Food Oils and Fats: Chemistry & Technology

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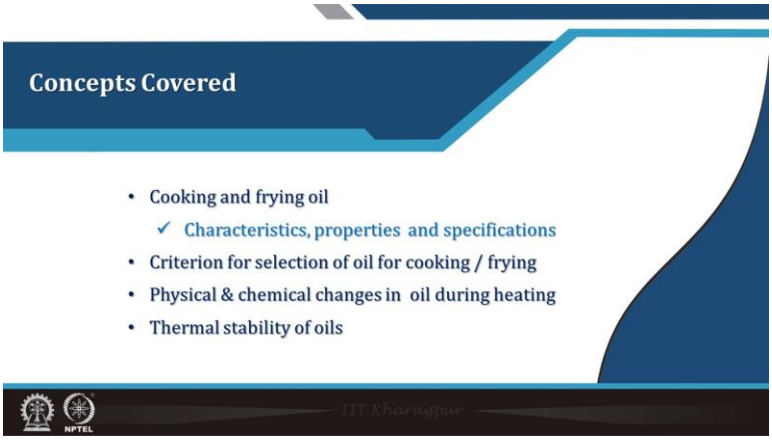
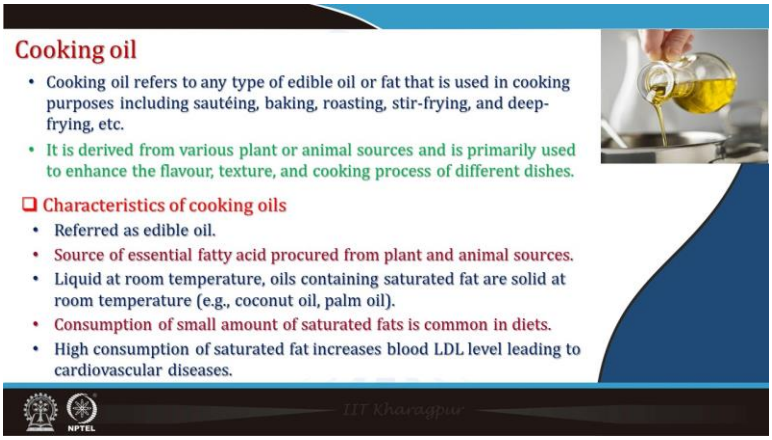
Module 9: Cooking & Frying Oils

Lecture 41: Characteristics and Specifications

Hello everyone. Namaskar. Now, we are entering in the 9th module of the course. The five lectures of this module will be devoted to Cooking and Frying Oils. In today's lecture, that is lecture 41, we will talk about the characteristics and specifications of cooking and frying oils.

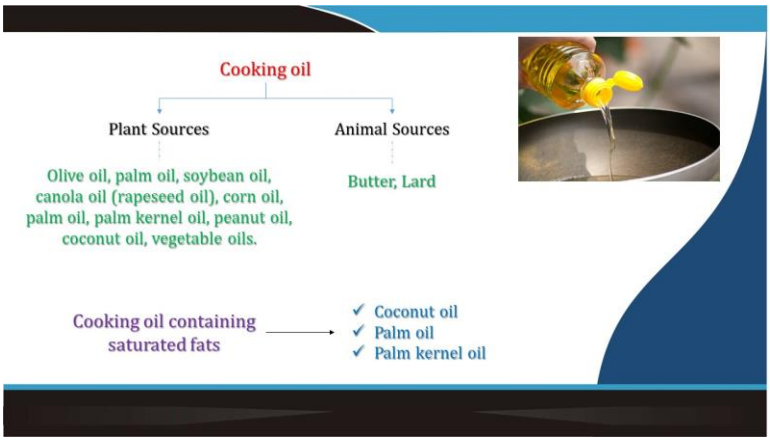


The concept which I will discuss today is what are the basic characteristics, properties, and specifications of cooking and frying oils. What are the criteria for the selection of oil for cooking or frying purposes? Physical and chemical changes that take place in oil during heating and particularly during cooking or frying processes. And then finally, we will also discuss something on the thermal stability of oils.



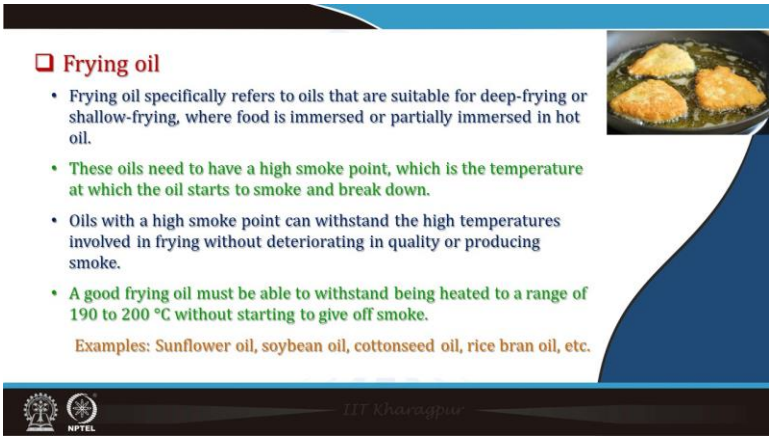
Cooking oil refers to any type of edible oil or fat that is used in cooking purposes, including sautéing, baking, roasting, stir-frying, and deep-frying. It is derived from various plant or animal sources and is primarily used to enhance the flavor, texture, and cooking process for different dishes.

In fact, the food materials used are processed using different methods like cooking, etcetera, and having different oils and fats, they give different taste, different texture, different flavors. So, for the cooking oil, what specific characteristics should be there which is referred to as cooking oil? It is an edible oil, and sources of the essential fatty acids which is procured from plant and animal sources because you know these oils are basically triglyceride. We have studied earlier the detailed composition. This is liquid at room temperature. This oil, it contains saturated fats which are solid at room temperature and there are some plant oils, plant fats like coconut oil, palm oil, which have more amount of saturated fat, and that's why on cooling down or even at room temperature they solidify. High consumption of saturated fat increases blood LDL levels leading to cardiovascular diseases etc.

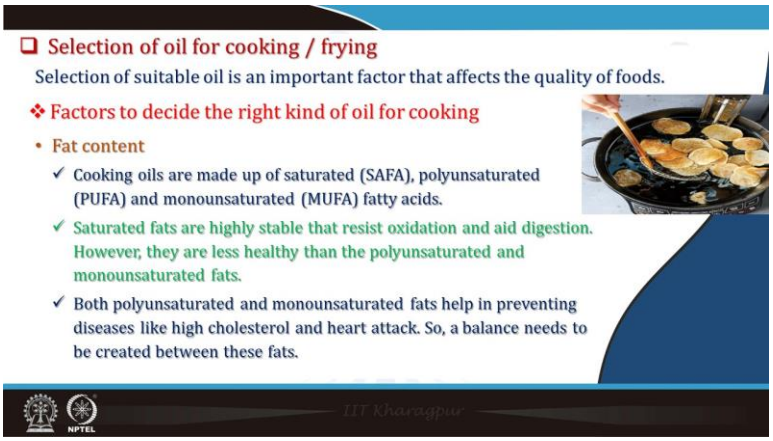


So, as I told you, cooking oils can be obtained from both the plant sources as well as animal sources. From the plant sources, the commonly used cooking oils are olive oil, palm oil, soybean oil, canola oil i.e. rapeseed oil, corn oil, palm oil, palm kernel oil, then

peanut oil, coconut oil, and other vegetable oil. Then, from animal sources are the butter oil or lard. Butter or lard are used for cooking that is obtained from animal sources. Then cooking oil contains saturated fats that is those cooking oil from the plant sources which have more amount of saturated fat are coconut oil, palm oil, and palm kernel oil.

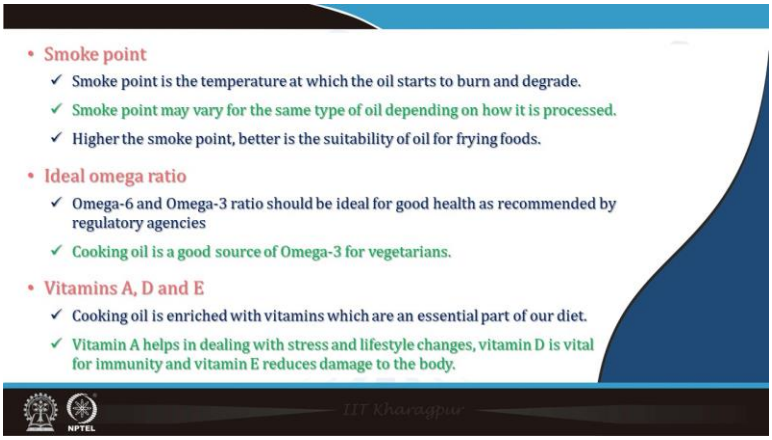


The frying oil especially refers to the oil that are suitable for deep-frying or shallow-frying, where food is immersed or partially immersed in hot oil. These oils need to have a high smoke point, which is the temperature at which the oil starts to smoke and break down. Oils with a high smoke point can withstand the high temperature involved in frying without deteriorating in quality or without producing smoke. So, a good frying oil must be able to withstand being heated to a range of around 190 to 200 degree Celsius without starting to give a smoke. The examples of such oil include sunflower oil, soybean oil, cottonseed oil, rice brown oil, etcetera.



So, what are the criteria, how do we go for selecting oil for cooking or frying purposes and factors to decide the right kind of oil for cooking. Let us take one by one the number one factor is the fat content. As you know that cooking oils are made up of saturated fatty acids, polyunsaturated fatty acids, and monounsaturated fatty acids. Saturated fats are highly stable that resist oxidation and aid in digestion. However, they are less healthy than the polyunsaturated fats and monounsaturated fats. So, both polyunsaturated and

monounsaturated fats help in preventing diseases like high cholesterol and heart attack. So, a balance needs to be created between these fats. So, while selecting the oil, that is the best condition that is the MUFA-PUFA ratio and it have some antioxidants and there is a MUFA-PUFA even saturated fats, solid fats all these things should be in the proper proportion that should be one criterion as a fat content.



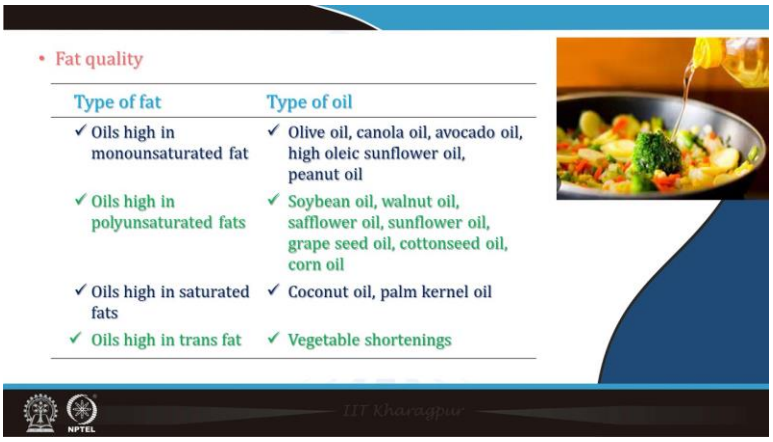
The other criteria is the smoke point. Smoke point is the temperature at which the oil starts to burn and degrade that is when you heat the oil that is there will be a time, oil will go on, its temperature will rise, and a point will come where the surface of the oil will catch fire and that is a smoke point. You cannot heat the oil beyond that; rather oil will catch fire and it will burn any smoke. So, that is the highest point up to which the oil can be heated. So, obviously, the smoke point an oil if you want to fry them at a product at 200 degree Celsius; you have to select an oil whose smoke point is more than 200 degree Celsius. So, higher the smoke point better is the suitability of oil for frying foods.

Then ideal omega ratio, that is, omega-6 and omega-3 ratio should be ideal for good health and as recommended by regulatory agencies. Cooking oil is a good source of omega-3 fatty acids for vegetarian people. So, also like the MUFA to PUFA ratio, similarly, omega 3 to omega 6 ratio should be in a proper ratio. There are regulatory agencies for heart-healthy oils etcetera. It should be in the proper range that should be maintained.

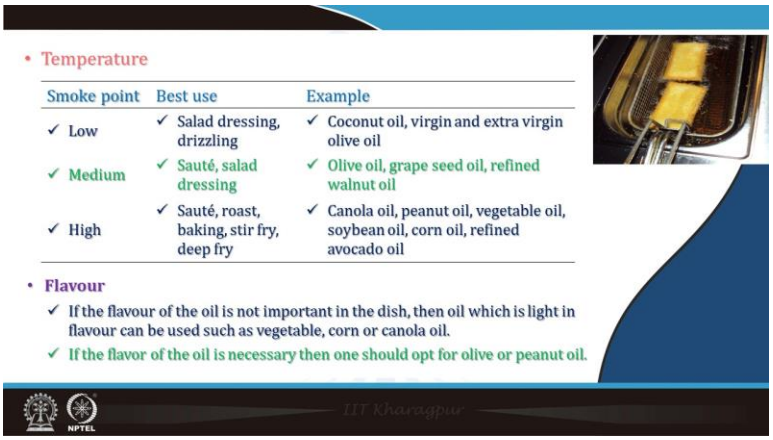
Then vitamin A, D, and E content. Cooking oil is enriched with vitamins, which are an essential part of our diet. Vitamin A helps in dealing with stress and lifestyle changes, vitamin D is vital for immunity, and vitamin E reduces damage to the body. So, it is always and these are the natural plant oils, they are good sources of vitamins A, D, and E. So, their content also should be ensured that it is good.

Then fat quality, you see the type of fat, and type of oil. You take the type of fats or oils which are high in monounsaturated fatty acids. The oils which are high in monounsaturated fatty acids are olive oil, canola oil, avocado oil, high oleic sunflower oil, and peanut oil. Whereas, the oils high in polyunsaturated fatty acids include soybean

oil, walnut oil, sunflower oil, safflower oil, grapeseed oil, cottonseed oil, corn oil, flaxseed oil, canola oil, and so on.



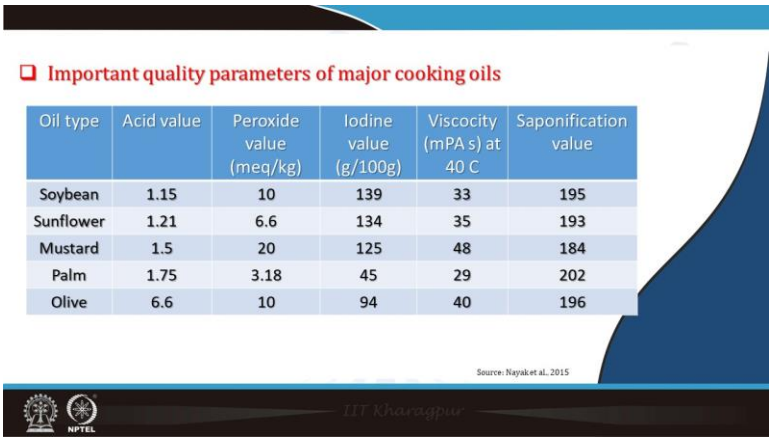
Oils which are high in saturated fats include coconut oil, palm kernel oil, and oils which are high in trans-fat, they are mainly vegetable shortening that is which are given excessive heat treatment during its manufacture.



The temperature, if you look, that is smoke point on the basis of temperature, the oils can be those which are low smoke point, medium smoke point, and high smoke point. Low smoke point, the oils can be used for salad dressing, drizzling, etcetera and the examples of such oils are coconut oil, virgin, and extra virgin olive oils. Then, those having medium smoke point, they can be used for sauces, salad dressing, etcetera and the examples of such oils are olive oil, grapeseed oil, refined walnut oil, etcetera. Then, high smoke point oils, they can be used for saute, roasting process, baking process, stir-fry, or deep fry, etc. and the oils which comes in this category are canola oil, peanut oil, in general plant vegetable oil, soybean oil, corn oil, refined avocado oil, and so on.

Flavor is another important criteria. If the flavor of the oil is not important in the dish, then the oil which is light in flavor can be used such as vegetable, corn, or canola oil. If the flavor of the oil is necessary, then one should opt for olive or peanut oil because this

olive oil i.e. fresh natural value oils are known for its flavor. Peanut oil known for its flavor.

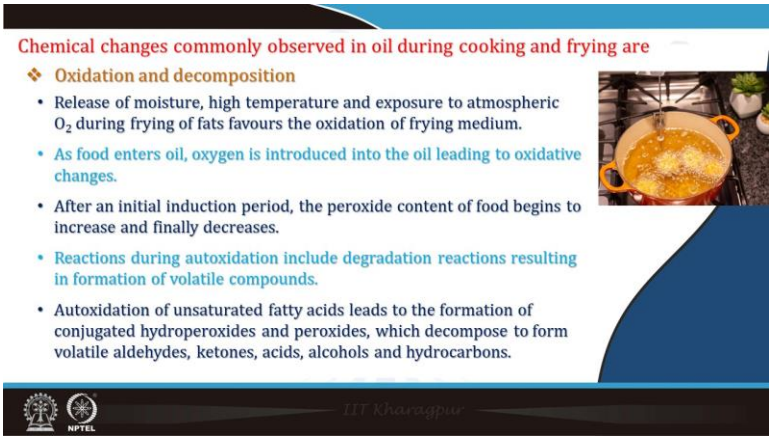


An important quality parameter of major cooking oil, you can see that, acid value, peroxide value, iodine value, viscosity, and saponification value. So, for soybean oil, acid value is normally 1.15, peroxide value 10, iodine value 130 to 139 gram per 100 gram, viscosity that is mPa second at 40 degree Celsius is 33, and saponification value should be 195.

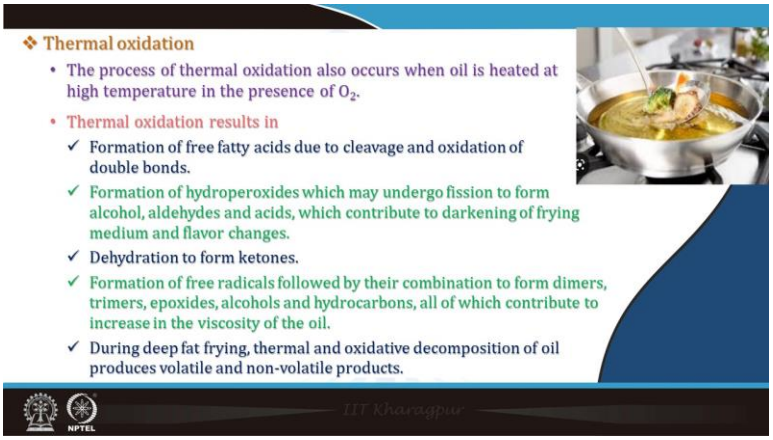
Similarly, for sunflower, mustard, palm, and olive oil, there is acid value in the range of 1.21 to 6.6 that olive oil has a very high acid value as high as 6.6, palm oil also contains considerably high acid value like 1.75. Then, peroxide value of course, sunflower oil 6.6, soybean 10, mustard 20, that in palm oil 3.18, and olive oil 10 milliequivalent meq per kg. The iodine value, you see that the soybean, sunflower, and mustard, they have considerably higher iodine value like 139, 134 and 125 grams per 100 grams, respectively. The palm oil contains 45 and olive oil contains 94 gram of iodine value per 100 grams.

So, that indicates which one is having more saturated fatty acids, which one is having more unsaturated fatty acids. Similarly, viscosity, that is olive oil has a more viscosity, mustard oil also has comparatively more viscosity, palm oil is less viscous. This and the saponification value, you see that palm oil has a 202, olive oil 176, and other sunflower oil, soybean oil 195, 193, and mustard oil has a saponification value of 184. So, these are the important quality parameters of major cooking oils.

So, now let’s discuss what are the various changes, particularly chemical changes commonly observed during oil cooking and frying processes, that is, when oils are heated depending upon subject to the conditions of heating whether heating under vacuum, heating under oxygen, and heat is more heat or less. These all will or even during frying operations when the material is put some moisture also, is there; heating in the presence of moisture, in the absence of moisture. All these will influence the various quality changes or various reactions which will take place in the triglyceride in the oil.

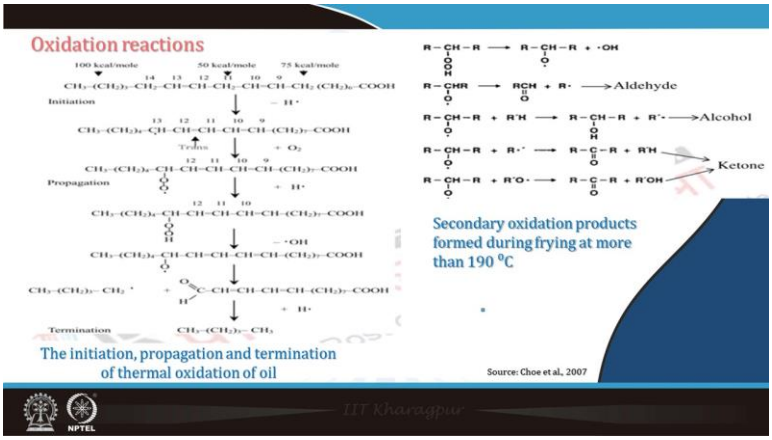


So, the major reactions are the oxidation, and decomposition of the oil. Release of moisture, high temperature, and exposure to atmospheric oxygen during frying of fats favors the oxidation of the frying medium that is oil. As food enters the oil, oxygen is introduced into the oil leading to oxidative changes. After an initial induction period, the peroxide content of the food begins to increase and finally, it decreases. Reactions during autooxidation include degradation reactions resulting in the formation of various volatile compounds. Auto oxidation of unsaturated fatty acids leads to the formation of conjugated hydroperoxide and peroxides which decompose to form volatile aldehydes, ketones, acids, alcohols, and hydrocarbon. So, details of all these various reactions we had already discussed in earlier lectures where we discussed about autooxidation process. So, similar reactions here also are encouraged if the temperature is more during the heating process.



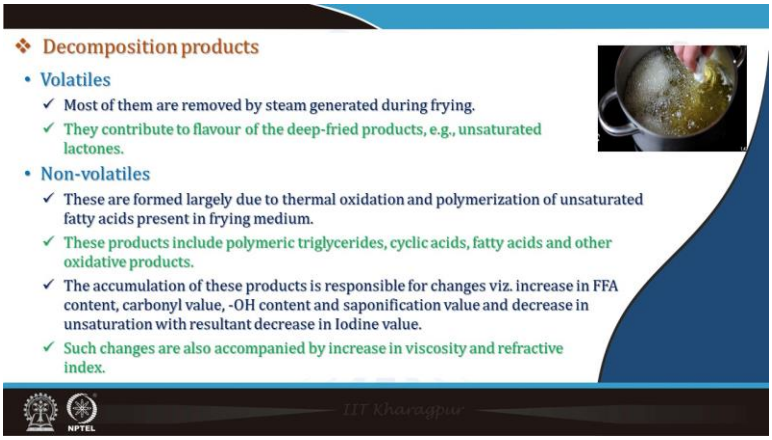
The next is thermal oxidation, that is presence of thermal oxidation process also occurs when the oil is heated at a high temperature in the presence of oxygen. This thermal oxidation results in formation of the free fatty acid due to cleavage and oxidation of the double bonds. There is a formation of hydroperoxides which may undergo fission to form alcohol, aldehydes, and acids, which contribute to the darkening of the oil or frying medium as well as the flavor changes in the product and in the flavor medium may take place.

There is a dehydration to form ketones. There is a formation of free radicals followed by their combination to form dimers, trimers, epoxides, alcohols, and hydrocarbons and all of which contribute to an increase in the viscosity of the oil. During deep fat frying, thermal and oxidative decomposition of oil produces volatile and non-volatile compounds.



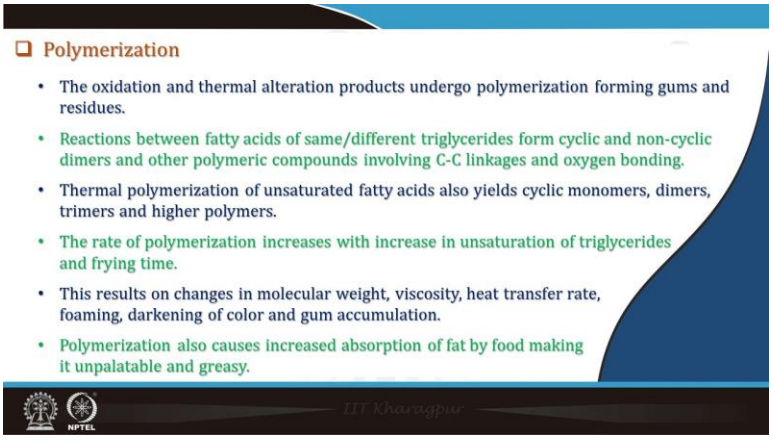
And the oxidation reactions here, you see is shown in this process and it is similar to that the autooxidation process. So, it is also initiated by thermal heat that decomposition, the initiation, propagation, and termination of the thermal oxidation of the oil. Then secondary oxidation products, when the oil is heated more than at a frying period, fried at more than 100 degree Celsius temperature, the aldehyde, alcohols, and ketones, etc. are the secondary oxidation products.

So, these initiation, propagation, and finally termination reactions with various carbonyl compounds are formed. So, these details of these reactions we had studied in earlier classes. Similar phenomena takes place here also, which is catalyzed by heat that we call thermal oxidation.



Then the various decomposition products in the oxidation, air oxidation, thermal oxidation, and moisture related, the various decomposition products which are formed. Number one they are various volatiles and the non-volatile compounds. Volatiles are

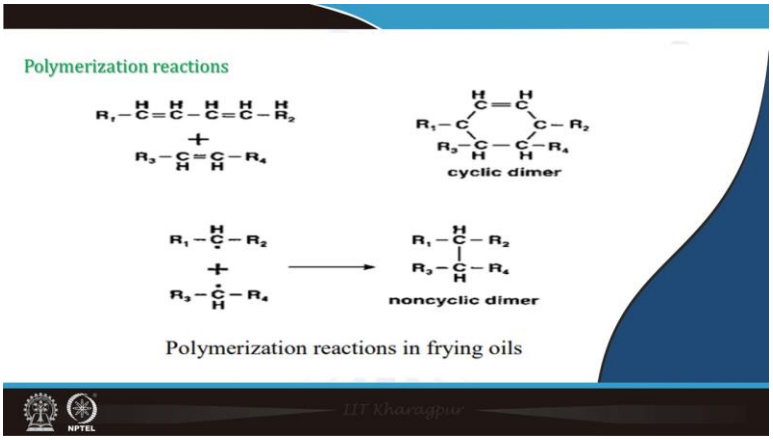
those, which are most of them are removed by steam generated during frying, and they contribute to the flavor of the deep-fried products. For example, unsaturated lactones etc. Non-volatile compounds are formed largely due to thermal oxidation and polymerization of unsaturated fatty acids present in frying medium. These products include polymeric triglycerides, cyclic acids, fatty acids, and other oxidative products. The accumulation of these products is responsible for changes such as an increase in the free fatty acid content, an increase in the carbonyl value, OH content, and saponification value, and a decrease in the unsaturation with a resultant decrease in the iodine value etc. are the changes in the oil. Such changes are also accompanied by increase in viscosity and refractive index of the oil.



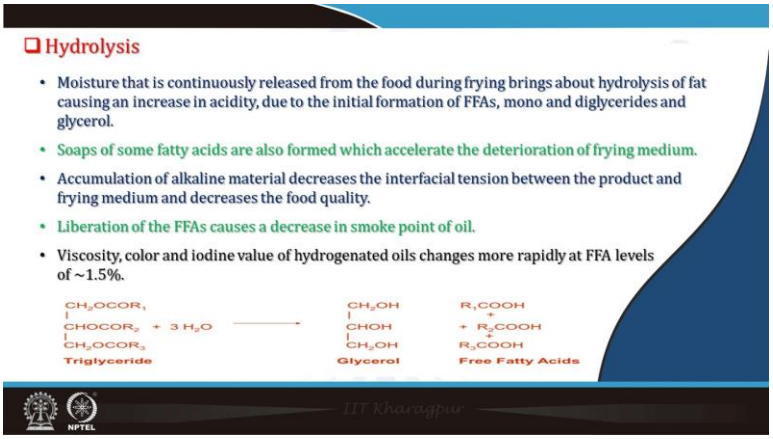
Another very important and common reaction during the frying of the oil, particularly deep frying of the oil, is the polymerization reaction. The oxidation and thermal alteration products undergo polymerization, forming gums and other various residues. Reactions between fatty acids of the same or different triglycerides form cyclic and non-cyclic dimers, other polymeric compounds involving carbon-carbon linkages, and oxygen bonding. Thermal polymerization of unsaturated fatty acids also yields cyclic monomers, dimers, trimers, and higher polymers.

The rate of polymerization increases with an increase in the unsaturation of the triglyceride and frying time. This results on changes in the molecular weight, viscosity, heat transfer rate, forming, darkening of color, and gum accumulation. That is the reason why the frying remains of the oil, it should not be reused. That is for frying purposes only should desired quantity of oil should be used. If you re-heat oil, various polymers are formed and then polymers will give the dark color. The food product which is heated in the oil having dark color compound, polymer compound, it has more intake of the oils, and even the product surface becomes brown. It will have a cracked surface. More importantly that these toxicity or carcinogenicity of these polymers, one cannot say that is the dangers of carcinogenicity cannot be completely overruled. These polymeric compounds may be toxic at a time.

Polymerization also causes increased absorption of fat by food, making it unpalatable and greasy. More heat absorption will take place. Various changes are there. We should not use re-heat oil. That is one major problem in the street food etc. Street vendors, when they take the oil, then go on heating it. There is a polymer oil, not much this is a challenging area that still remains. That is how to remove these polymers from these oils and reuse of this oil for better products. Of course, there are some molecular filters or membrane filtration, etc. But these technologies are little expensive.



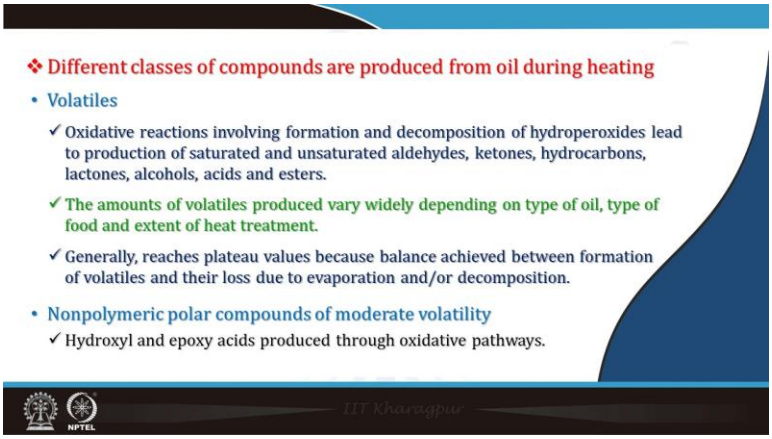
The polymerization reactions etc. As I told you that polymerization reactions in frying oil, there is desired saturated oil converted to the cyclic dimers and non-cyclic dimers etc. and which give the various changes that we discussed in the earlier slide. And these monomers may be even toxic.



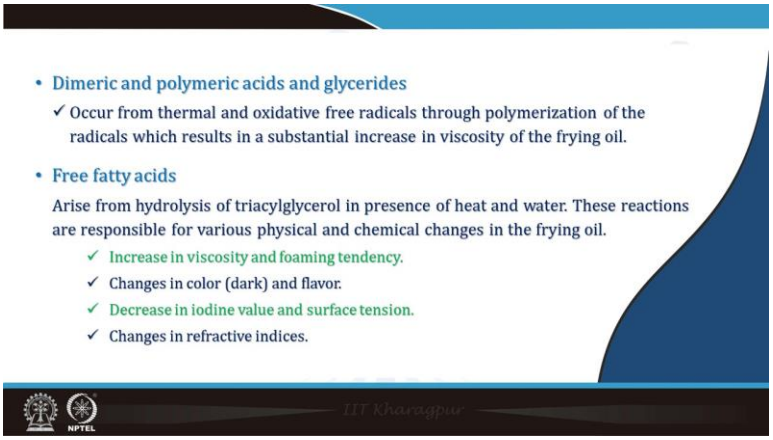
Other change that may take also is provided because when you are putting the food or it has some moisture content, then moisture from the food, the moisture is liberated and released into the oil. And then, the heating is continuously released from the food during the frying and it brings about the moisture brings about the hydrolysis of the triglyceride, causing the increase in the acidity. That is free fatty acids are more formation of free fatty acids, or formation of free fatty acids results into the monoglyceride, diglyceride formation and finally, if there might be some glycerol molecules also. So, all these

products monoglyceride, diglyceride, glycerol, and triglyceride, are free fatty acids that might be there as a result of hydrolysis of the fat.

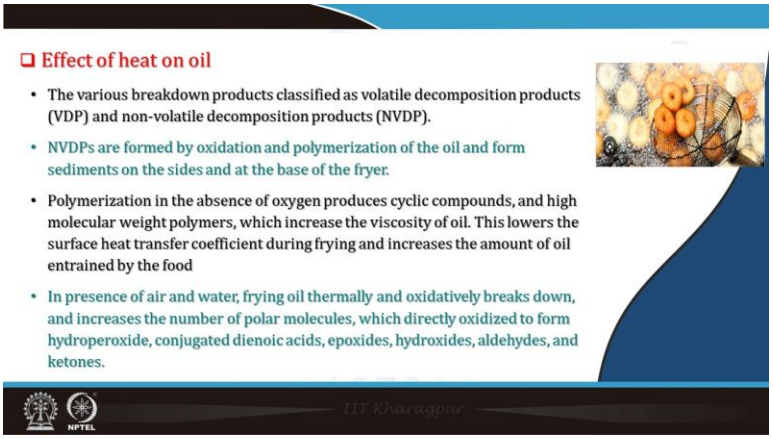
Soaps of some fatty acids are also formed which accelerate the deterioration of the frying medium. Accumulation of alkaline material decreases the interfacial tension between the product and frying medium and decreases the food quality. Liberation of the free fatty acids causes a decrease in the smoke point of the oil. Even 1 percent change in the free fatty acid depresses the smoke point by 100 degree or 50 degree in some oils. Viscosity, colour, iodine value of the hydrogenated oil also changes more rapidly at free fatty acid levels are up 1 to 1.5 percent. So, this is the reaction how is that, in the earlier class details we have discussed.



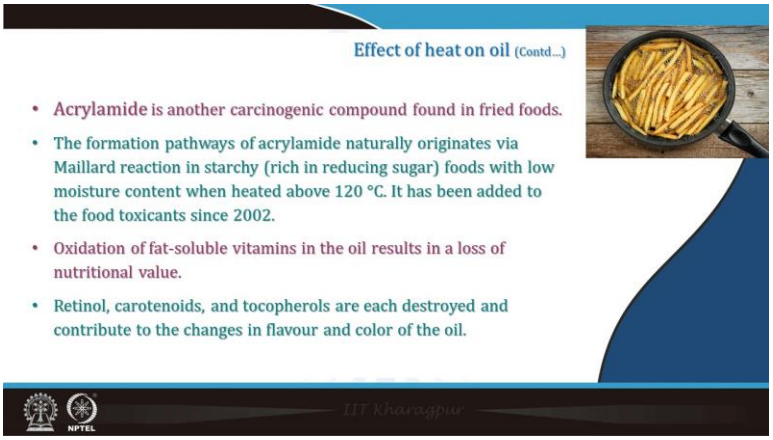
So, different classes of compounds which are produced from oil during heating. If you summarize that is volatile compounds, that is oxidative reactions involving the formation of decomposition and hydroperoxide lead to the production of saturated and unsaturated aldehydes, ketones, hydrocarbons, lactones, alcohols, acids, esters, etc. The amounts of volatile produce vary widely depending on the type of oil, type of food, and extent of heat treatment. Generally, it reaches plateau values because balance is achieved between the formation of volatiles and their loss due to evaporation and decomposition. Also, non-polymeric polar compounds of moderate volatility, like hydroxy and epoxy acids, are produced through oxidative pathways.



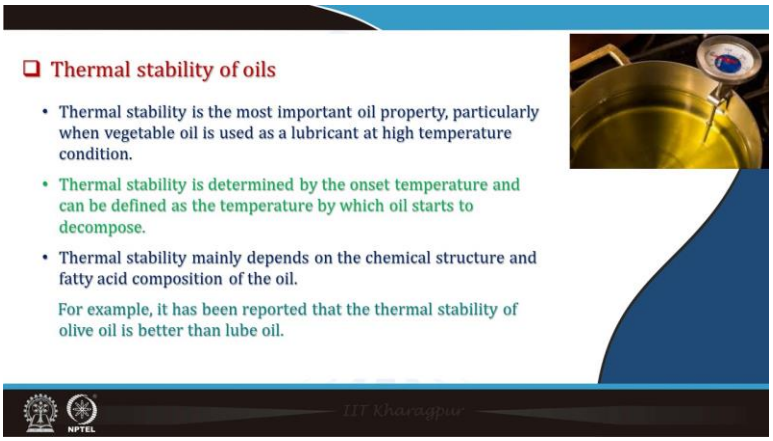
Then dimeric and polymeric acids and glycerides occur from the thermal and oxidative free radicals through polymerization of the radicals which results in a substantial increase in viscosity of the frying oils. The free fatty acids arise from the hydrolysis of triglycerols in the presence of heat and water. These reactions are responsible for various physical and chemical changes in the frying oil. They result in an increase in the viscosity and foaming tendency, changes in the colour (dark colour may become darker) or even changes in the flavour of the oil. There is a decrease in iodine value and surface tension, and also there is a change in the refractive index.



Let's see some case study. The effect of heat on the oil that is various breakdown products classified as volatile decomposition products and non-volatile decomposition products are found. We discussed in the various earlier slides. Non-volatile decomposition products are formed by oxidation and polymerization of the oil and form sediments on the sides and at the bottom of the fryer. Polymerization in the absence of oxygen produces cyclic compounds, and high molecular weight polymers, which increase the viscosity of the oil. This lowers the surface heat transfer coefficient during frying and increases the amount of oil entrained by the food. In the presence of air and water, frying oil thermally and oxidatively breaks down, and increases the number of polar molecules, which directly oxidize to form hydroperoxide, conjugated dienoic acids, epoxides, hydroxides, aldehydes, and ketones.



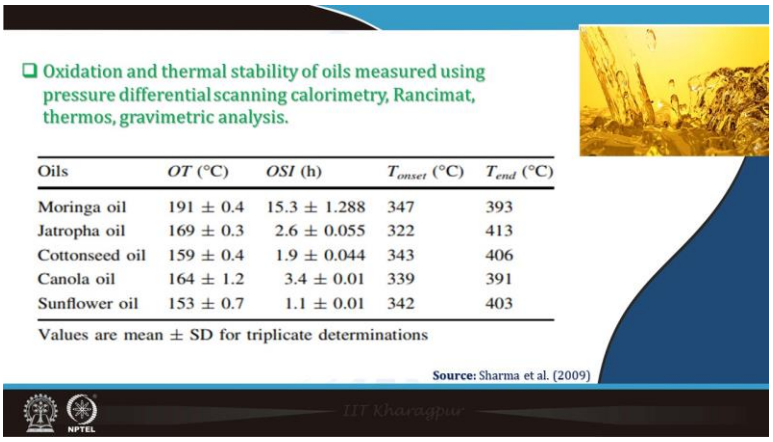
Then another very important phenomenon is the acrylamide formation. It is another carcinogenic compound that is found in fried food. So, the formation pathways of acrylamide naturally originate by a Maillard reaction in the starchy food which is rich in reduced sugar and with low moisture content when heated above 120 degree Celsius. It has been added to food toxicants since 2002. Oxidation of fats-soluble vitamins in the oil results in a loss of nutritional value. Retinols, carotenoids, and tocopherols are each destroyed, and contribute to the changes in the flavor and color of the oil.



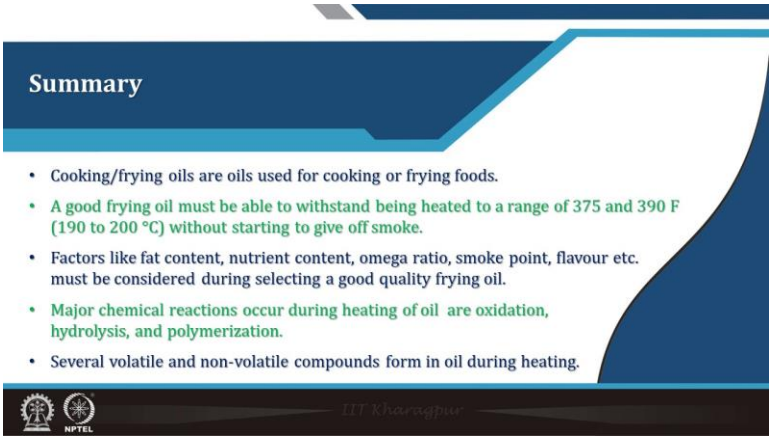
Then, we will talk about briefly thermally stability of the oil. Thermal stability is the most important oil property, particularly when vegetable oil is used as a lubricant at high-temperature conditions. Thermal stability is determined by the onset temperature and can be defined as the temperature by which oil starts to decompose. Thermal stability mainly depends on the chemical structure and fatty acid composition of the oil. For example, it has been reported that the thermal stability of olive oil is better than that of the lube oil.

So, here oxidation and thermal stability of oils measured using pressure, differential scanning calorimetry, rancimat, thermos, gravimetric analysis, etc. are done. This, some common oil that is moringa oil, jatropha oil, cottonseed oil, canola oil, and sunflower oil are the common oils. Oxidation temperature, OSI, onset temperature in degree Celsius, and T end degree Celsius are indicated here. As you can see here, the cottonseed oil, its

OT value is 159 plus minus 0.04. Moringa oil has the highest OT that is among these which are included in this list that is it has 191.



Oxidation stability index is highest again in the moringa oil and it is lowest in the sunflower oil, and this is obviously because of the more polyunsaturated fatty acids content in the T onset that is onset temperature and oxidation that is the 347 is in the case of moringa oil, 342 in the case of sunflower oil and other is the 343 in the cottonseed oil. T end that is at the temperature at which this is 400 ranges from 391 to 413 in these oils.



So, finally, I would like to summarize this lecture by saying that cooking or frying oils or the oils which are used for various food operations, food processing operations such as cooking or frying, deep-fat frying, shallow-frying, baking, roasting, and so on. The food frying oils must be able to be sustained to being heated to a range of temperatures may be 375 to 390 degree Fahrenheit or 190 to 200 degree Celsius in general without starting to give off smoke. Factors like like fat content, nutrient content, omega ratio, smoke point, flavor, etcetera must be considered during selecting a good quality cooking oil or frying oil. Major chemical reactions that occur during the heating of the oil are oxidation, hydrolysis, and polymerization, and several volatile and non-volatile compounds form in oil during heating. And so, heating and frying operations should be properly controlled and conditions should be used in such a way so that the formation of these compounds

can be eliminated. And more important, the reheated oil, fried oil, fry remain it should not be used again and again it is not a healthy option.

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So, these are the references which are used in making this preparing this lecture.

Thank you very much for your patience.