Organic Chemical Technology
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Lecture - 04
Edible and Essential Oils

Welcome to the MOOCs course organic chemical technology. The title of today's lecture is edible and essential oils. This lecture and coming couple of lectures we will be discussing about the production of oils especially vegetable oils and then essential oils in chemical industries, right? So, the production includes extraction of crude oil, let us say if you are getting or if you are producing vegetable oils what you do? You try to do the extraction of crude oil from oil seeds. So, this extraction is in general two types, you know extraction by mechanical methods and by using solvent extraction process, right? So, by following either of these approach or by combination of these two approaches you will get crude oil which is obviously not the final refined one. So, then this crude oil would be processed or purified where hydrogenation, catalytic hydrogenation is one of the important process.

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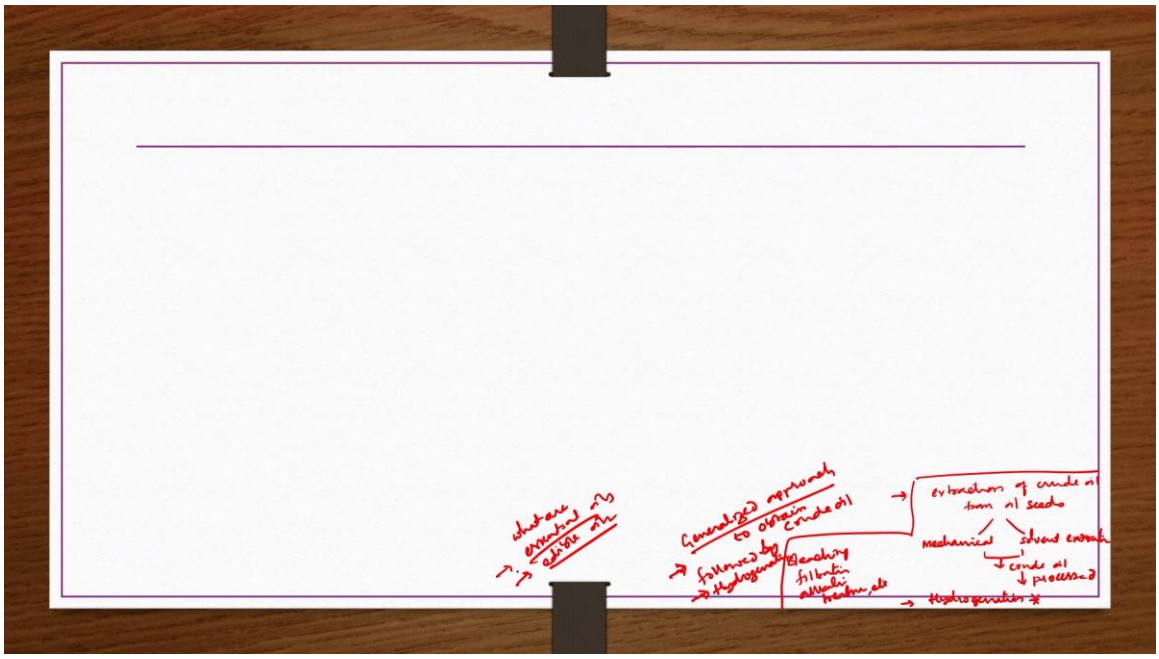

However, in addition to this one purification process also include bleaching, filtration, then alkali treatment, etc., right? So, this particular week, this lecture and then coming couple of lectures primarily targeted on these particular things, right? So, but what we

do? The approach would be first you know generalized approach to obtain crude oil followed by processing something like hydrogenation. So, both extraction as well as the hydrogenation a generalized approach we see irrespective of the type of oil that we are producing. Then after that generalized approach we will be discussing specific to given type of oils also we are going to discuss, okay? We are going to discuss about the kinetics, thermodynamic feasibility, etc., of the process as well, okay? And then finally we conclude with the major engineering problems of the processes associated with the production of edible and essential oils we are going to discuss. However, before going into the details of all such things, it is essential to understand what are these essential oils or edible oils, etc., what is the difference these things we need to understand. So, we need to go through a few basic introductory concepts about these oils, their chemical composition, properties, etc., those things are very essential from learning point of view. So, we start with the introduction of these edible and essential oils followed by their properties.

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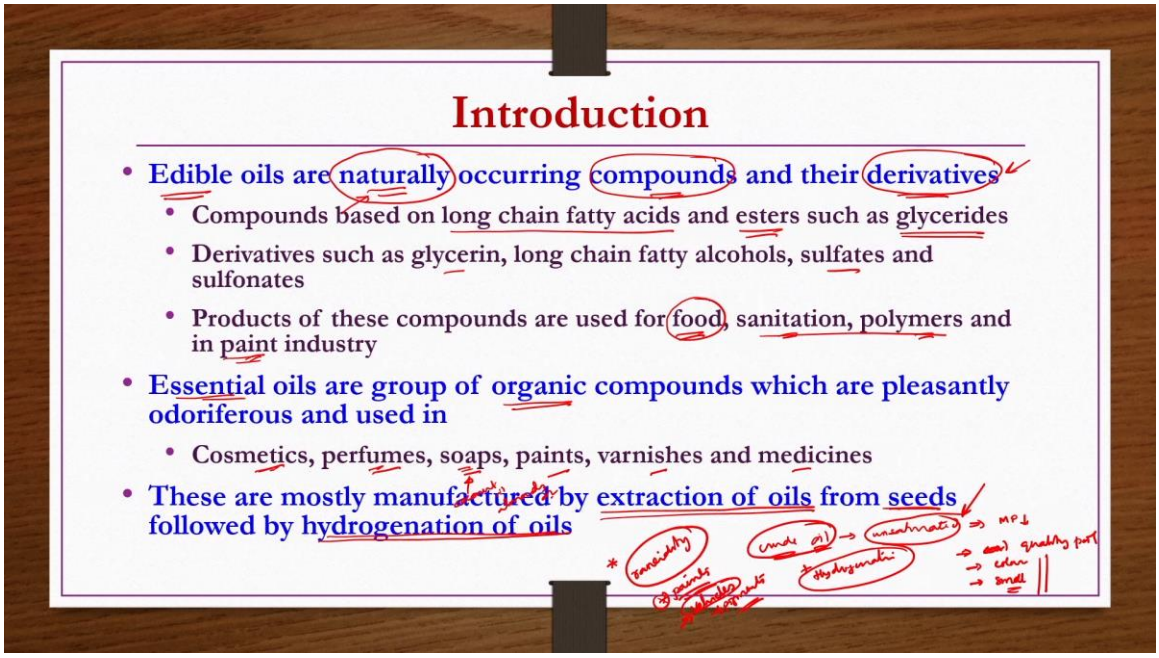

So, let us start with introduction. Edible oils are naturally occurring compounds and their derivatives naturally occurring. Most of the edible oils, you know edible oils actually you know it is used as a kind of synonym to the vegetables as well though not all edible oils are vegetable oils, those things we are going to see anyway. These are naturally occurring compounds actually. What does mean by naturally? Let us say we are getting vegetable oils, we are getting from the naturally available oil, seeds, etc., by doing some mechanical extraction or solvent extraction process and then purification kind of thing. Even if it is like you know fish or something like that, those things are also available

naturally. So, that is the reason this oils and fats industry is coming under the natural product industry of organic chemical technology as we have already discussed in the previous week. So, these oils, edible oils essentially, they are naturally occurring compounds and their derivatives. Compounds such as long chain fatty acids and esters, esters something like glycerides, whereas their derivatives are nothing but long chain fatty alcohols, something like glycerin or glycerol and then sulfates and sulfonates, etc., okay? So, basically the chemical composition if you see from this definition, edible oils consisting of long chain fatty acids, alcohols and then glycerides, etc., or their esters, etc., okay? Most of them are glyceride type esters. Products of these compounds are used for food purpose as cooking oil or also for the salad dressing, etc., also some of these vegetables or edible oils are used not only for the cooking purpose or food purpose, but also they are used for other purpose like sanitation, polymers, paint industry like that. Individual oil and then what is the corresponding individual industrial application, those things are also we are going to see in general anyway in coming slides. But in general, these edible oils they are primarily used for the food purpose. However, they are also used in industries like polymers and paint industries, etc., something like making for soaps purpose also, some of the vegetable oils are used, okay? Whereas the essential oils are group of organic compounds which are pleasantly odoriferous and used in cosmetics, perfumes, soaps, paints, varnishes, medicines, etc. These are not edible oils, we do not use for the food purpose or salad dressing purpose, etc., but they have so many other applications, applications in the cosmetic industries, perfume industries, soaps. Nowadays you see so many types of soaps are coming which are rich in coconut oil or maybe rich in almonds, oil, etc., these kind of you know so many types of different types of soaps available in the market which are rich in different types of oils as well, okay? Not only essential oils, some of the edible oils also being increasingly used in the industries nowadays, those things are also we are going to discuss anyway, okay? These are mostly manufactured by extraction of oils from seeds, they are vegetable oils followed by hydrogenation of oils, right? Because these oils whatever you get, crude oil, they are nothing but long chain fatty acids, esters, etc. and most of them are unsaturated. If they are unsaturated, what happens? Their melting point is low, okay? So, in order to have the increased melting point and then in order to make them saturated, you need to do hydrogenation. What if we do not do this hydrogenation? Then the oil quality would be very poor, that would be having color dark brown kind of color and then that would also be smelling. All these things happen because if the oils are unsaturated, then if they are exposed to the air or oxygen, they will undergo some kind of oxidation. When they undergo oxidation, then rancidity will take place and then rancidity of oil is not good. Once the rancidity of oil has been taken place, you cannot use for the cooking oil, right? So though it is a disadvantage from the cooking oil point of view, but however, from the industrial application point of view, some of the industrial applications like paints and varnishes industries, there paints are having the vehicles plus pigments, right? Pigments,

they bring the color and then translators, etc., those kind of things would be brought into the paint by the pigments, whereas the vehicles are nothing but the oils or some kind of solvents or liquids, most of them are oils. So, if these oils are unsaturated, they would be good for the paints industries. So the same thing if you wanted to use the crude oil for the cooking purpose, it is not good, so you have to do the hydrogenation, but if you wanted to use it for the industrial purpose, it depends on industry to industry. For example, paints industry if you take, you do not need to do hydrogenation of oil, crude oil itself you can use as vehicles in the paint industries. Vehicles are nothing but the solvents or liquids which are nothing but the oils in which the pigments are dispersed, dispersed homogeneously so that you have a paint, okay? So those vehicles are nothing but some kind of oils, fine?

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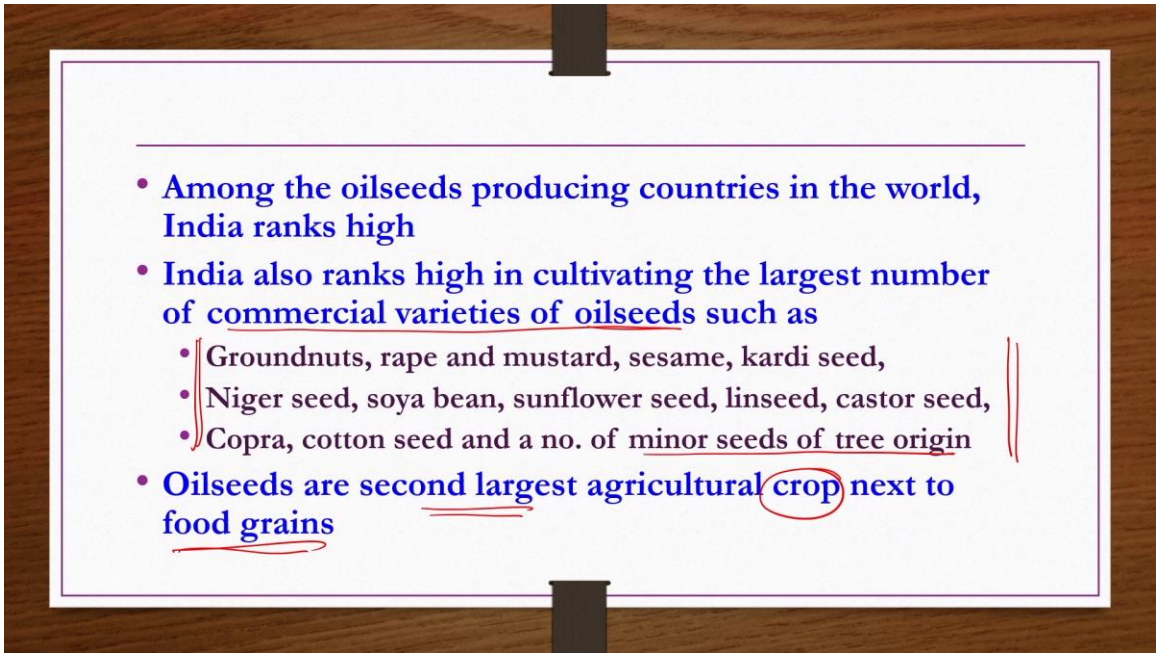

Now coming to the statistics ranks, etc., among the oilseeds producing countries in the world, India ranks very high. India also ranks high in cultivating the largest number of commercial varieties of oilseeds. Large number of commercial varieties of oilseeds are being produced in India, okay? So that way also India's rank is quite high globally. Some of the commercial varieties of oilseeds include coconuts, rape and mustard seeds, sesame, kardi seed, niger seed, soya bean, sunflower, linseed, castor seed, etc., copra, cotton seed and variety of number of minor seeds of tree origin. So, these many number of different types of oilseeds are being produced for the commercial purpose in India. Oilseeds are second largest agricultural crop next to the food grains in India, okay? That large amount, not only the numbers wise but also quantity wise also, huge quantity of such kind of

varieties of oilseeds are being produced in India. They are so much huge that they are next to the food grains.

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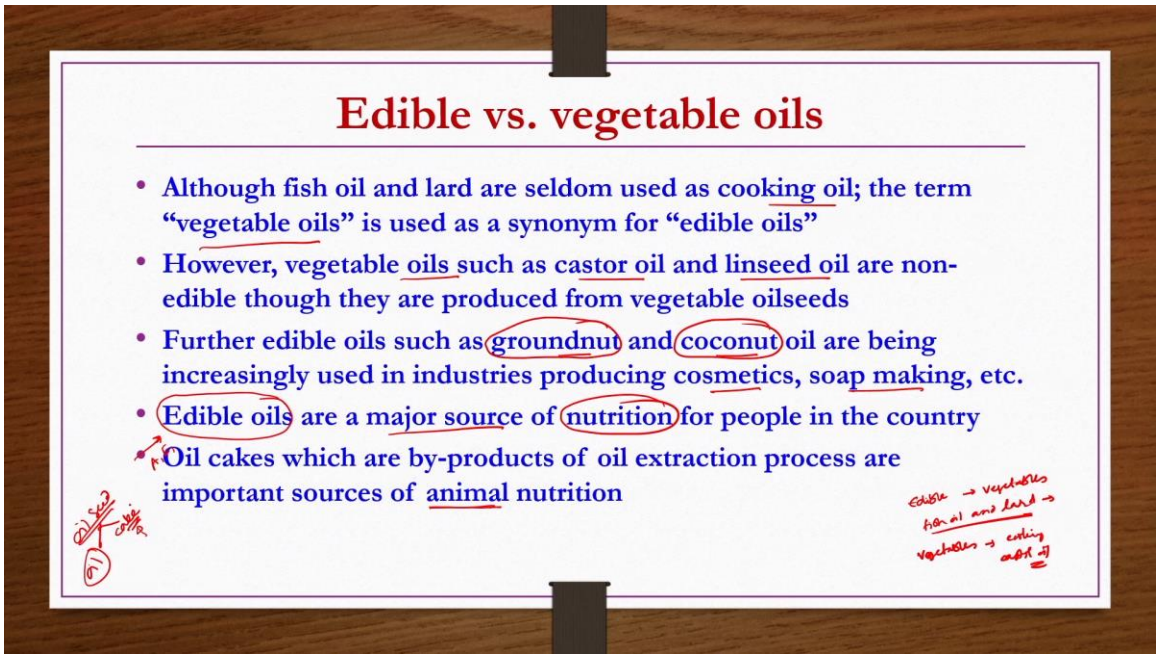

Now we see edible versus vegetable oils. Actually, commonly people use vegetable oils as synonym to the edible oils but it is not true because some of the oils like you know fish oil and lard etc., they are also used for the cooking but they are not vegetable oils, okay? So likewise, you know not all vegetable oils used for cooking or you know food purpose, something like you know castor oil etc., they are not used for the cooking purpose, okay? So, these differences are essential to be understood, okay? Although fish oil and lard are seldom used as cooking oil. The term vegetable oils is used as a synonym for edible oils. However, vegetable oils such as castor oil and linseed oil are non-edible though they are produced from vegetable oilseeds. Further, edible oils such as groundnut and coconut oil are being increasingly used in industries producing cosmetics, soaps etc. So, this groundnut, coconut oil are in general used as edible oils mostly in fact but however these are also used you know for making some of the cosmetics, soaps etc. in industries, okay? So, there are many other such kind of examples are existing in fact. So edible oils are major source of nutrition for people at the countryside in general. So, whatever the nutritional requirement of body is there, so most of them are being fulfilled by edible oils. Nowadays you can see most of the cooking oils etc., you may see on their packets you know they may be enriched with A vitamin, E vitamin etc., D vitamin etc., those kind of advertisements are also being there. So, this way most of the you know nutritional requirements are fulfilled by the edible oils, right? So, in the oils industry when we do the extraction of oil from the oilseeds what you get? You get a deoiled cake or solid wastage

whatever is there that we call deoiled cake. After extracting all the oil content whatever the solid waste remaining is there that is known as the deoiled cake and then that deoiled cake is also very rich in nutritional contents, right? And those things are used as animal food. So entire oilseed if you take, oil is providing nutritional requirement for the human being whereas the deoiled cake solid residue is there that is you know supplying nutrition to the animals or it is being used as animal feed. So the entire oilseed quantity whatever is there it is being utilized one way or other way. Sometimes the cake whatever is there that is usually dried and then made into the flour and then it is added along with the you know protein rich edible flours as well, okay?

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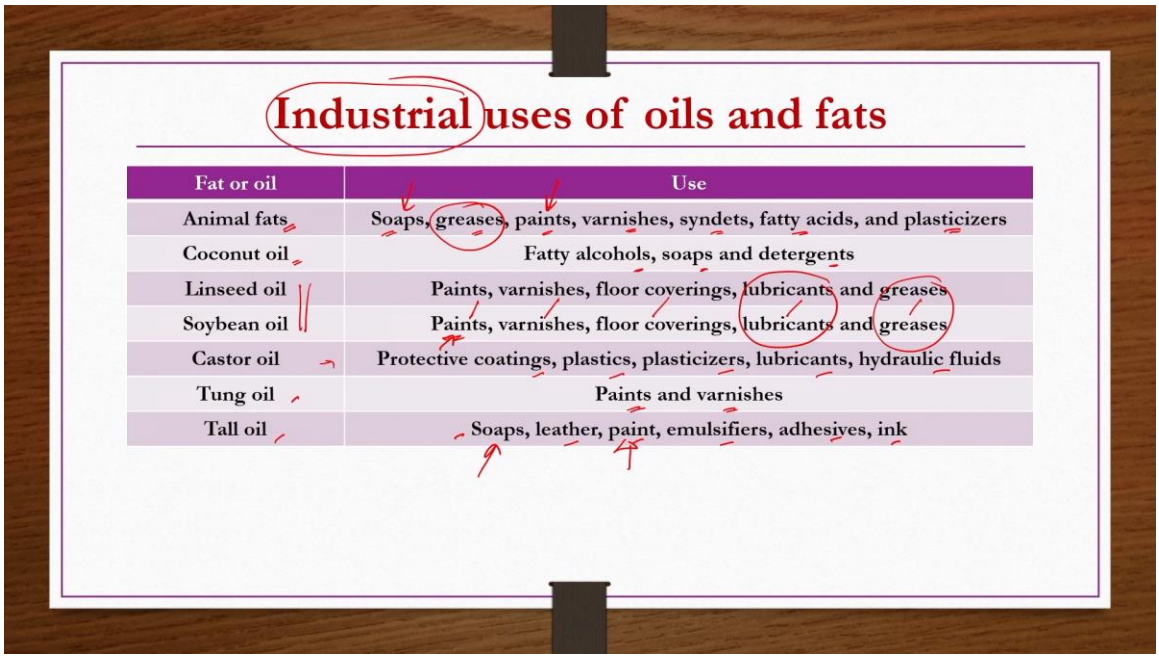

Now we see industrial uses of oils and fats. Specifically, we take a particular type of oil and then what is the corresponding industrial application in a tabular form we are going to see. Let us say animal fats they are in general used for soaps, greases, paints, varnishes, syndets, fatty acids, plasticizers, manufacturing purpose. Remember these are only industrial applications of different types of oils and fats. We are talking about industrial applications. Coconut oil used in fatty alcohol, soaps and detergents manufacturing. Linseed and soya bean oil in general used for the paints, varnishes, floor coverings, lubricants and greases manufacturing. Castor oil is used for protective coatings, plastics, plasticizers, lubricants, hydraulic fluids, etc. for those purpose it is used. Tung oil is used for the paints and varnishes industries. Tall oil is in general used for the soaps, leather, paint, emulsifiers, adhesives, ink industries, etc. Now you can see mostly either for the lubricants, greases or soaps, paints these purposes these things are primarily used or from the quantitative point of view you see soaps and detergents, lubricants, greases and then paints etc. you know these industries are increasingly using

different types of oils and fats. Though there are many other industries also which are using these you know different types of oils and fats.

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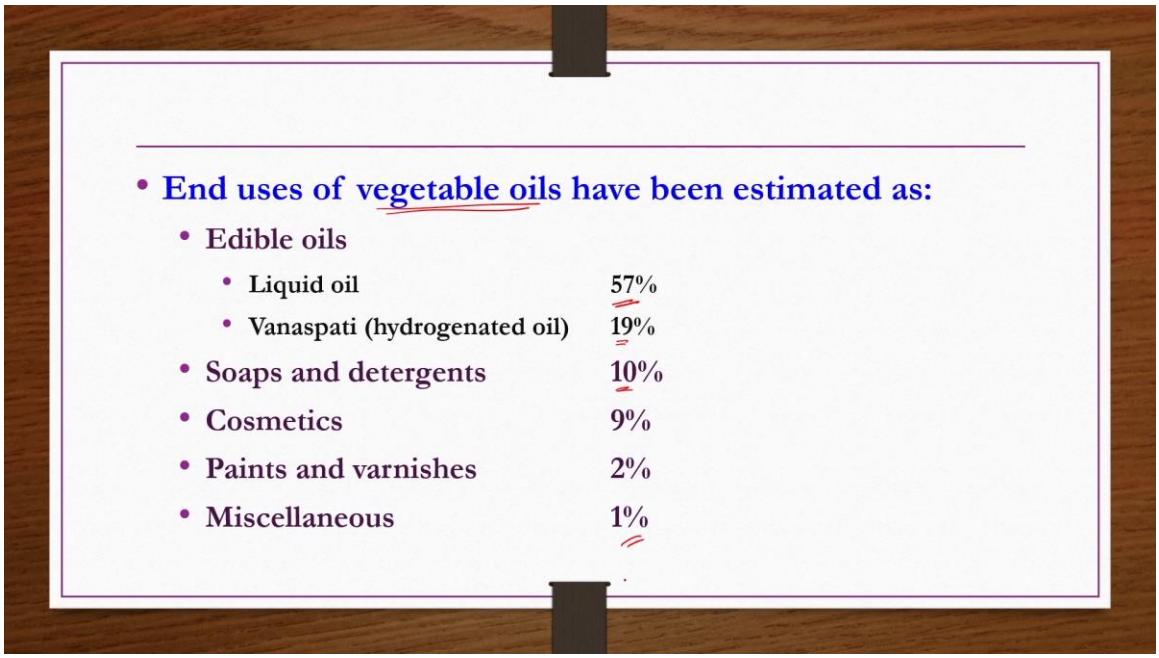

Now we talk about solvent extraction to get the crude vegetable oil. So whatever the oil seeds are there, so what you do you try to crush using the rolls etc. to get the crude oil in general that is how it is being done. But that may not be always you know profitable. So for that purpose solvent extraction has been developed. Actually, solvent extraction has developed for the soybean oils because it has been found by using solvent extraction method one can get up to 98 percent yield of oil from the seeds. So such kind of reasons are there. So, the solvent extraction has been developed and then subsequently the solvent extraction process has also been applied to the different types of other oils production and then nowadays most of the oil industries are using a combination methods as well. So, let us see about the solvent extraction. Physical crushing for oil extraction is not a feasible process for processing oil seeds especially when you wanted to do a continuous process at large tonnages quantities. So continuous solvent extraction is main process for processing of oil seeds such as groundnut, soybean and rapeseed. So, this good thing about this process is that you can do continuous solvent extraction. When you have a process continuous so then what is the benefit? Your capital cost would be you know less. The size of the equipment etc. would be smaller and then you can operate you know for the you know large quantities of raw materials you can operate if it is reaction raw material or if it is processing you know large quantities of the material can be processed in a continuous approach in lesser time. Main product from solvent extraction is obviously crude vegetable oil. If you wanted to use it for the cooking oil purpose then

you have to do the hydrogenation of this oil. It is having other applications as well in industrial level as I have already seen in the previous slide. It is primarily used in the manufacture of refined edible oils and vanaspati. This vanaspati is nothing but the hydrogenated or hardened oil whatever is there. So that is nothing but the vanaspati. It is also used to a lesser extent in glycerol and fatty acids production for usage in soaps and other toiletries. Actually, for soaps manufacturing it is better to have the glycerols. Most of the soaps are having glycerol content up to 30-40% also in general. So that glycerol etc. are coming from such kind of crude vegetable oils. There are a number of other value added products for varied applications as well for domestic industry and thus there is a huge market for the crude vegetable oil itself. Byproduct of this process is nothing but de-oiled cake as already mentioned which is high in protein content and used as cattle food as well. Now we see end uses of vegetable oils only. These vegetable oils in general often used as edible oils as liquid 57%. That means in liquid form these edible oils are used and then that is up to 57% or even more also. Vanaspati which is nothing but hydrogenated oil harder one which is 19%. For soaps and detergents roughly 10%, cosmetics 9%, paints and varnishes 2% and another miscellaneous maybe 1%.

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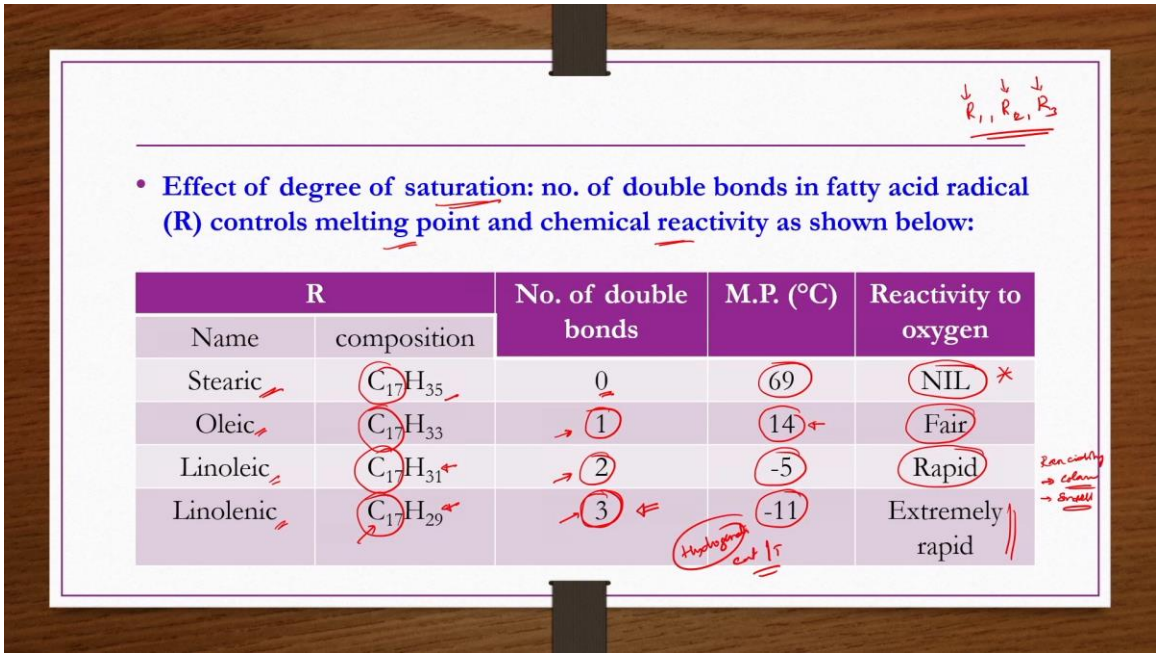

Now we see chemical composition and physical properties of vegetable oils. So chemical composition is very much essential to understand so that we try to do as we have already discussed fats and oils are nothing but mixtures of glycerides of fatty acids of this particular kind of structure. Here this R1, R2, R3 are some organic radicals. So, they need not to be same. So, they are having different structures. So, we see some of them in the next slide anyway. These glycerides mostly unsaturated. So, if they are unsaturated

definitely this R1, R2, R3, etc. whatever are there they would be having double bonds. If you remove those double bonds then they will become saturated and then that is possible by doing the hydrogenation. As per industrial terminology all oils are liquids and fats are solids at normal temperature. Coming to the waxes they are mixed esters of polyhydric alcohols other than the glycerin or glycerol. Glycerin is also known as the glycerol in common terminology and these waxes are solid at room temperatures. Now we see effect of degree of saturation as I mentioned this R1, R2, R3, etc. whatever are there. So, they are nothing but organic radical to be specific fatty acid radicals. These would be having double bonds. So, depending on number of double bonds the melting point and then chemical reactivity with oxygen or air changes. So that we have to see. So, if you see that one here so let us say stearic radical if you have its composition is C17H35 and there are no double bonds at all. That means if there are no double bonds its reactivity to oxygen at normal conditions is nil and thus its melting point is high. So, if you take other type of radical oleic which is nothing but 2 hydrogens less than the stearic one that is C17H33. If 2 hydrogens are less that means 1 double bond would be there. 2 hydrogen atoms are less that means 1 hydrogen or 1 double bond is possible because C is same because the C is same all of these things C17 atoms are there. So now you can see only by bringing in 1 double bond its melting point has decreased from 69 to 14 degrees centigrade and then its reactivity to oxygen from nil to it has become fair. If you take linolenic radical which is nothing but 4 hydrogen atom less than the stearic that is C17H31. So if 4 hydrogen atoms are less but the C number of C atoms are same then that means 2 double bonds would be existing there. So, if the 2 double bonds are there you can see the melting point is substantially decreased to minus 5 degrees centigrade and then reactivity to oxygen is very rapid. Likewise linolenic if you take which is having 6 hydrogen atoms less compared to the stearic keeping the C same as 17 that is C17H29 then 6 are there 6 hydrogen atoms are less compared to the saturated one that means 3 hydrogen bonds 3 double bonds are possible 3 double bonds are possible and then you can see the melting point is further decreased to minus 11 degrees centigrade and then reactivity to oxygen is extremely rapid. So, this first one is better from the cooking oil point of view. It should not be unsaturated it should be saturated one so that reactivity to the oxygen is nil. What happens if the reactivity to the oxygen takes place it leads to the rancidity because of that one the color of the oil would be become a brownish dark brownish kind of thing and there would also be some kind of smell there and then because of such kind of reasons you do not feel to use it not only feel but also it is not good from the health point of view. But however, if you are using them for industrial applications some of the unsaturated fatty acid alcohols, glyceride esters etc. Can also be used. So, under such conditions you do not need to do hydrogenation if you have the crude oil which is highly unsaturated like large number of double bonds are there and then you definitely need to do the hydrogenation using catalyst and then certain temperature conditions etc.Those things we see those details anyway. So, such hydrogenation is compulsory if you are using this oil

for the refining refined cooking oil purpose. If you are using for the industrial applications point of view that depends on application to application what degree of hydrogenation is required is it required or not.

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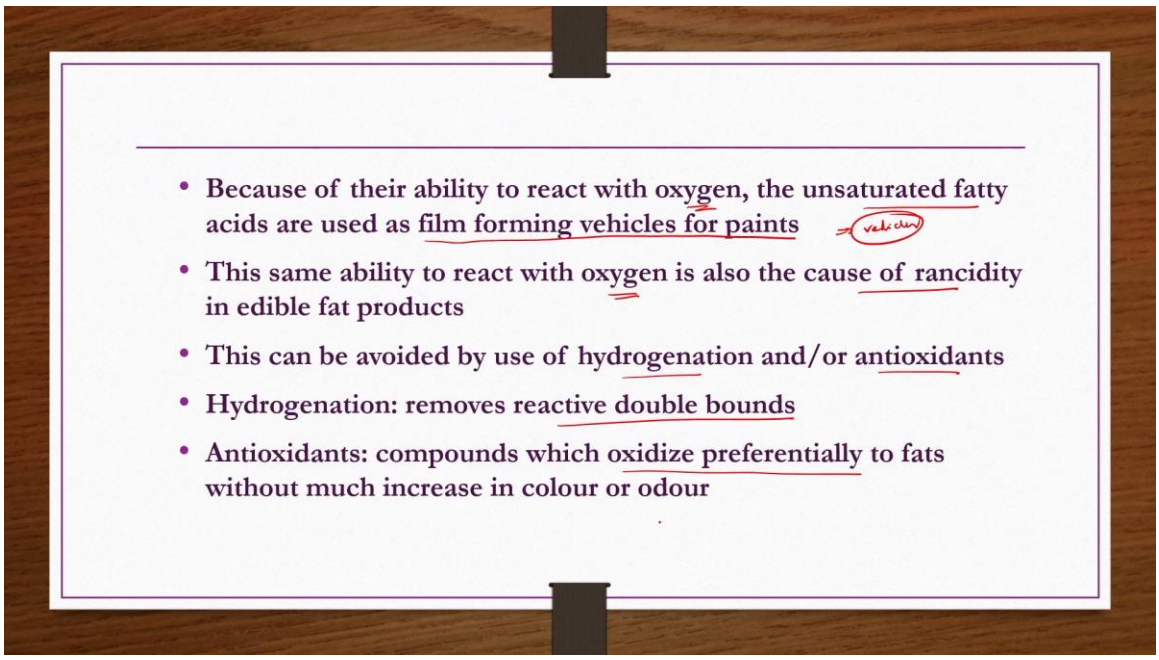

You know that way one has to decide because of their ability to react with oxygen the unsaturated fatty acids are used as film forming vehicles for the paints industries that is unsaturated fatty acids whatever are there you know if there are double bonds then they can be used as a vehicles in paint industry that is one example. Other industries there may be other kind of applications for same unsaturated fatty acids and then esters. The same ability to react with oxygen is also the cause of rancidity in edible fat production. So this can be avoided by the hydrogenation and or by adding antioxidants. Hydrogenation removes the reactive double bonds by reacting with hydrogen in the presence of a suitable catalyst so that those double bonds would be you know get saturated and then you have the single bands and then saturated fatty alcohol acids you may be having. Antioxidants are nothing but compounds which oxidize preferentially to fats without much increase in color or order.

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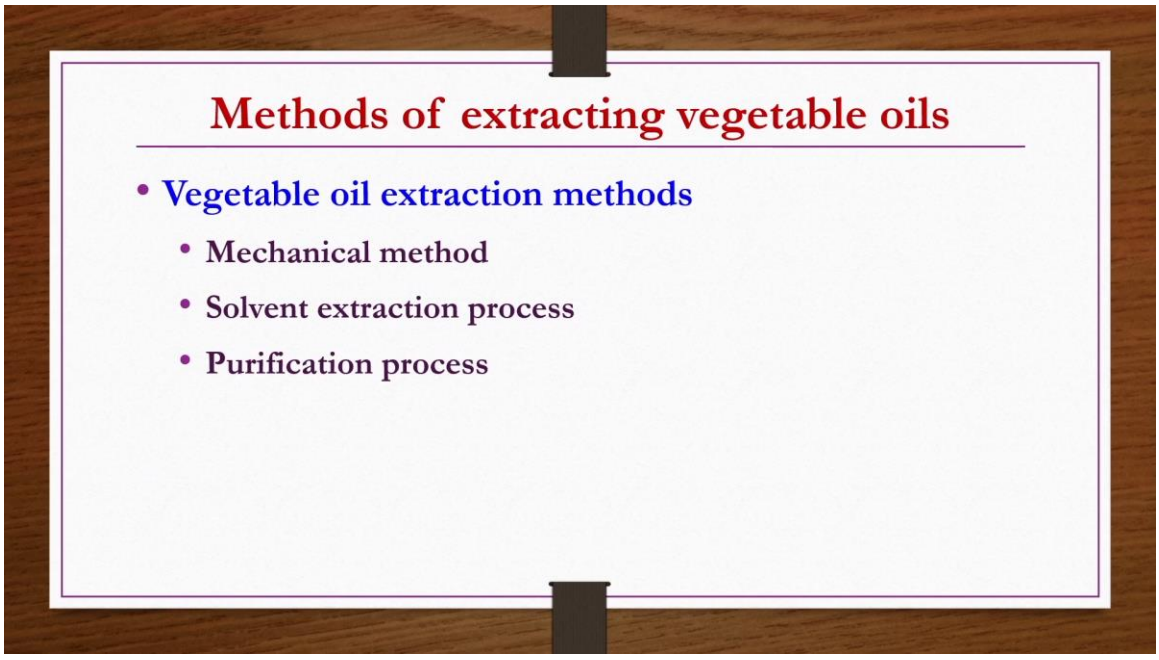

Now we talk about methods of extracting vegetable oils. Vegetable oil extraction methods if you see mechanical methods, solvent extraction method and purification processes are there.

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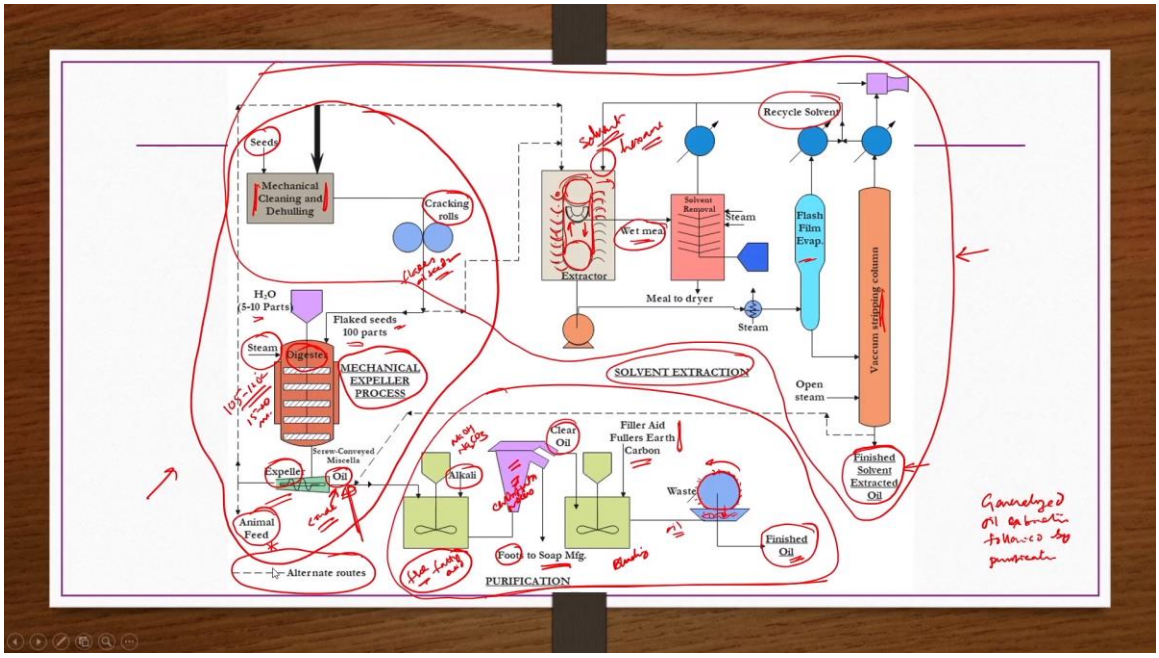

Now we see all 3 of them in one single slide. Here it is a generalized oil extraction followed by purification or processing. All of them we see here in one particular flow chart itself. First, we see mechanical approach. Whatever the oil seeds are there you do the cleaning and dehulling using some mechanical approach. Once you do the required cleaning and dehulling of the seeds, those seeds you pass through rolls. When these seeds pass through these hard metallic rolls what happen they will be crushed and then flakes would form. Flakes of oil seeds would form. Now actually they would be in distorted form. Why are we doing that one? Because these flakes would be having you know better particle size and shape to undergo subsequent digestion process. That is the only reason. So, after passing through these rolls whatever the flaked seeds are there those things along with water you take in into a digester. At what ratio if you are having 100 parts of flaked seeds then 5 to 10 parts of water is required and to this digester you are supplying the heat energy by steam and then you do heating or cooking or digestion approximately 105 to 120 degrees centigrade for 15 to 20 minutes. So here this particular section is nothing but the mechanical expelling process. In fact, this entire thing whatever from here to this section is there. This is mechanical approach. So, after this digestion section whatever the mixture that you have digested system that you are having that you pass through an expeller to get the oil. This oil is nothing but the crude oil. This oil you take to a alkalization section where you can add NaOH or Na2CO3 solutions at appropriate ratios and then stir them mix them thoroughly. So, then what happens this process releases free fatty acids and those free fatty acids collected as foods in a centrifugation column. In the centrifugation section this is the centrifugation section centrifugation process here. In the centrifugation process the free acids should be separated as food and then they are not good for the cooking oil purpose so they will be taken to the soap manufacturing process. Soap manufacturing you need only fatty acid, fatty alcohols, etc. free fatty acid, free fatty alcohols. So you can use those foods for the soap manufacturing purpose whereas the clear oil whatever is there that you take to the bleaching section or you do the adsorption process using activated carbon or filler aid, fuller earth carbon, etc. those kind of materials are used and then through this adsorption column when this clear oil passes through if any impurities are there they will be absorbed by this adsorption media like activated carbon, etc. After that the material will pass through a rotary drum filter. This is a drum which is actually rotating. This drum is having covered by a perforated cloth. In fact, the drum is also having some kind of perforations and then that drum circumference has been covered with the filtration cloth something like that. And then this is a bowl kind of section column vessel tank kind of thing in which the oil after bleaching whatever the oil is there that is taken here and this drum whatever is there that is immersed into this liquid to certain level and then this drum rotating. While rotating from the inside of the drum you apply the vacuum so that the clear liquid finished oil would be sucked by the vacuum applied inside this rotating drum and then collected as the finished oil. Whereas some minor small traces of the particles, etc. whatever are still

remaining in the oil after bleaching they will be collected on the filter cloth. After the end of the process you can take out those one also and then use as animal feed. After this expeller section here when you take this mixture from the digester then you do the expelling, expeller process when you do then crude oil you got and then you have done this purification steps. So, all these steps are nothing but the purification steps. So, after getting the crude oil whatever the solid waste was there which is nothing but the de-oiled seeds or de-oiled cake that means cake form that solid is in the cake form and then there is no oil content in that one that is also rich in nutritional content so that is used as animal feed. This is about the mechanical approach followed by the purification steps of the vegetable oils. Now let us say if you wanted to do the other approach that is the solvent extraction approach. So, the remaining process is the solvent extraction. In fact, this solvent extraction these steps are also involved. This particular thing is solvent extraction. Here the process first two steps of the process are same like in mechanical process where cleaning and de-hulling would be done by mechanical means. Once clean seeds are there then they will be passed through rolls, cracking rolls where these seeds would be converted into the flakes forms. The flaked oil seeds whatever are there they will be taken to extraction column. Now this extractor what it is having? It is having two rotating shafts like this and then they are connected with some kind of belt something like this and to this belt actually there are buckets provided like this. These are nothing but buckets. So, this material comes and then falls on these buckets like this and then its rotation is taking place in this direction. So, left one moves up and then right side this falls down like this. So, what happens? So, this material whatever the flaked oil seeds are there they come on this bucket and then the material fills it and then whatever is there so that comes here and then other side it is discharged here as a wet mill. Now to these buckets the solvent is also provided solvent. Solvent is also provided in general you know n-hexane kind of solvents are used. So, this solvent used to extract the oil from the flaked oil seeds in this extractor. It is a continuous process. So, after this process whatever the wet mill is there so that is collected from the other side where the buckets are becoming upside down because these buckets are you know kind of fixed. Actually, they can also move slightly here and there but they cannot flip down upside down suddenly in one direction. So, this direction they are upward moving collecting the material other side they are downward moving and then you know they are discharging material as wet mill. This wet mill would be taken to solvent recovery sections. Solvent removal is done by the steam distillation in general or flash film evaporation or vacuum stripping column different types of things are there. You may need all 3 of them 3 types of them more than one such kind of units you know all or you may be requiring 1 or 2 of them only depends on the application to the applications. So, whatever the solvent is recovered that would be recycled back to the extractor. From the final stripping column whatever is there from there you get finished solvent extracted oil. See this finished oil is the final purified oil whereas this oil here this one is nothing but this is also crude oil like this. So this finished oil this finished solvent

extracted oil whatever is there that would be again processed through purification steps like this dotted lines. So, all these dotted lines are alternative routes. So, this is about a generalized approach for the oil extraction and purification by 2 methods extraction by mechanical methods as well as the extraction by the solvent extraction method followed by the purification methods are same. So, this is very generalized one and more or less in all kind of vegetable oils manufacturing process similar approaches are there. So specific to individual oils we are going to discuss in the next class anyway. But in this class we have seen a very generalized approach.

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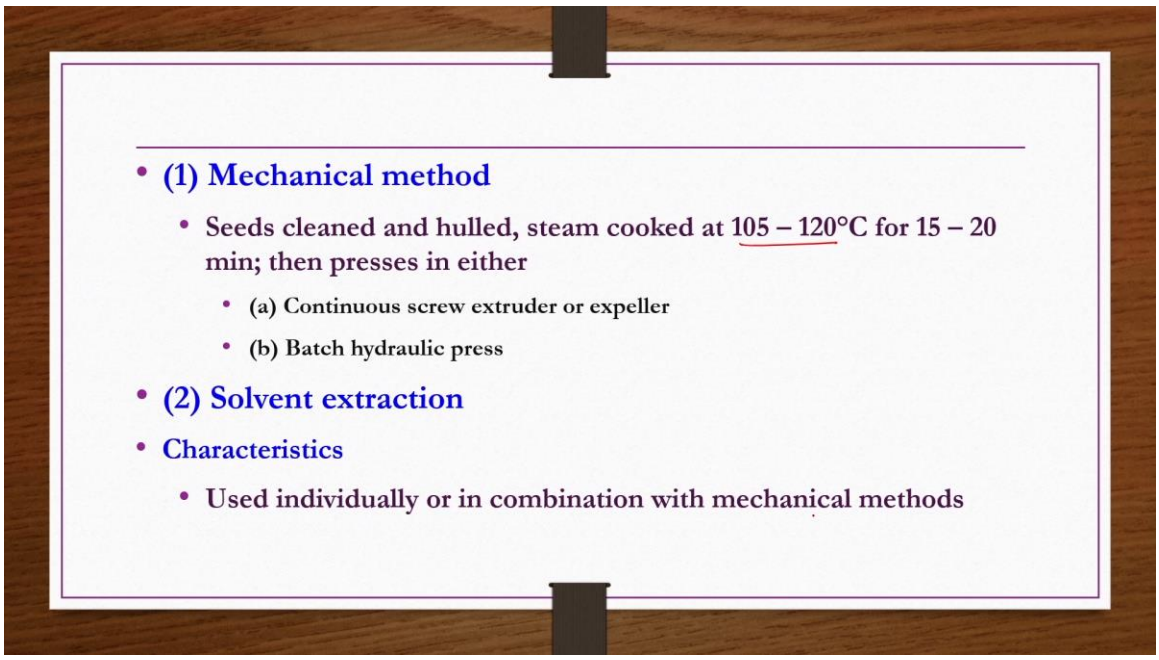

Whatever we discussed here all those things are provided here again. Mechanical method that is seeds are cleaned, hulled and steam cooked at 105 to 120 degree centigrade for 15 to 20 minutes. Then presses in either continuous screw extruder or expeller as shown or batch hydraulic press. Whereas in the solvent extraction if you see the characteristics they are used individually or in combination with mechanical methods.

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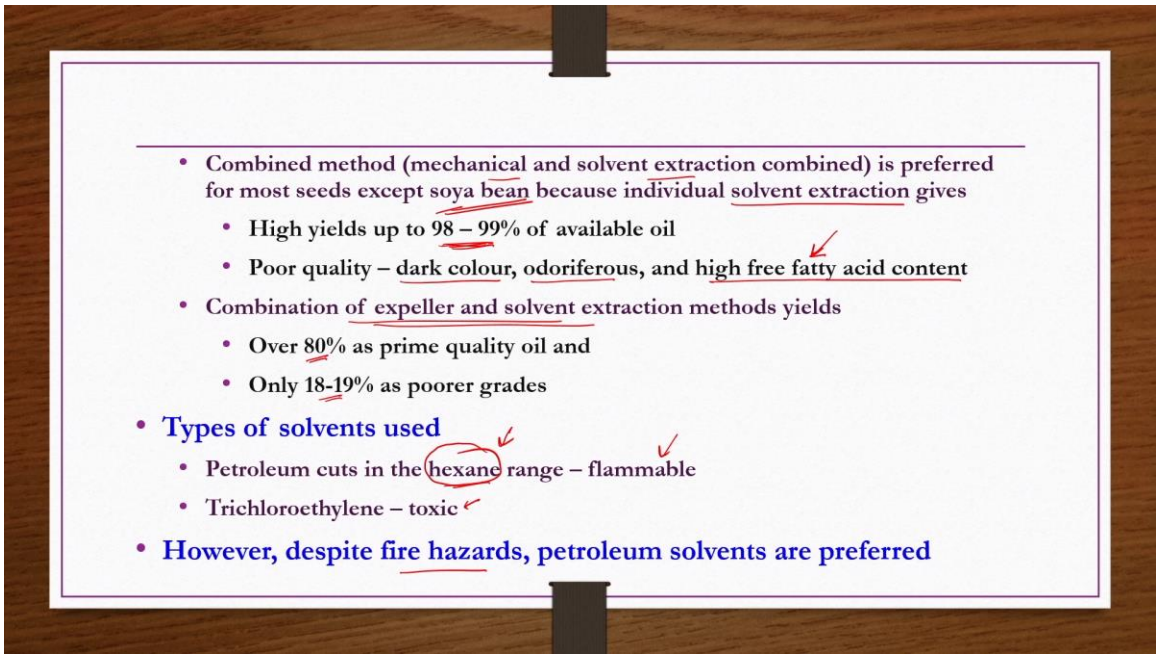

If you are using combined method as the mechanical and then solvent extraction methods are combined to extract the oil from the seed it is preferred actually for most of the seed except the soya bean because as I mentioned for the soya bean if you use individual solvent extraction the yield of oil is very high up to 98 to 99 percent of the oil that is present in the seeds all that amount can be extracted by using individual solvent extraction process. So, whereas for other seeds it is better to go for the combined method where both mechanical and solvent extraction methods are applied followed by the purification. So, if you do the extraction of oil from soya bean by using individual solvent extraction method which is better one because the yield is very high 98 to 99 percent but however the quality is poor dark color odoriferous and high free fatty acid contents would be there. These free fatty acid contents are good for the soap manufacturing purpose etc. but not good for the cooking oil purpose. If you use the combination of expeller and solvent extraction methods for other oils other than soya bean then you can have over 80 percent of extraction as prime quality oil and then only 18 to 19 percent as poorer grade that is the advantage of a combination of these two methods mechanical and then solvent extraction methods. Types of solvents used for solvent extraction methods are petroleum cuts in the hexane range which are flammable, trichloroethylene also used which is nothing but toxic. So however, though petroleum cuts such as hexane are flammable people prefer for this one because of superiority or superior quality of the solvent for the extraction. So, n-hexane is a very good solvent for the extraction process. That is the reason despite of fire hazards petroleum solvents are preferred for solvent extraction of crude oils from the oilseeds.

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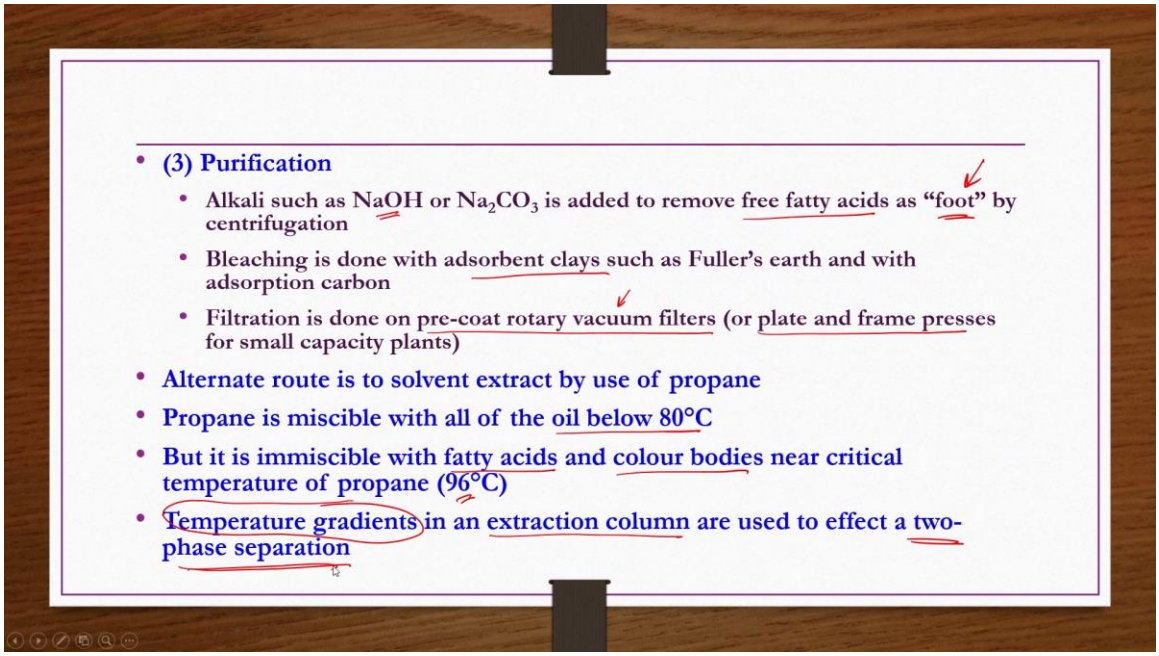

Purification, different approaches are there. First one is treating with alkali such as NaOH or Na2CO3 to remove free fatty acids as food by centrifugation. These foods may be used for the soaps manufacturing. Then followed by bleaching is done with adsorbent clays such as Fuller's earth and with adsorption carbon followed by filtration is done on pre coat rotary drum filters. In some cases, plate and frame presses also used. We studied rotary vacuum filter approach for the purification in the flow chart. So different types of filtration process you may be studying in mechanical unit operation course. These are important unit operations for chemical industries. Alternative route is to solvent extract by use of propane because propane is miscible with all of the oil below 80 degrees centigrade. However, it is immiscible with fatty acids and color bodies near critical temperature of propane which is approximately 96 degrees centigrade. In extraction column temperature gradients are maintained such a way that you can have effective two phase separation in the process.

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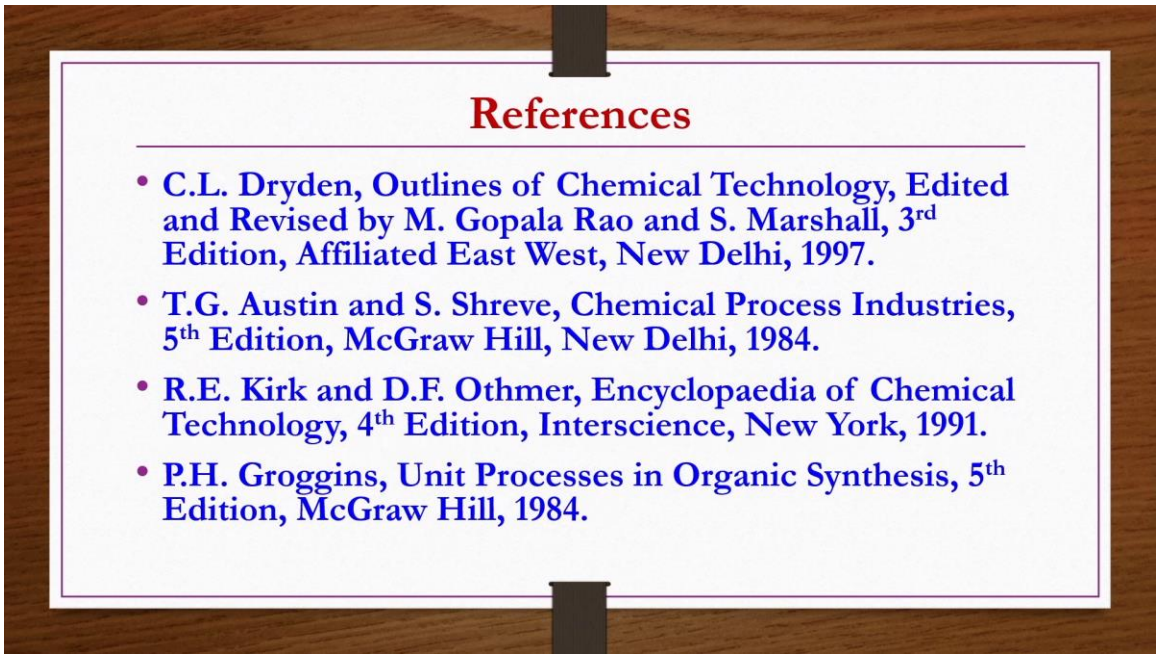

References for this particular lecture are provided here. Outlines of Chemical Technology by Dryden edited and revised by Gopala Rao and Marshall third edition. Chemical Process Industries by Austin and Shreve fifth edition. Encyclopedia of Chemical Technology Kirk and Othmer fourth edition. Unit Processes in Organic Synthesis by Groggins fifth edition. Thank you.