction yield is indicated. It was found that the microwave pretreatment method can help in the microstructural modification of the substrate tissues. Therefore, it results into the increase in the mass transfer of oils, and other lipids improving the extraction yield. So, in fact the microwave pretreatment results into the comparatively better extraction yield.

And another important observation made in this study was that microwave pretreatment of seeds lended higher stability both to the oil as well as to the meal i.e. oxidative deterioration was less; induction time was 23.9 hours for the treated sample as compared to the 8.8 hours for the untreated sample.



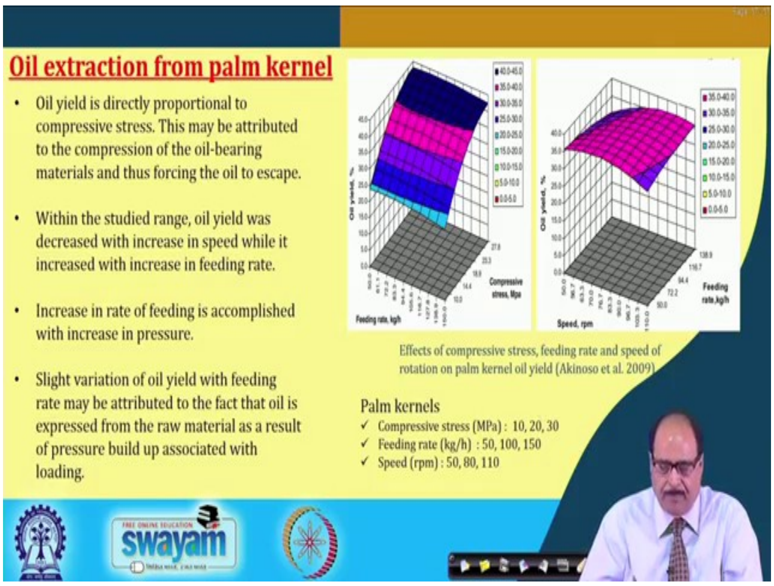
Effect of moisture on pressing rate and sediment content in Jatropha seeds:

By increasing the moisture content and temperature (see Fig.), it results into the significant reduction or increase in the pressing rate of the sedimentation content as the case may be. The pressure rate was decreased for both cooked and uncooked samples as the moisture content was reduced from about 12 to 7 %. The increased friction resistance from the protein denaturation and decreased moisture results in higher back pressure. And high back pressure apparently diverts more solids to the barrel openings. So, the moisture apparently behaves as lubricant that reduced the resistance during pressing, resulting in the higher pressing rate.



Effect of moisture on oil recovery and residual oil in the Jatropha seed:

The oil recovery increased with increased seed moisture and reached the highest value at moisture content of about 8.19 % dry basis for cooked seeds, 9.8 % dry basis for uncooked seeds (see Fig.). Further increasing the seed moisture however, resulted in a rapid decrease in the oil recovery. This can be related to mucilage development on the oil cells. A comparison of the oil recovery shows that the yield obtained from uncooked samples were lower than those obtained from cooked sample.



Oil extraction from palm kernel:

The oil yield is directly proportional to the compressive stress. This may be attributed to the compression of the oil bearing material and thus forcing oil to escape. The experiments were conducted under these conditions: compressive stresses were 10, 20, and 30 MPa, feeding rate was 50, 100 and 150 kg/h and speed of the pressing was 50, 80 and 110 rpm.

The effect of feeding rate, compressive stress and speed of rotation on palm kernel oil yield is shown by the response surface curves. Increase in the rate of feeding is accomplished with increase in pressure. The 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 build up associated with loading.