Food Oils and Fats: Chemistry & Technology

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Week 1: Course Overview and Introduction

Lecture 5: Composition, Nutrition and Health Values of Animal Fats and Oils

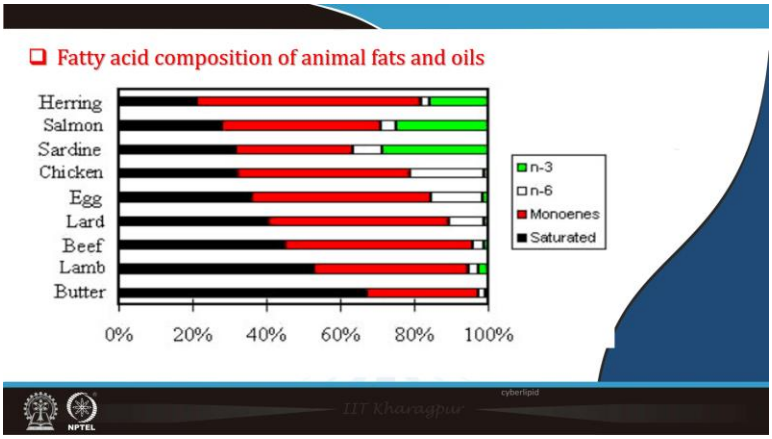
Hello friends, welcome you all to this 5th lecture of the course today. In the earlier class we studied about sources and availability of animal fats and oil. Today, we will talk about composition, nutrition and health values of animal fats and oils.

The topics which we will cover today include milk fat, rendered fat and fish oil, their properties that is the different types of animal fats and oils. Then major and minor components present in these major fats and oils of animal sources particularly their composition, fatty acids, MUFA PUFA ratio, antioxidant content and so on. Also, towards the end we will have a look and compare the important properties of animal fat and vegetable oil and finally, we will conclude the lecture with speaking something about nutritional properties and health values of animal oil and fat.

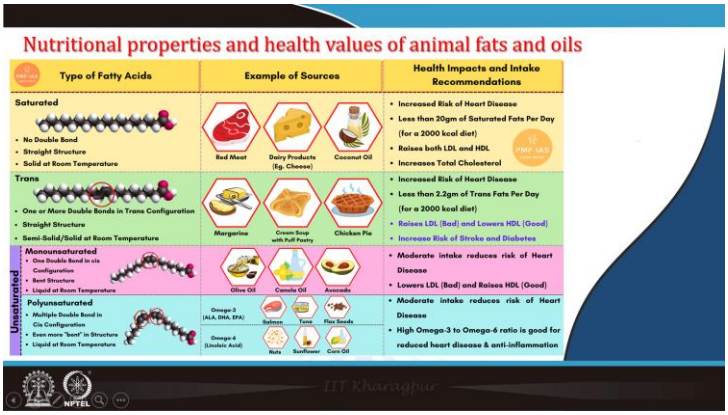
Let us see the properties of the animal fat. In the last class, we discussed about their sources. In the earlier class also, I talked about that animal fat is commonly classified as depot fat, which is localized fat present in the adipose tissues and intramuscular fat that is localized fat present in the muscle tissues. Depot fats are mostly present in the subcutaneous layer, although they also include some intramuscular deposits as well like seam fats. Intramuscular fats include lipids from adipose cells in the muscle and membrane

bound lipids. In fresh red meat, the principal lipid component of depot fats are triglycerides, which can be easily extracted using non-polar organic solvents. Butter and lamb fats are very saturated. More than 50% of their fatty acid content is saturated.

Among land animals, only eggs and chickens have a consistent amount of essential fatty acid, that is the fats, which are present in eggs and chickens. They have the significant amount of essential fatty acids. Even aquatic sources have that oils and fats which are available in aquatic sources. They have the richest amount of essential fatty acids. Herring, salmon, and sardine are precious dietary sources of omega 3 polyunsaturated fatty acids that is mostly 20:5 and 22:6 as far as the carbon number and their number of double bonds is concerned.



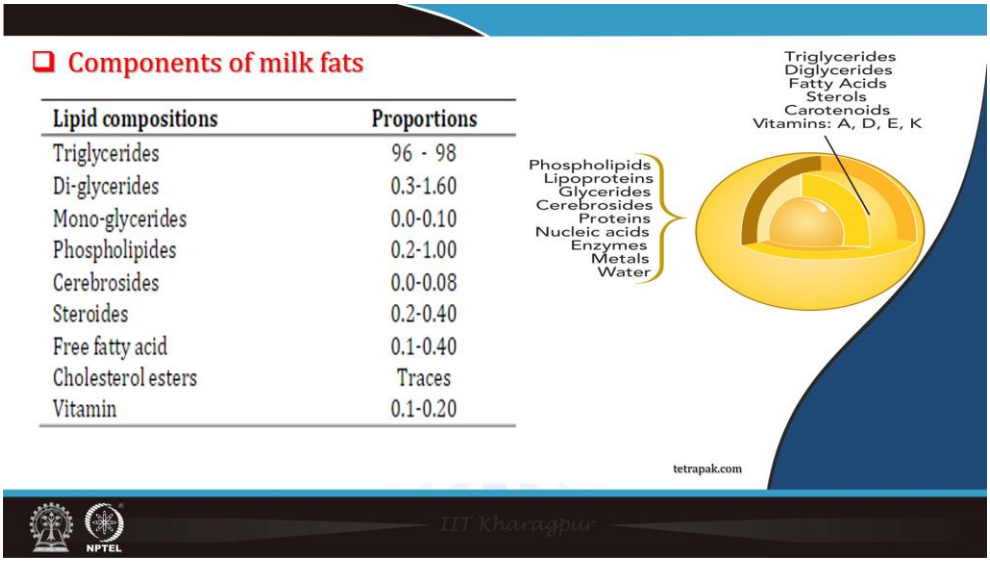
So, here in this slide, I have just given you a comparison of fatty acid content in major animal fats and oils. You see that the red color indicates monoenes, white color indicates omega-6, green color indicates omega-3, and black color is the saturated fatty acids. So, you can see that major proportion in almost all the animal fats particularly butter you see, it has around 70 % saturated fat, lamb has around 50 % saturated fat and similarly other fats also. Then, this monosaturated fats are also present in the significant amounts. Herring has the maximum one. Even egg and chicken fats also include significant proportion of monoenes. As far as the omega-3 and omega-6 proportion is concerned, you can see that sardines, salmon and herring have a significant amount of omega-3 fatty acids. Whereas, the chicken, egg and lard have also good amount of omega-6 fatty acids. If you look at the nutritional properties and health values of animal fats and oils, there is the saturated fats. They are present in the red meat, dairy products, coconut oil as you saw in the earlier also.



And we have discussed these, what are the health benefits of these various saturated fats, trans fats, monosaturated and polyunsaturated fats etc. The saturated fats result into increased risk of heart diseases and less than 20 gram of saturated fat per day should be consumed. It raises both LDL and HDL and increases the total cholesterol, if you take too much saturated fat from the animal sources. The trans fats equally that is even they are sometime more problematic than the saturated fats, they increased risk of heart diseases and less than 2.2 gram of trans fat per day should be consumed. and it raises the LDL that is the bad and lower HDL cholesterol levels and increases the risk of stroke and diabetes. And this trans-fat has been found that in the margarine, cream soup with puff pastry, chicken pies etc. particularly the product which are given heat treatment and the fat containing the fatty acid during heat treatment cis form is converted into trans form. In major cases it has been found. Then monosaturated fats, which are present in the olive oil, canola oil, avocado oil, this earlier we discussed because plant oils mainly they are the rich sources of these monosaturated fatty acids. And in the polyunsaturated fatty acids particularly omega-3 is found more in salmon, tuna, and omega 6 is found mostly in the that is a vegetable oil source. This moderate intake of these polyunsaturated fatty acids reduces the risk of heart damages etc. High omega-3 to omega-6 ratio is good for the reduced disease and anti-inflammation. Then now let us discuss about the properties of milk fat which is one of the major sources of fat in the Indian dietary or even the majority of the people in the world, those are who are vegetarian the milk fat becomes a major source for them. So, it is also available in two form that is milk fat and one is the anhydrous butter fat and the other form is butter oil.

Anhydrous butter fat is milk fat separated directly from milk or cream and the butter oil is milk fat made by removing water from the butter. The composition of milk fat is somewhat complex, triglycerides constitute approximately 98 % of milk fat with the remainder being made up of diglycerides, monoglycerides, phospholipids, cerebrosides, even some amount of cholesterol, vitamins, tocopherols, carotene, and some flavor compounds. Milk fat contains more fatty acids than any other fat or animal of animal or vegetable origin. Cow's milk fat is now known to contain over 500 different fatty acids. Most of these fatty acids

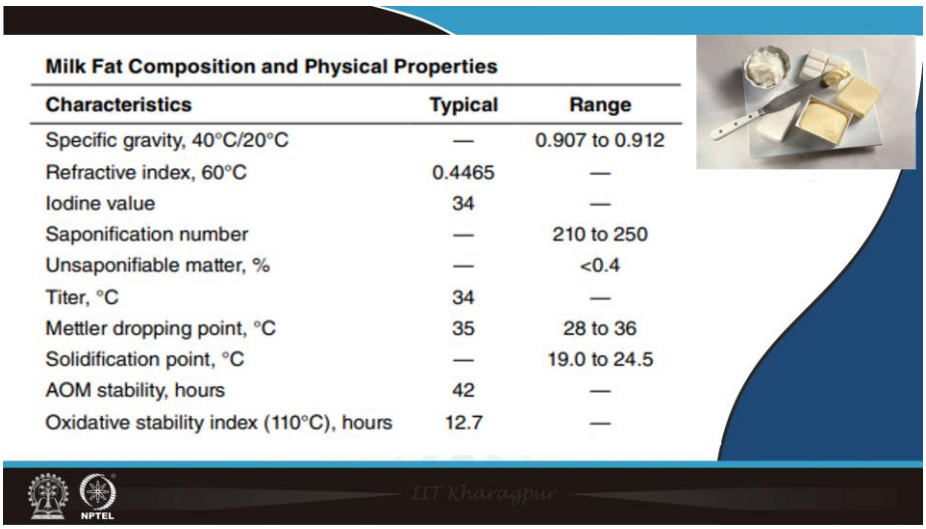
are present at exceedingly low levels, but some of these minor components are very important, such as lactones, which contributes to the unique flavor of the milk fats.



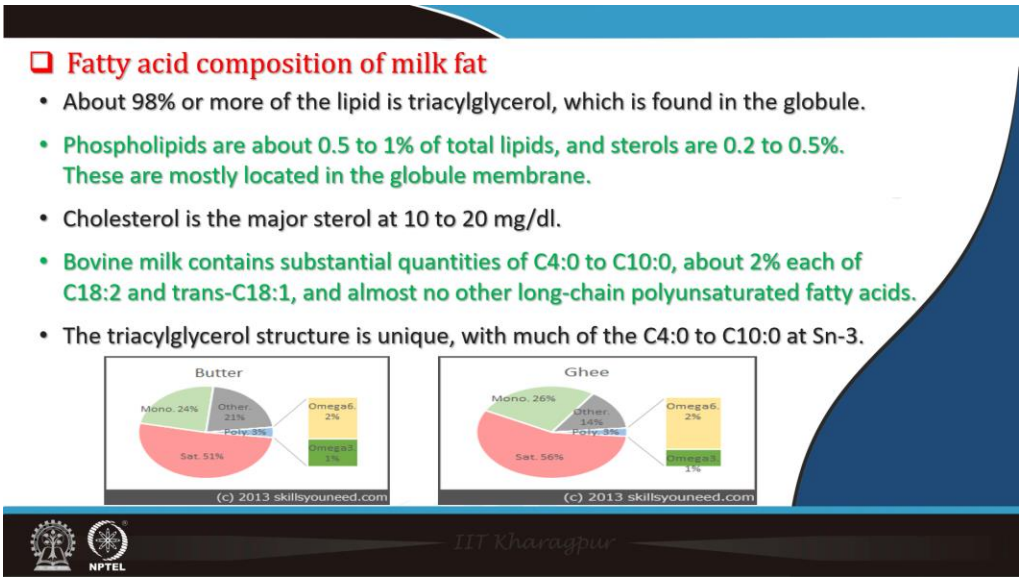
So, here in this slide I have given you the composition of milk fat that is the triglyceride as I told you include 96 to 98 percent, diglycerides very less 0.3 to 1.6 percent, similarly monoglycerides also very less 0.1 percent, phospholipids it contains 0.2 to 1 percent, that steroids 0.2 to 0.4 percent, it has free fatty acids 0.1 to 0.4 percent and traces of cholesterol esters and vitamin also it has 0.1 to 0.2 percent. In the earlier class, I gave you the structure that is in the milk how the fat is present in the milk fat globule inside and there in the serum how these are dissolved. So, here you can see this is just a structure of fat globule which shows that in this globule there is a fat globule membrane and inside there are, that is the yellow portion here you can see, these are the majorly constitute phospholipids, lipoproteins, glycerides, cerebrosides, and some proteins nucleic acid enzymes etc. whereas, the other portion that is, these are the triglyceride, they are concentrated here that little more yellow part triglyceride, diglyceride, fatty acid, sterols, carotenase, and vitamin A, D, E and K and all these are obviously, include inside a fat globule membrane they are present in the serum milk serum.

So, if you look at the physical properties of the milk fat, it is distinguished from other fat except the laurics, by the low average molecular weight of its fatty acid that is milk fat its fatty acids are generally of low molecular weight as indicated by a high saponification value and low refractive index. This saponification value, refractive index etc. these are the properties of the milk fat in general, we will be taking up separately when we discuss the details of the chemistry and properties of fats and oils may be in the next week. So, butter fat differs from the lauric oils by a high content of steam volatile, short, and medium chain fatty acids that is butyric acid, caproic acid, caprylic acid and capric acid. The fatty acid distribution in milk fat triglycerides is not random and the short chain fatty

acids preferentially occupy the SN3 position. Ruminant milk fat contains relatively low concentrations of polyunsaturated fatty acids as a result of bio hydrogenation of dairy lipids in the rumen. The bio hydrogenation process also converts 6.8 to 7.5 % of the unsaturated fatty acids to the trans configuration mainly C-16 and C-18 monoene acids. Conjugated linoleic fatty acid CLA isomer that is cis-9 and trans-11 isomers has been associated with the beneficial health effects, including cancer protection, heart disease defense, reduction in body fat, enhanced immunity, and increased bone mineralization.



So, the milk fat composition and their physical properties here majority most of the important physical properties has been shown here in this table like you see that a specific gravity at 40 to 20 degree Celsius, it ranges between 0.907 to 0.912. The refractive index of milk fat at 60 degree Celsius is 0.4465, its iodine value is 34. Similarly, saponification value, unsaponifiable matter, titer value melting or Mettler dropping point, solidification point all these oxidation stability index of the milk fat at 110 degree Celsius is around 12.7 hours. So, these are the important characteristics of the milk fat.

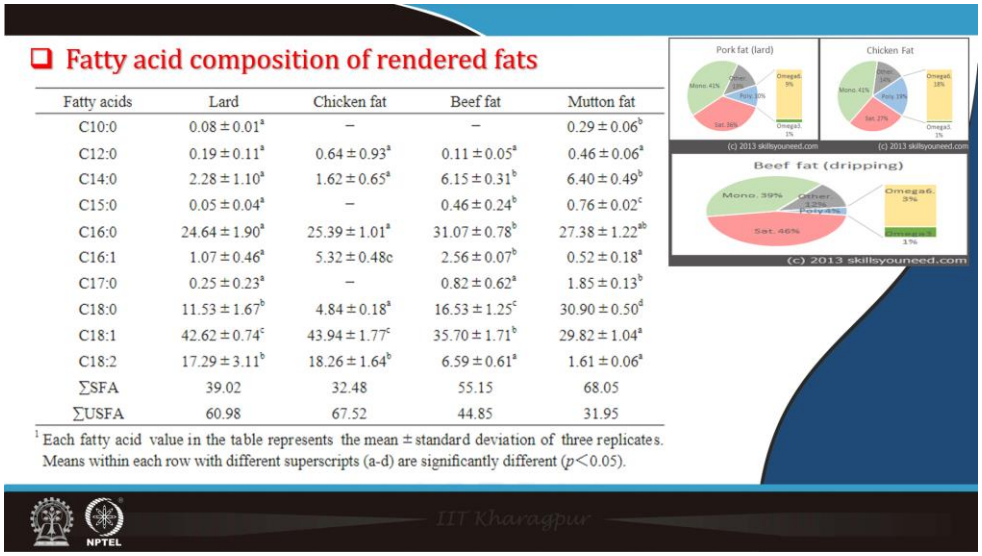


The fatty acid composition of the milk fat if we discuss about 98% or more of the lipids in triglycerides particularly milk triglycerides are found in the globule inside in the globule which I showed you in the earlier picture. Phospholipids are about 0.5 to 1 percent of the total lipids and sterols are about 0.2 to 0.5 percent. These are mostly located in the globule membrane. The other triglycerides etc. they are inside the globule, but these phospholipids and they are mostly present in the globule membrane. Cholesterol is the major sterol that is present at the 10 to 20 milligram per dl in the milk. Bovine milk contains substantial quantities of C4:0 to C10:0 and about 2 percent of C18:2 and trans C18:1 and almost no other long chain polyunsaturated fatty acids. The triacylglycerol structure of the milk fat is unique with much of the C4 to C10 at SN 3 position. So, if you see here that in the butter, it contains around mono fatty acid 24 percent saturated 51 and others are 21. omega 6 is 2 percent and omega 3 is 1 percent. Whereas in the ghee the monosaturated fatty acid is around 26 percent, saturated fats are 56%, polyunsaturated fat is about 3%, in which omega-6 include 2% and omega 3 includes 1%. So, this is the fatty acid composition of milk proper fat.

So, now, the nutritional properties and health value of milk fat you know lipids can be directly absorbed in the digestive system without hydrolysis and which contributes to very high digestibility of milk fat and about 97 to 99 percent of the milk fat is easily digestible in majority of the people. Then the unique nutritional value of the bovine milk can be attributed to the presence of short chain fatty acids and medium chain fatty acids which are important sources of energy to the muscles, heart, liver, kidney, blood platelets and nervous system. They do not pose an obesity risk, they prevent ulcerative colitis, cancer, atherosclerosis, hypertension. They have anti-inflammatory and antibacterial effects and they boost natural immunity, but mind it milk contains cholesterol. Lipid derivative which stabilizes and stiffens cell membrane builds the cell cytoskeleton, protects nerve fibers, and

acts as a precursor of steroid hormones, bile acids and vitamin D_3. So, the cholesterol is an equally very important component for our body even the sex and adrenal hormones that they are synthesized from the cholesterol. Cholesterol is raw material part, but excess of the cholesterol is bad. It invites heart problem. So, one should regulate the cholesterol level in the body and therefore, that consumption of animal fat should be controlled. Bovine milk lipids do not exert hypercholesterolemic or atherogenic effects in the human body.

Now, let us see the rendered fat. What are rendered fat? We had discussed in the earlier class, what are their sources, we had discussed. Now let us see the some of the properties. So, the major rendered fats are their components include tallow, the major constituent of tallow are the glycerides of oleic that is 37 to 43 percent, palmitic 24 to 32 percent and glycerides of stearic 20 to 25 percent, myristic 3 to 6 percent and linoleic 2 to 3 percent. Minor components include cholesterol and arachidonic acid, elaidic acid and vaccenic acid. Hydrogenation of the carbonyl group is used to obtain the corresponding fatty alcohols and this may also be achieved by the hydrogenation of the glycerides. The other major component in the rendered fat include lard. The structure of lard contains a high percentage of medium melting oil, di-saturated and monosaturated triglycerides. It has about 0.95% cholesterol. As a saturated fat, consumption of this food has been associated with the high blood pressure and coronary heart diseases. That is if you take more lard, obviously you will be consuming more cholesterol and which will be risk to high blood pressure and coronary heart diseases or CVD cardiovascular diseases. However, it has less saturated fat than some other fat like butter etc. by weight.



Fatty acids	Lard	Chicken fat	Beef fat	Mutton fat
C10:0	0.08 ± 0.01^{a}	–	–	0.29 ± 0.06^{b}
C12:0	0.19 ± 0.11^{a}	0.64 ± 0.93^{a}	0.11 ± 0.05^{a}	0.46 ± 0.06^{a}
C14:0	2.28 ± 1.10^{a}	1.62 ± 0.65^{a}	6.15 ± 0.31^{b}	6.40 ± 0.49^{b}
C15:0	0.05 ± 0.04^{a}	–	0.46 ± 0.24^{b}	0.76 ± 0.02^{c}
C16:0	24.64 ± 1.90^{a}	25.39 ± 1.01^{a}	31.07 ± 0.78^{b}	27.38 ± 1.22^{ab}
C16:1	1.07 ± 0.46^{a}	5.32 ± 0.48c	2.56 ± 0.07^{b}	0.52 ± 0.18^{a}
C17:0	0.25 ± 0.23^{a}	–	0.82 ± 0.62^{a}	1.85 ± 0.13^{b}
C18:0	11.53 ± 1.67^{b}	4.84 ± 0.18^{a}	16.53 ± 1.25^{c}	30.90 ± 0.50^{d}
C18:1	42.62 ± 0.74^{c}	43.94 ± 1.77^{c}	35.70 ± 1.71^{b}	29.82 ± 1.04^{a}
C18:2	17.29 ± 3.11^{b}	18.26 ± 1.64^{b}	6.59 ± 0.61^{a}	1.61 ± 0.06^{a}
∑SFA	39.02	32.48	55.15	68.05
∑USFA	60.98	67.52	44.85	31.95

[1] Each fatty acid value in the table represents the mean ± standard deviation of three replicates. Means within each row with different superscripts (a-d) are significantly different ($p<0.05$).

The fatty acid composition of rendered fat mainly the lard, chicken fat, beef fat and mutton fat. If you see here that is the different fatty acid like C 10, C 12, C 14, C 15, C 16, these are mostly saturated fatty acids and their content obviously you see in the lard, saturated

fatty acid C 16 is more. In the chicken fat also, it has a higher amounts 25 percent, in the beef 31% and in the mutton fat around 26%. The other short chain fatty acids they are not present much in these rendered fats and the polyunsaturated fatty acids particularly C18:2, this is also present in the lard, chicken fat, a significant amount in beef fat also, but in the mutton fat it has very less quantity. But C18:1 that monosaturated fatty acids in the mutton fat as well as C18:0, these are have the significant amount ok. So, this shows that as what are the fatty acid particularly saturated fatty acids, unsaturated fatty acids and monosaturated fatty acids etc., which are present in the. So, on an average you can say lard contains around 30 percent saturated fatty acids, 60% or 60.98%, Lard contains 39% saturated fatty acids and 61% unsaturated fatty acids and accordingly others that is the mutton fat it contains around 68% saturated fatty acids and approximately 32% unsaturated fatty acids.

So, the let us see little elaboration of the hogs a lard. So, hogs are monogastric and their stored fats closely resemble dietary intake. Consequently, the degree of unsaturation of lard depends on the amount of the fatty acid composition of the oils in the feed. Lard is rancid at a peroxide value of 20 milliequivalent per kg of the oil as opposed to the whereas, this peroxide development of rancidity in the vegetable oil will be almost at a much higher value of peroxide like 70 to 100 milliequivalent per kg. It is the range for the most of the vegetable oil. So, major reason for is that that these vegetable oils they have natural antioxidants which is not present there in the lard or other milk fats. Lard responds well to the addition of antioxidants such as butylated hydroxy anisole, butylated hydroxy toluene, toluene, TBHQ and other various tocopherols, which along with the if the metal chelators are such as citric acid etc. are added. So, the lard's help life or even that is the development of rancidity in the lard can be prevented or can be extended. The structure of lard contains a high percentage of medium melting disaturated monounsaturated triglycerides. These triglycerides are largely in a symmetrical arrangement which causes lard to crystallize in the b form. And this characteristic has restricted the use of lard to application requiring low structural properties, but high lubricity.

Lard Composition and Physical Properties

Characteristics	Typical	Range
Specific gravity, 50°C	—	0.896 to 0.904
Refractive index, 50°C	—	1.448 to 1.460
Iodine value	57	45 to 70
Saponification number	—	192 to 203
Unsaponifiable matter, %	—	<1.0
Titer, °C	—	32 to 45
Mettler dropping point, °C	32.5	31.5 to 33.0
Solidification point, °C	—	4 to –2
AOM stability, hours	54	53 to 60
Oxidative stability index (110°C), hours	16.9	16.6 to 19.0

So, here again the composition like in the milk fat we saw that a specific characteristic that is then some important physical properties these are similarly here for the lard. That physical properties and composition like a specific gravity is 0.896 to 0.904 at 50 degreeCelsius, refractive index may be 1.448 to 1.460, iodine value is 57 range may be 45 to 70. Similarly, saponification value and unsaponifiable value etc. and oxidative stability index, if you see here, it has a range of 16.6 to 19. So, at 110 degree Celsius it is a 16.6 to 19 hours or typically this at 16.9 hours.

Now tallow, this tallow contains a high level of cholesterol that is approximately 1000 ppm. Almost half of the fatty acids present in the tallow are saturated and they include myristic acid which has the greatest effect on raising the blood plasma cholesterol level. In addition, tallow contains approximately 5% trans fatty acids which is characteristics of the ruminant digestive system. Trans fatty acids originate from the microbial biohydrogenation of polyunsaturated fatty acids in the digestive tract of ruminants and therefore, occur naturally in ruminant meat and milk fats. The predominant trans fatty acids of biohydrogenations are C18-1 trans 11 isomer vaccine and C18-2 cis 9 trans 11 conjugated linolenic acid (rumenic). The tallow contains very little red or yellow pigments, but can have a high green colour caused by the chlorophyll.

Tallow Composition and Physical Properties

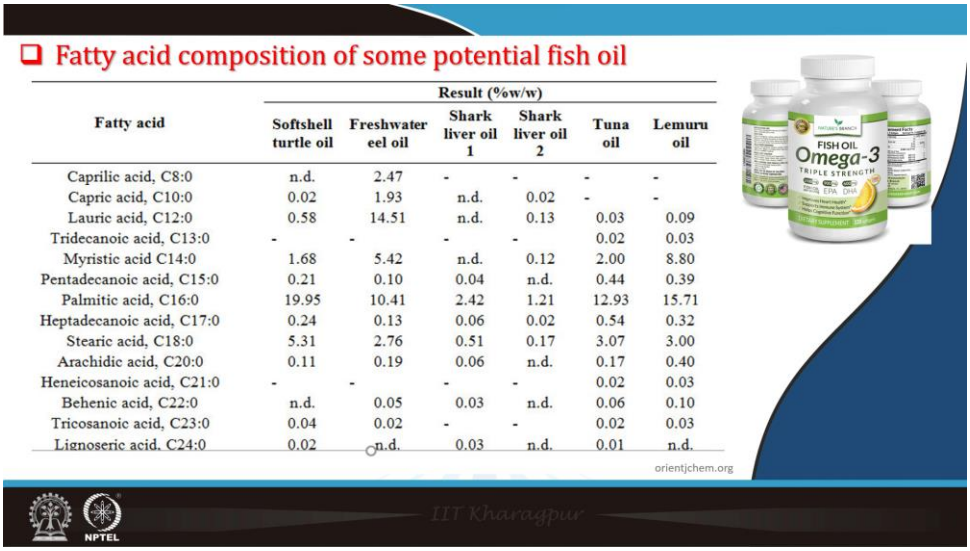
Characteristics	Typical	Range
Specific gravity, 40°C/water at 20°C	—	0.893 to 0.904
Refractive index, 40°C	—	1.448 to 1.460
Iodine value	45	40 to 49
Saponification number	—	190 to 202
Unsaponifiable matter, %	—	<0.8
Titer, °C	—	40 to 49
Mettler dropping point, °C	46.5	45 to 48
Solidification point, °C	—	
AOM stability, hours	16	—
Oxidative stability index, hours	3.6	—

The composition and physical properties of tallow are given in this slide. A specific gravity at 40 degree Celsius temperature and water at 20 degree Celsius it is 0.893 to 0.904, refractive index is 1.448 to 1.460, iodine value is 40, saponification value is in the range of 190 to 202 and its oxidative stability index is around 3.6 hours. So, it is generally very prone to oxidative stability.

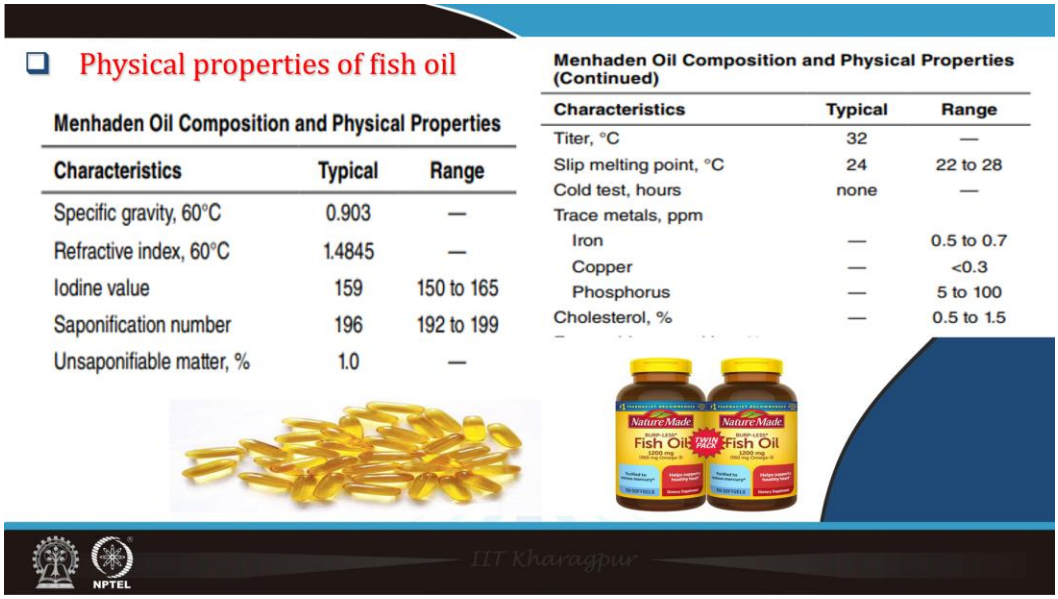
Then nutritional properties and health values of rendered fats you see that is the tallow is rich in nutrients it helps to absorb more nutrients from the food, but it is rich in vitamin content like A D E K and B_1. Tallow reduces inflammation. It contains conjugated linoleic acids which is a natural anti-inflammatory. One of the fatty acids in beef tallow that is the palmitoleic acid possesses antimicrobial properties which may help to ward off infections. It is good for your nervous system; tallow is high in choline a nutrient that supports the nervous system also the healthy fatty acids help to protect nerve cells. It helps the body burn the fat that is consuming healthy fats stimulates the release of glucagon the hormone that signals body it is time to burn stored fat to use for energy. Tallow is also rich in vitamin E which helps to protect the body cells from free radical damage.

Now, let us see the characteristics and properties of fish oil that is menhaden oil is a refined marine oil that is derived from menhaden fish of the genus Brevoortia. Menhaden is a pelagic-type fish especially for use pursued for reduction to meal and oil. Crude menhaden oil contains non triglyceride materials such as waxes, moisture, insoluble impurities, free fatty acids, trace metals, sulphur, halogen, nitrogen compounds, pigments, and sterols. Menhaden oil differs from vegetable oils and animal fats by its high proportion of poly and saturated fatty acids especially the long chain omega 3 fatty acids. EPA and DHA are the major sources of omega 3 fatty acids which comprise 30% or more of the oil. The ratio of omega-3 to omega-6 fatty acid in menhaden oil approaches around 10 to 1, a

reverse of the omega 6 to omega-3 ratio of soyaben oil and canola oil, that is, which is there 7 to 1 and 2.5 to 1 respectively.



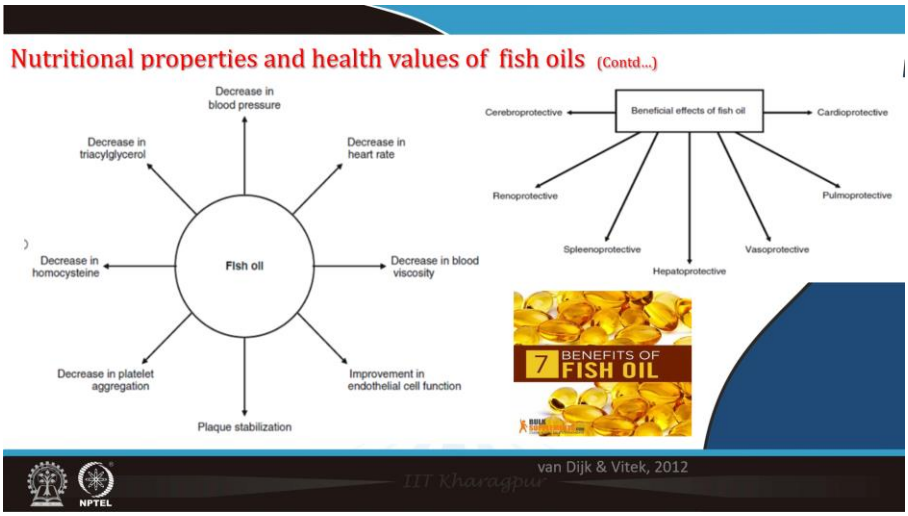
Fatty acid composition of some potential fish oil is given here that is that softshell turtle oil, fresh water eel oil, shark liver oil 1, shark liver oil 2, and the tuna oil and lemuru oil. Here you see those contents of caprilic acid, capric acid. So, normally caprilic and capric they are very insignificant or in some of the oil they are not detected. But the other oils like you see palmitic, it is present softshell fish oil and also fresh water eel oil, in tuna oil, lemuru oil etc. And then again that is the stearic acid that is there is almost of the saturated fatty acid, saturated stearic and fatty acid saturated they are the major content of this and apart from this even some amount of that even tri-equation alkalization, lemuru silica acid etc. very insignificant proportions are presented there.



So, physical properties of the fish oil that is a specific gravity it has at 60 degree Celsius 0.903, refractive index 1.485, iodine value 159, range is 152, 165 means that is iodine value it is high means that is, it has a high unsaturation value. Saponification value is 196. So, saponification value larger the saponification it indicates the chain length of the fatty acid, un saponifiable manner is 1 percent. Similarly, that even cholesterol in this fish oil may be contained from 0.5 to 1.5 % and the trace metal iron, copper, phosphorus etc. may also be found in this in the range significant range.

So, major components of the marine oil that is the fatty liquid consists mainly of saturated fatty acid as you would see in the earlier slides with palmitic acid 16:0 at the most relevant monounsaturated fatty acids with the oleic acid 18:1 omega 9 as a predominant and polyunsaturated fatty acid (PUFA) which are represented by eicosapentaenoic acid and docosahexanoic acid and omega-3 fatty acids are in the linolenic region they are present in less amount. Omega_3 PUFA especially EPA that is 20:5 omega 3 and DHA 22:6 omega 3 are among the main component of the fish oil. Cholesterol is another lipid relevant to health and is the main sterol in the marine species accounting for more than 90 % of the all sterols, but in some cell species such percentage can lower to about 25 percent. Vitamins A D and E are the fat soluble vitamins which occur most commonly that is the determined in the fish oil going to their high concentrations of not only in the liver, but in the fresh fish as well.

Regarding nutritional properties and health values of fish oil omega fish oil omega 3 fatty acids EPA are essential polyunsaturated fatty acids for the brain since the brain tissues lack sufficient enzymatic activity necessary for de novo omega 5 3 synthesis. So, therefore, that is it is always recommended that one should consume good amount of fish oils which is a important precursor to the brain formation. The American Heart Association recommends that everyone should eat oily fish twice per week and that those with coronary heart diseases should consume 1 gram per day of EPA plus DHA from oily fish or supplements. Fish oil preparations can lower plasma triglycerides, increase bleeding time, down regulate gene expression for platelet, derived growth factors, lower blood pressure, decrease the number of endothrial adhesion molecule, improve lipoprotein size and decrease the risk of cardiovascular and cerebrovascular diseases. In non-neural diseases the dietary intake of omega 3 fatty acids reduces pre-athrogenic cytokines, improves endothelial function, reduces vascular-oscular indeed coronary atherosclerosis.



So, here the nutritional properties and health value of fish oil is continued. You can say beneficial effect of fish oil, it has cerebroprotective, renoprotective, subnoprotective, heptotective, baspoprotective, promoprotective, and cardioprotective. All these properties good health value properties are there in the fish oil. It causes decrease in blood pressure, decrease in heart rate, decrease in blood viscosity, improvement in endothelial cell function, plate destabilization, decrease in platelet aggregation, decrease in homocysteine, decrease in triacylglycerol etc. So, all these good properties are associated with the fish oil.

So, finally, before summary a final overall summary comparison between the plant fat and animal fat in the earlier classes we discussed also the plant fat and their sources and their properties also we discussed in detail animal fat and its composition and properties. So, if you have a comparison that is in comparison with more vegetal oils, the animal fats are much more saturated and contain a relatively narrow range of fatty acids. An exception would be the ruminant milk fat which contains large proportion of short chain fatty acid. In contrast with the plants where lipids are stored in seeds or fruits in animals the fats are found almost everywhere. They are more abundant in adipose cells which are found either in concentrated location like in the subcutaneous form or intraperitoneal form or in filtered among the muscle cells that and are present in the high concentration in bones.

In contrast with plants fatty acids with odd carbon numbers are with branched chains are found in animal fats, but in a small amount. These fats have also an important content in monounsaturated fatty acids.

So, now I would like to summarize finally, this lecture by saying that animal fat is commonly classified as dipot fats which are localized in adipose tissues and intramuscular fats, which are localized in muscle tissues. Among land animals only eggs and chicken fats have a consistent amount of essential fatty acids. Aquatic sources being the richest milk fat contains more fatty acid than any other fat of animal or plant origin.

Tallow contains a high level of cholesterol that is the 1000 ppm the consumption of Tallow accordingly should be restricted. Herring, salmon, and sardine are the precious dietary sources of omega 3 and polyunsaturated fatty acid that is 20:5 and 22:6.

So, these are the references which are used in this lecture and with this thank you all for your patience hearing. Thank you.