Food Oils and Fats: Chemistry & Technology
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Module 8 : Animal & Dairy Fats
Lecture 37: Fish and Algal Oils

Hello everyone, Namaste. Now, in this lecture 37, in the next half an hour or so, we will discuss about fish and algal oils.

Concepts Covered

- Fish oil
  - ✓ Nutritional and health values
  - ✓ Manufacturing process
  - ✓ Packaging materials and methods
- Algal oils and their production
- Delivering omega-3 fatty acids into food products
  - ✓ Stable algal oil forms and their uses

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We will talk about fish oil, its nutritional and health values, its manufacturing process, packaging materials and methods for the fish oil packaging. Then also algal oil and their production. Finally, we will also throw some lights on delivering omega 3 fatty acids into food products like stable algal oil forms and their usage.

Fish oil

- Fish oil is derived from the tissues of oily fish.
- It is recommended for a healthy diet because it contains the ω−3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), precursors to eicosanoids that reduce inflammation throughout the body.
- Fish oil is a good dietary source of ω−3 fatty acids. Human body needs ω−3 fatty acids for many functions, from muscle activity to general health.
- Fish oil has numerous beneficial effects to human body. It prevents atherosclerosis, angina, heart attack, congestive heart failure, arrhythmias, stroke, and peripheral vascular disease. Clinical trials have shown that it is also effective in the treatment of many disorders including rheumatoid arthritis, diabetes, cancer etc.

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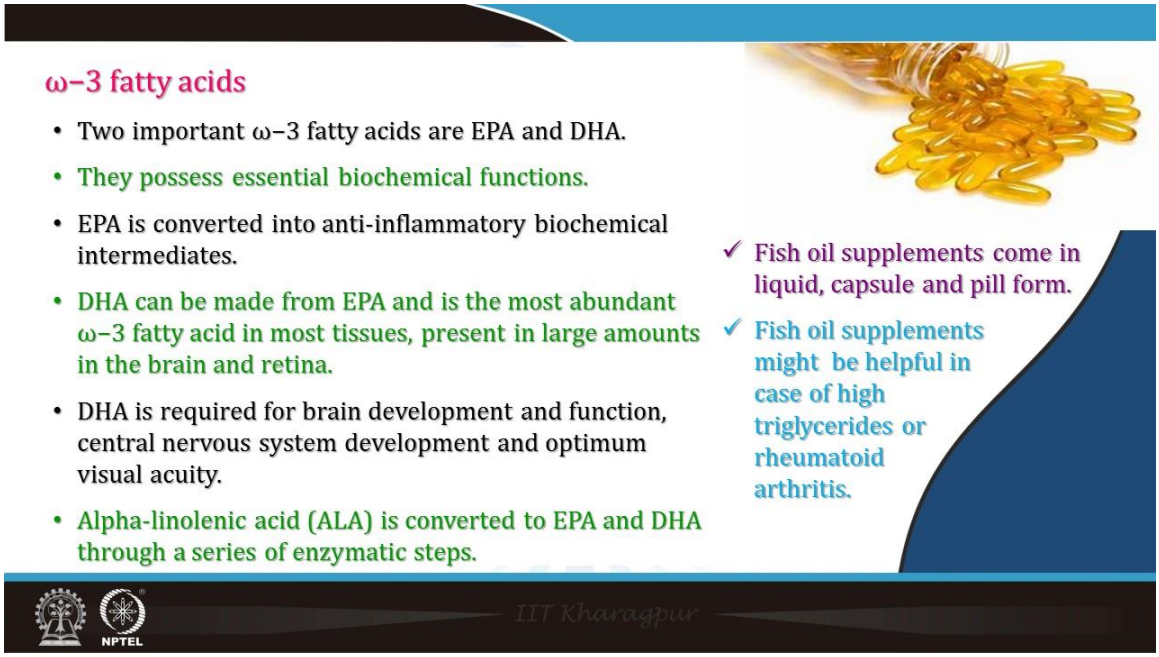
Let us see what is a fish oil.

It is the oil which is derived from tissues of oily fish. Fish oil is recommended for a healthy diet because it contains the omega 3 fatty acids like eicosapentaenoic acid which is commonly known as EPA and Docosahexaenoic acid (DHA). And these are precursors to eicosanoids that reduce inflammation throughout the body. Fish oil is a good dietary source of omega 3 fatty acids.

Human body needs omega 3 fatty acids for many functions for muscle activity or even to general health. Fish oil has numerous beneficial effects to human body. It prevents atherosclerosis, angina, heart attack, congestive heart failure, arrhythmias, stroke, and peripheral vascular diseases. Clinical trials have shown that it is also effective in treatment of many disorders including rheumatoid arthritis, diabetes, cancers, etcetera.

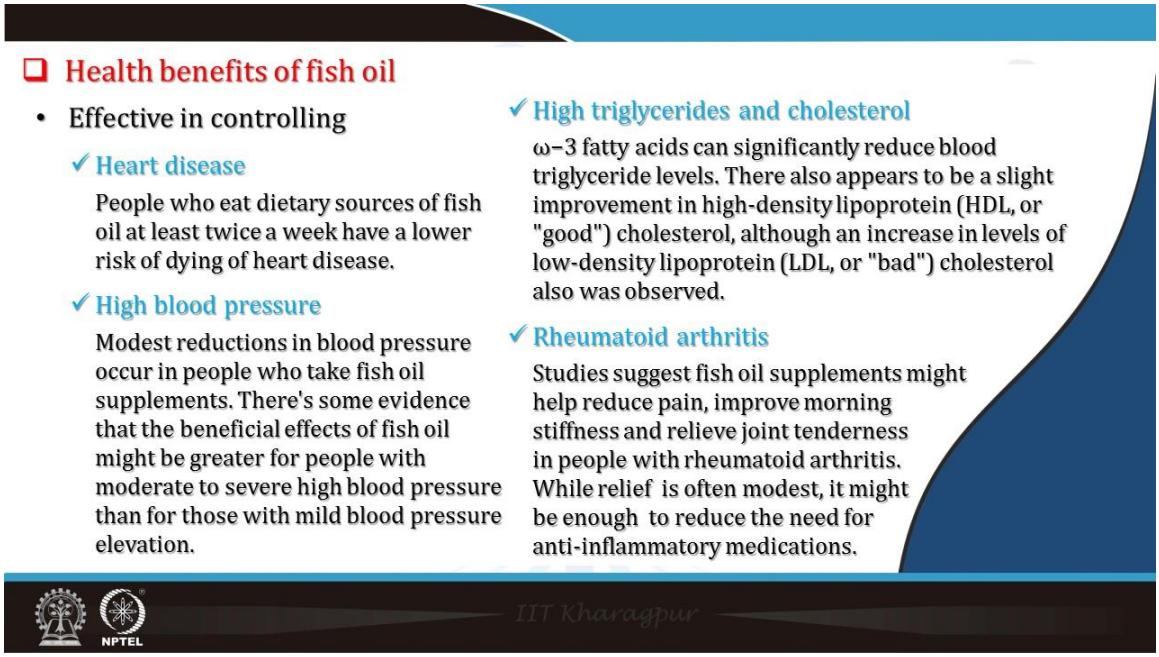


Let us see what are omega 3 fatty acids.

There are two important omega 3 fatty acids as I told you include EPA and DHA. They possess essential biochemical functions. EPA is converted into anti-inflammatory biochemical intermediates whereas DHA can be made from EPA and in the most abundant omega 3 fatty acids in most tissues present in large amounts in the brain and retina. DHA is required for brain development and functions, central nervous system

development and for optimal visual activity. Alpha linoleic acid is converted into EPA and DHA through a series of enzymatic steps.

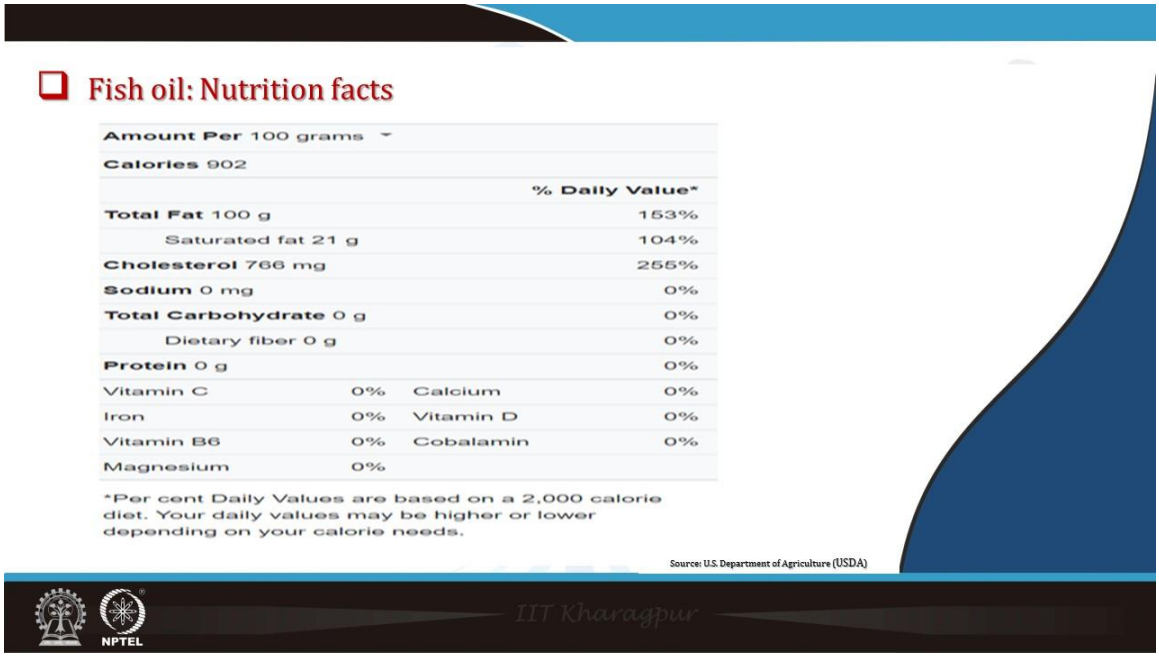
There is a fish oil supplements come in liquid form in capsule as well as in the pill forms. Fish oil supplements might be helpful in case of high triglyceride or rheumatoid arthritis.



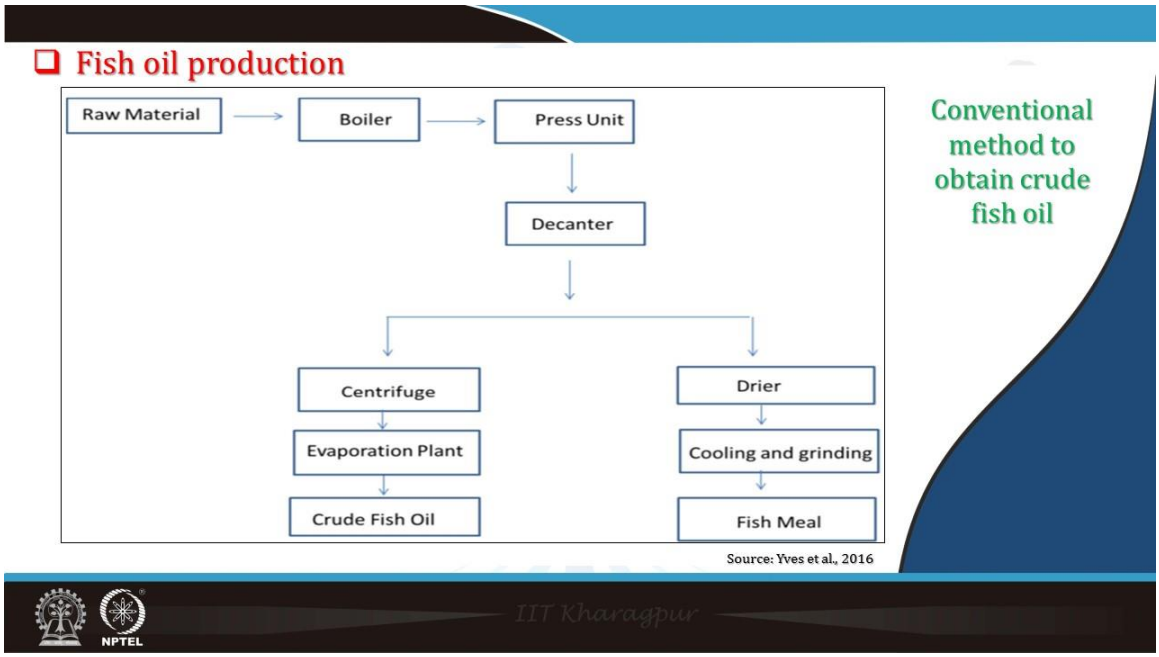
Health benefits of fish oil you discuss ok. It is effective in controlling heart diseases that is people who eat dietary sources of fish oil at least twice a week have a lower risk of dying of heart diseases. Also it controls high blood pressure that is the modest reduction in blood pressure occurs in people who take fish oil supplements.

There is some evidence that beneficial effects of fish oils might be greater for people with moderate to severe high blood pressure than those with mild blood pressure elevation. Also it has high triglycerides and cholesterol reduction. Omega 3 fatty acids can significantly reduce blood triglyceride levels. They also appear to be slight improvement in high density lipoprotein that is HDL or good cholesterol or through an increase in the level of low density lipoprotein that is the LDL or bad cholesterol although it was also apparent. So, they improve that they increase that high density cholesterol although there is some time that is bad cholesterol also increases.

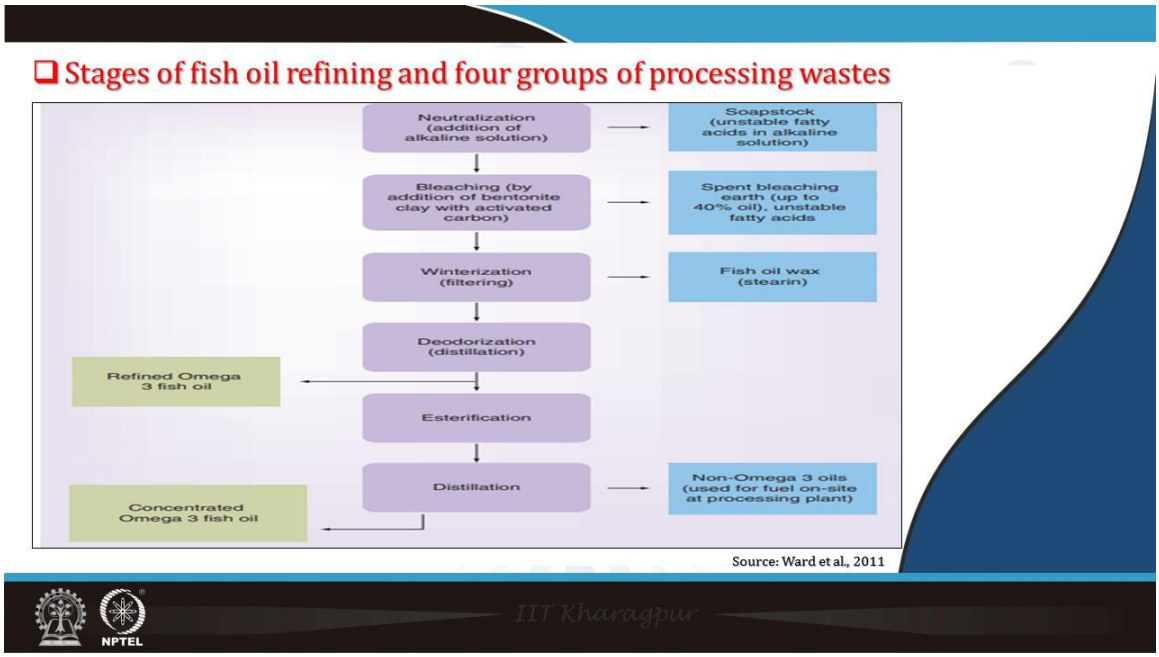
Then rheumatoid arthritis studies suggest the fish oil supplements might help reduce pain, improve morning stiffness and relieve joint tenderness in people with rheumatoid arthritis. While relief is often modest it might be enough to reduce the need for anti-inflammatory medications.



The nutritional factt of fish oil that is the per 100 gram it gives around 902 kilocalories. It gives a saturated fat that is 21 gram, it 153 percent of daily value that is out of if you take 100 gram of this fish oil then its cholesterol it gives around 766 milligram that is 255 percent of daily value and it is almost it does not give any carbohydrate fiber, vitamins etcetera. So, this is the it is you can say that is saturated fat gives and total fat and cholesterol.



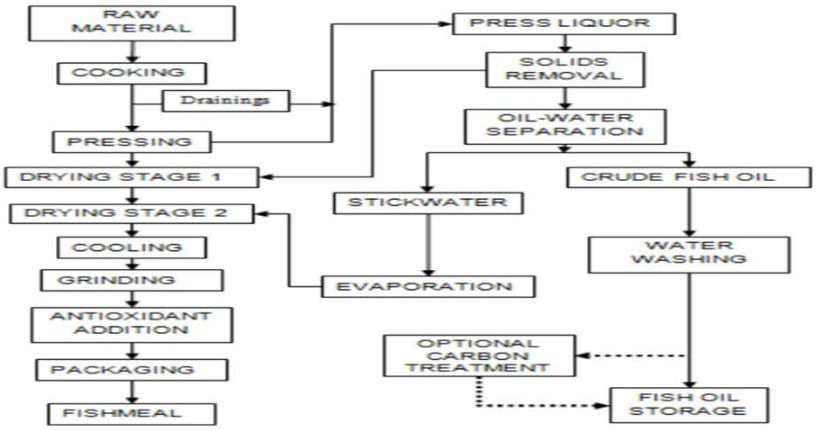
As far as the method of fish oil production is the conventional method to obtain crude fish oil include that is again here the fishes are also taken the sorted and their fatty tissues are trimmed, it is boiled and it is pressed in the unit and then decanted. So, decanted by either centrifugal method, the press plant and crude fish oil is obtained, moisture etcetera is evaporated. Then there the remaining material dried, cooled and graded and it is a fish meal. So, you get that is the process is similar to that which we got in the rendering that is some sort of trimming, chopping, crushing, heating, centrifugation and then drying this and we get a crude oil and then meal.



So, stages of fish oil refining and four groups of processing waste which are obtained from the fish oil that is the number one you get the crude fish oil, then it is a neutralization addition of alkaline solution that you have referred in the chemical refining process.

So, you get soap stock that is the unstable fatty tissues in alkaline solution is obtained. So, that is can be further. Then bleaching by adding the bentonite clay with activated carbon, then spent bleaching earth is obtained and you get that is the oil, then oil is winterized, then the fish oil wax that is stearin is separated during the winterization process, then it is subjected to deodorization and after deodorization, refined omega 3 fish oil is obtained, then esterification that is interesterification etcetera and distillation you get concentrated omega 3 fish oil and here non omega 3 oils which are used for fuel or onsite processing plant etcetera. So, these are the some refining stages and at different stages which are the various impurities etcetera are obtained which are also used for making some useful products.

Wet reduction process to produce fish oil



Source: https://lipidlibrary.aocs.org/edible-oil-processing/marine-oils

Then wet reduction process to produce fish oil in this slide is shown that is raw material it is cooked, then drained pressed and the drainings are there that is pressed liquid is solids removal and then it is oil and water separation you get a stick water and which is evaporated and different drying stages you get and finally, you get fish meal and after this pressing in different operations you get various fish oil ok.

Processing steps

Cooking	Steam cooking ruptures the fat cells, coagulates the protein and releases the oil
Dewatering-Pre-pressing	The cooked fish mass is screened to separate free liquid from the solids
Pressing	Pressing mechanically expresses the free liquid from the solids producing a press liquor (oil and water) and a press cake (semi-moist meat and bones). Some factories have used tricanters instead of presses to separate solids, oil and water.
Press liquor separation	This is 3-step process; decanters separate fine solids from the liquid fraction, separators split the liquid fraction into fish oil and water (stickwater), and polishing water washes the crude fish oil before it is pumped to storage.
Evaporation	Stickwater contains about 8% solids which are concentrated in multiple effect or waste heat evaporators to about 40-50% solids. If the factory uses steam dryers then the waste heat from the dryer can be used to heat and evaporate the stickwater.
Drying	The drying process is generally done in 2 stages. The solids from the decanter separation and the press cake are mixed and partially dried. The partially dried fishmeal is then mixed with the concentrated stickwater and the drying is completed to about 10% moisture. Factories use steam and indirect hot air dryers but older factories still use the old direct fired hot air dryers.
Grinding	Grinding reduces the particle size of the fishmeal.
Cooling and stabilization	The fishmeal is cooled and antioxidant is added. Generally ethoxyquin is the antioxidant of choice but for certain markets natural antioxidants based on tocopherols are used.
Packaging	The fishmeal is packaged in 50 kg bags or 1000 kg totes. The fishmeal can also be stored in bulk piles or in silos.
Optional fish oil carbon treatment	If the crude fish oil is destined for the Omega-3, animal feed, aquaculture or pet food market and if analyses indicate the presence of dioxins, furans and or polyaromatic hydrocarbons (PAH), it can be treated with activated carbon to reduce the levels of these compounds.

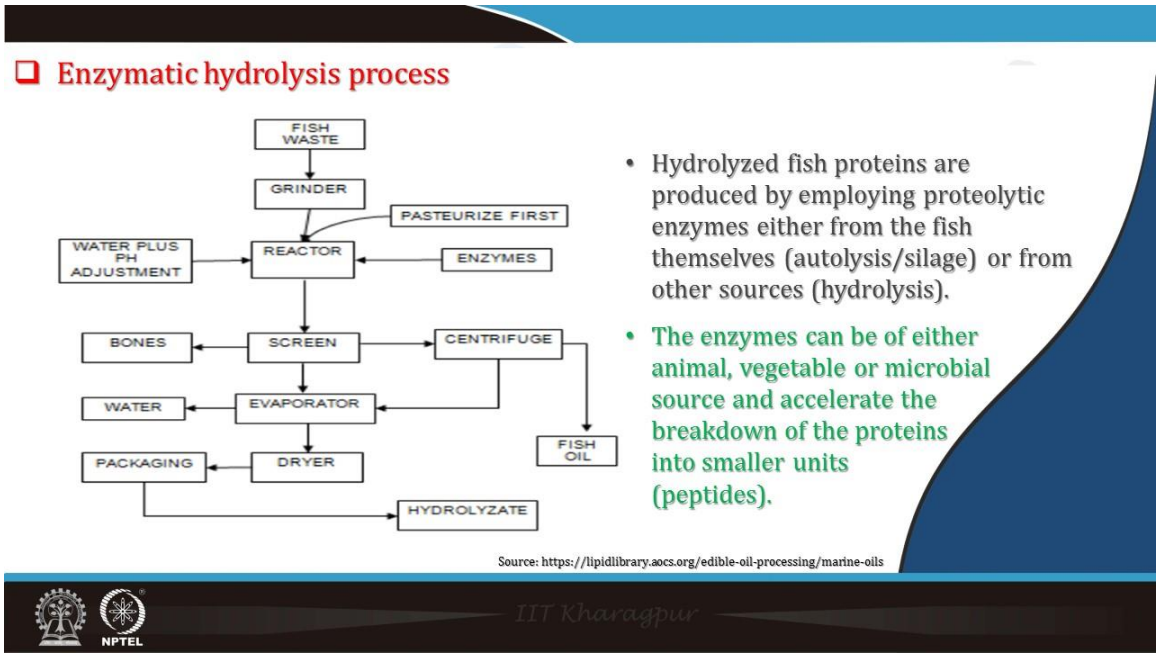
- Wet reduction process

Source: https://lipidlibrary.aocs.org/edible-oil-processing/marine-oils

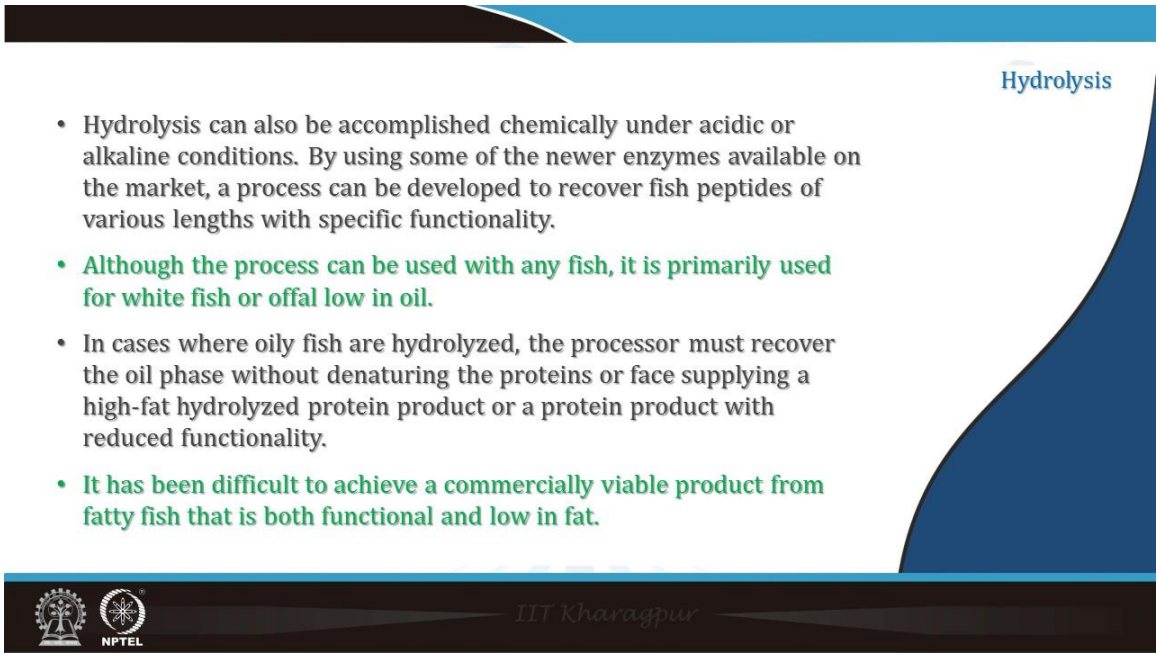
So, this is the wet reduction process ok and in this little detail of the processing steps we discussed it is wet reduction process what happens in different stages like cooking steam cooking ruptures the fat cells it calculates the protein and releases the oil and then it is subjected to dewatering pre pressing and this here the cooked fish mass is screened to separate free liquid from the solids and then in the pressing operation that is where the mechanically it is it expresses the free liquid from the solid producing a press liquor that is the oil and water and press cake which you saw in the earlier slide in the process flow chart ok. Then press liquor operations this is a three step process it decanters separate fine solids from the liquid fractions separators split the liquid fraction into fish oil and water that is called the stick water and there is a pulsing water which washes the crude fish oil before it is pumped to storage. Then in the evaporation this is a stick water contains about 8 percent solids which are concentrated in multiple effect to or waste heat evaporators to about 40 to 50 percent solid from 8 percent solid it is concentrated to 40 to 50 percent solid and in the factory that is using steam dryers then the waste heat from the dryer can be used as a to heat the and evaporate the stick water. Then finally, in the drying process that is a generally it is done in two stages the solids from the decanter separation and the press cake are mixed and partially dried. The partially dried fish meal is then mixed with the concentrated stick water and the drying is completed to about 10 percent moisture ok.

Then in the in the factory it is used steam and indirect hot dryer, but older factory still use the old direct fired hot air dryers ok. Then grinding, cooling and stabilization percent grinding reduces the particle size of the fish meal ok. Cooling is done stabilization and the fish meal is cooled and antioxidant is added generally ethoxyquin is the antioxidant of choice, but for certain markets natural antioxidant based and tocopherols are also used. Then packaging is done ok. The fish meal is packaged in 50 kg bags or 1000 kg totes the fish milk can also be stored in bulk fillers or in silos.

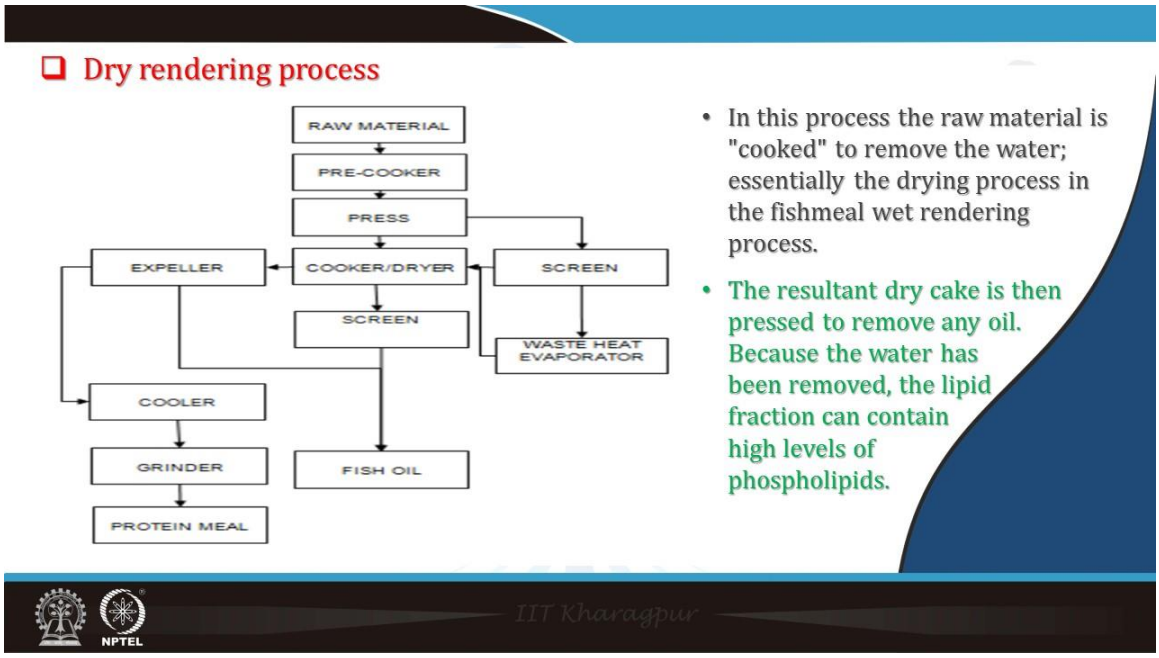
Then optional fish oil carbon treatment sometime is done that is if the crude fish oil is destined for the omega 3 animal feed aquaculture or pet food market and if analysis indicate the presence of dioxin, furans are poly aromatic hydrocarbons it can be treated with activated carbon to reduce the level of these compounds ok.



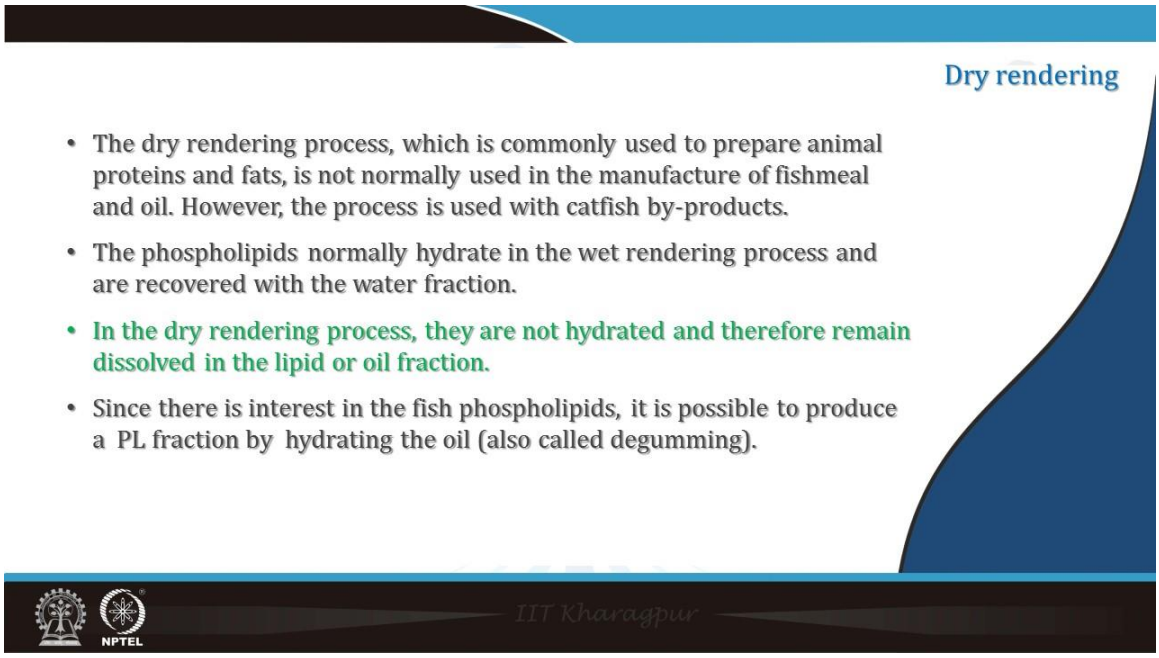
Then enzymatic hydrolysis process you can see here that is here this pasteurized first and then enzymes are added ok. That is hydrolyzed fish proteins are reduced by employing proteolytic enzymes either from the fish themselves that is autolysis or silage or from other tissues ok. The enzymes can be either animal sources or vegetable or microbial sources and they accelerate the breakdown of the protein into a smaller unit you get the smaller peptides containing proteins etcetera ok. So, this is the enzymatic hydrolysis of the meal ok.



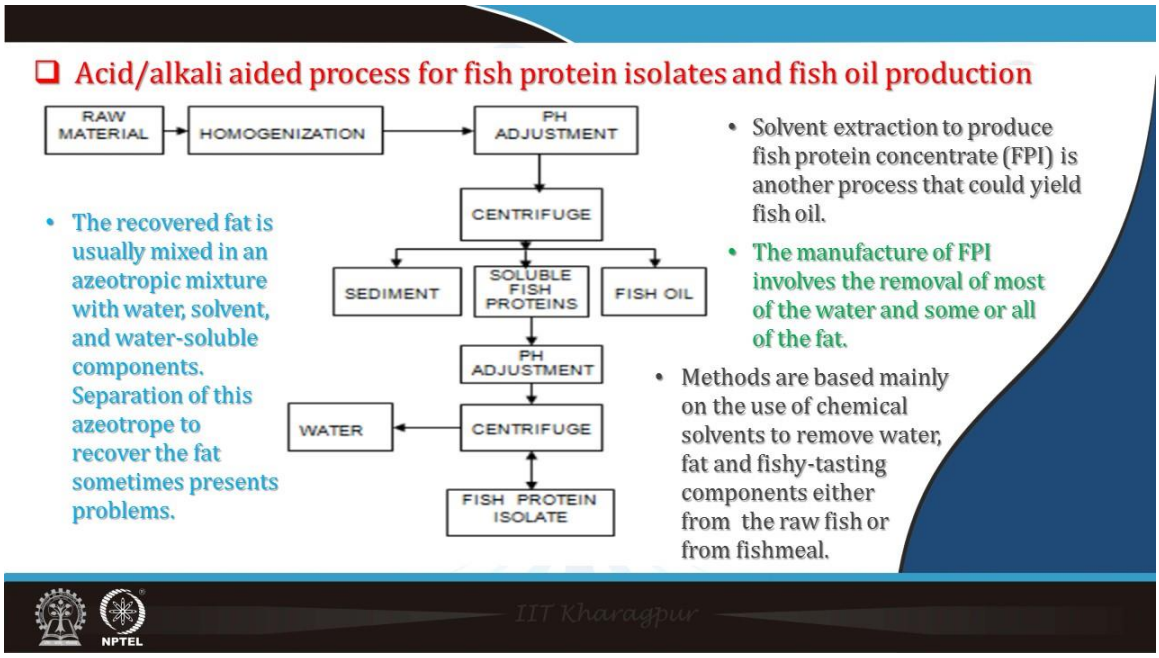
Hydrolysis can also be accomplished chemically under acidic or alkaline conditions by using some of the newer enzymes available on the market. A process can be developed to recover fish peptides of various length with specific functionality. Although the process can be used with any fish it is primarily used for white fish or offal low in oil. In cases where oily fish are hydrolyzed the precursor must recover the oil phase without denaturing the protein or face supplying a high-fat hydrolyzed product or a protein product with reduced functionality. It has been difficult to achieve a commercially viable product from fatty fish that is both functional or lower in fat.



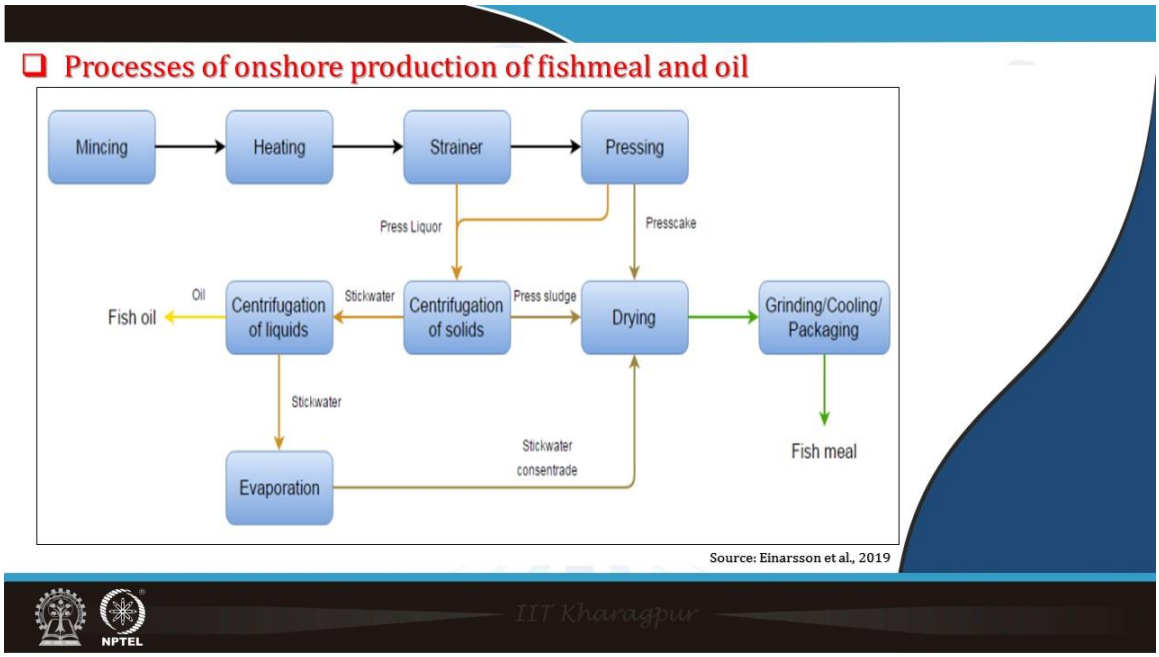
Then the dry rendering process you can see raw material, pre-cooler, press, you get screen and waste heat evaporator then it is cooked or dried. And after expelling, screen filtration, you get fish oil and the meal is obtained. In the process the raw material is cooked to remove the water essentially the drying process in the fish meal wet rendering process. And the resultant dry cake is then pressed to remove any oil. Because the water has been removed, the oil fraction the remove the lipid fraction can contain high level of phospholipids.



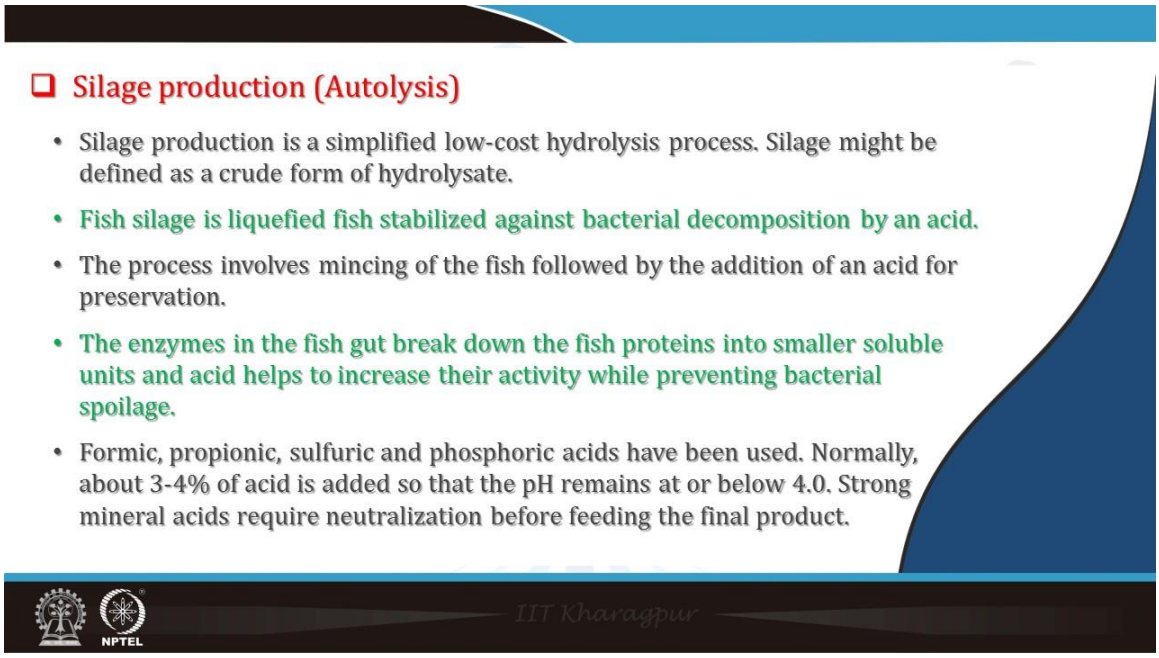
The rendering process that is the dry rendering process which is commonly used to prepare animal proteins and fats is not normally used in manufacture of fish meal and oil. However, the process is used with catfish by products. The phospholipids normally hydrate in the wet rendering process and are recovered with the water fraction. In the dry rendering process they are not hydrated and are therefore, remain dissolved in the liquid or oil fraction. Since there is a interest in the fish oil phospholipids it is possible to produce a phospholipid fraction by hydrating the oil also called degumming oil.



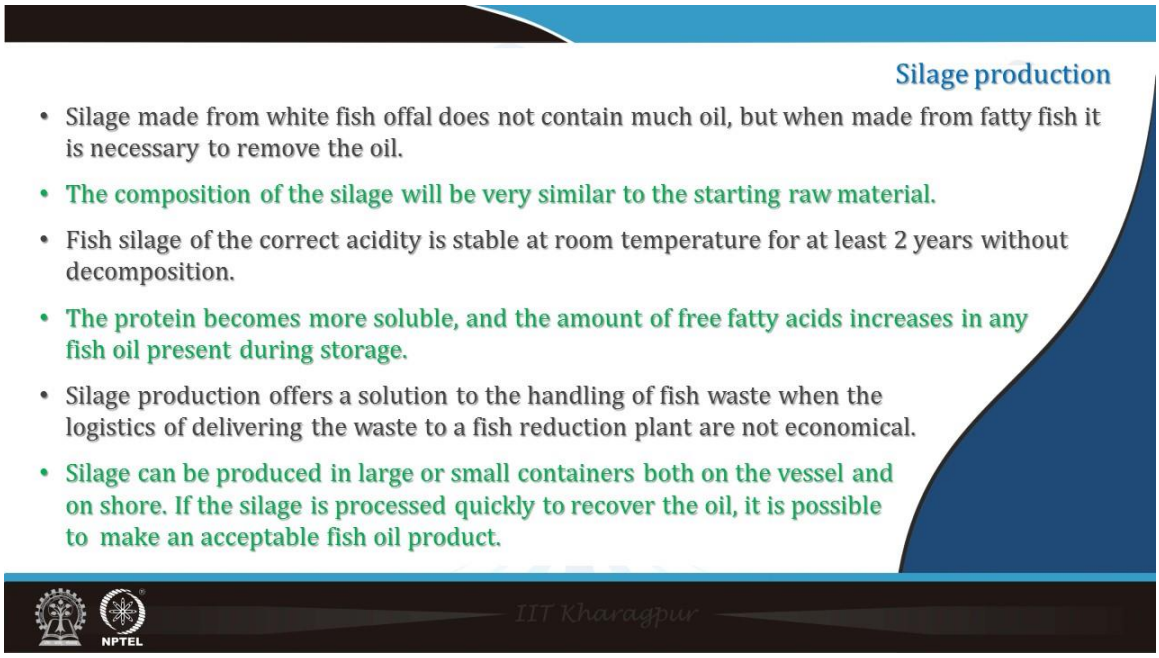
Then acid or alkali aided process for fish meal protein isolate and fish oil production. Here the solvent fraction is solvent extraction is used to produce fish protein concentrate and it is another process that could yield fish oil. The manufacture of fish protein isolate involves the removal of most of the water and some or all of the fats like you see raw material it is homogenized and pH adjustment is done. And then it is passed to centrifuges where sediment is separated, fish oil is obtained and soluble fish proteins. And then it is subjected to soluble fish proteins subjected to pH adjustment centrifuges water is obtained and fish protein. So, the methods for making fish protein isolates are based mainly on the use of chemical solvents to remove water, fat and fishy tasting components either from the raw fish or from the fish meal. The recovered fat is usually mixed in an azeotropic mixture with water solvent and water soluble components. Separation of this azeotrope to recover the fat sometimes presents our problems.



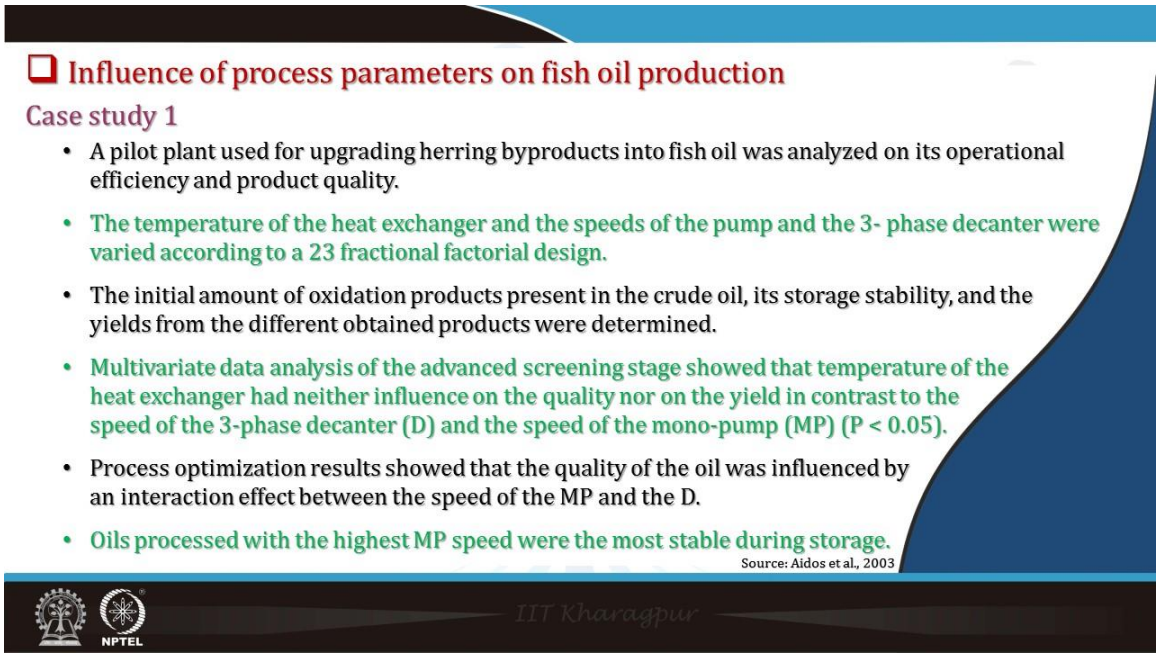
So, the process of onshore production of fish meal and oil you can see mincing, heating, strainer and pressing. So, after pressing you got press crate and the liquid that is strainer and pressing you get the liquid. So, it is used for centrifugation of solids get the stick water, centrifugation of liquids, oil, the fish oils and from these stages that is evaporated then stick water condensate and after pressing the remaining material they are dried, grind, cooled and packaged as a fish meal. So, by this it is a you get fish oil and fish meal ok.



Then silage production, that is autolysis. Silage production is simplified low cost hydrolysis process, ok. Silage might be defined as a crude form of hydrolysis. Fish silage is a liquefied fish stabilized against bacterial decomposition by an acid. The process involves mincing of the fish followed by the addition of an acid or preservative. The enzymes in the fish got break down the fish protein into a smaller soluble units and acid helps to increase their activity while preventing bacterial silage. Formic, propionic, sulfuric and phosphoric acids have been used. Normally, about 3 to 4 percent of the acid is added so that the pH remains at or below or it is pH remains below 4.0. Strong mineral acids require neutralization before feeding into the final product.

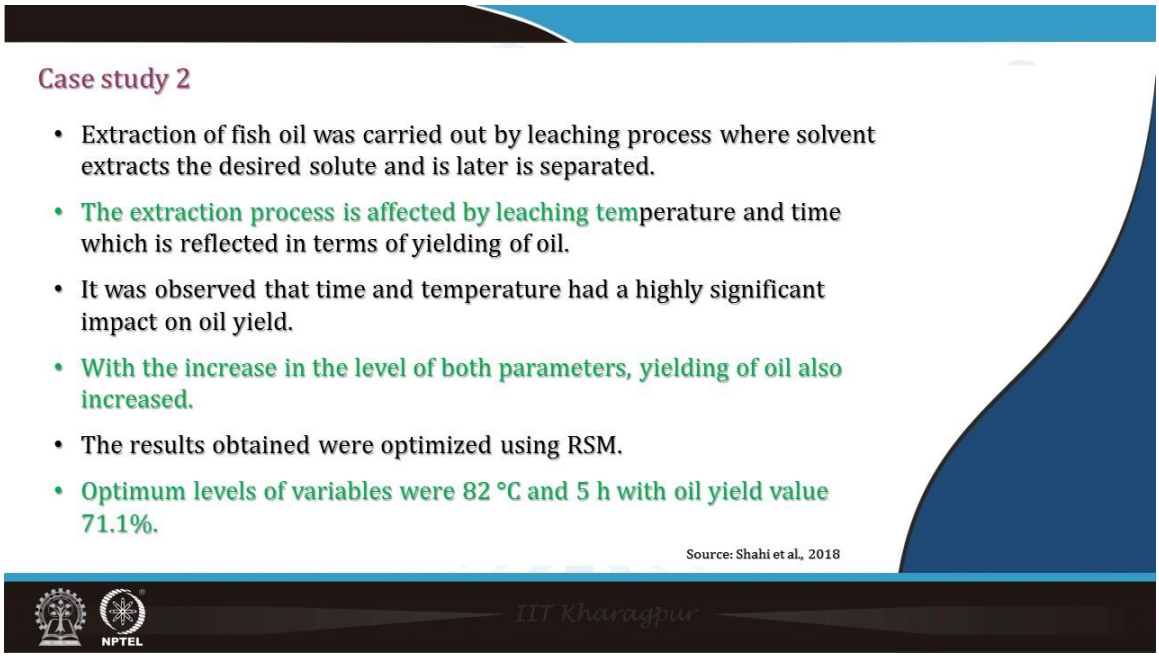


Silage made from white fish offal does not contain much oil or, but when it is made from fatty fish it is necessary to remove the oil. The composition of the silage will be very similar to the starting raw material. Fish silage of the correct acidity is suitable or it is stable at room temperature for at least 2 years without decomposition. The protein becomes more soluble and the amount of free fatty acids increases in any fish oil present during storage. Oil production offers a solution to the handling of fish waste when the logistics of delivering the waste to a fish reduction plant are not economical. Silage can be produced in large or small containers both on the vessels and on the source. If the silage is processed quickly to recover the oil, it is possible to make an acceptable fish oil product.

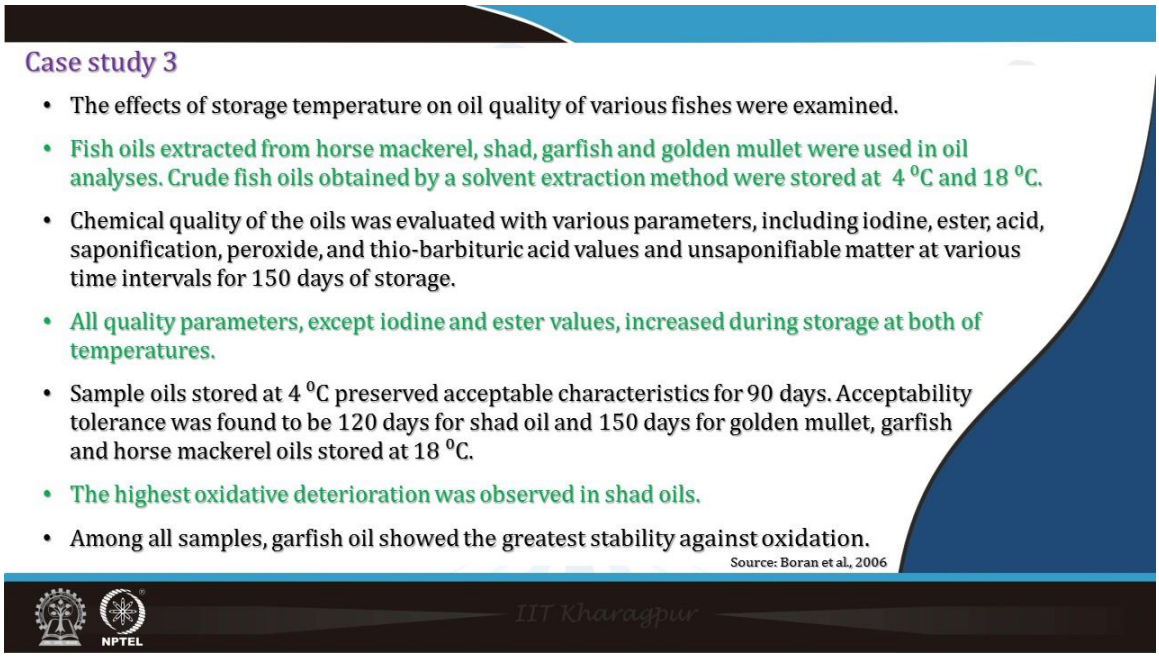


If you discuss the influence of process parameter on fish oil production, that is we take one or two case studies, that is case study 1 where there is a that is a Aldos et al. They used a pilot plant for preparing or upgrading herring byproducts into fish oil and then they analyzed various operational efficiency and the product quality. The temperature of the heat exchanger and the speeds of the pump and the three-phase decanters were varied according to a 23 factorial design. The initial amount of the oxidation products present in the crude oil, its storage stability and the yields from the different obtained products were determined.

Multivariate data analysis and advanced screening stage showed that temperature of the heat exchanger had neither influence on the quality nor on the yield in contrast to the speed of the omega phase or three-phase decanter that is D and the speed of the mono-pump that is MP. Process optimization results showed that the quality of the oil was influenced by an interaction effect between the speed of the MP, there is a mono-pump and the decanter. Oils processed with the highest mono-pump speed were the most stable during storage.



In another case study, Shahi et al. in 2018, they did extraction of fish oil by leaching process where solvent is used to extract the desired solute and the later one separated. The extraction process was affected by leaching temperature and time which is reflected in terms of yield of oil. It was observed that the time and temperature had a highly significant impact on the yield. With increase in the level of both parameters. yielding of oil also increased. The results obtained were optimized using RSM. And the optimum levels of variables were 82 degree Celsius temperature and 5 hours with oil yield value about 71 percent.



In another study, there is a Boran et al. They conducted and found the effect of storage temperature on oil quality of various species. Fish oil extracted from horse mackerel, shad, garfish and golden mullet were used for analysis. Crude fish oil obtained by a solvent extraction method were stored at 4 degree Celsius and 18 degree Celsius. Internal quality of the oil was evaluated with various parameters including iodine value, ester value, acid value, saponification value, peroxide value and thiobarbituric acid values and unsaponifiable matters at various time interval for 150 days of storage. And oil quality parameter except the iodine and ester value increased during storage at both the temperatures.

Acute oil stored at 4 degree Celsius preserved acceptable characteristics for 90 days. Acceptability tolerance was found to be 120 days for short oil and 150 days for golden mullet, garfish and horse mackerel oil stored at 18 degree Celsius. The higher oxidative deterioration was observed in shad oils. Among all samples, garfish oil showed the greatest stability against oxidation. Then packaging of fish oil, if we discuss the fish oil contained high unsaturated fatty acids, they are easily susceptible to oxidation and they are only exposed to air.

Packaging of fish oil

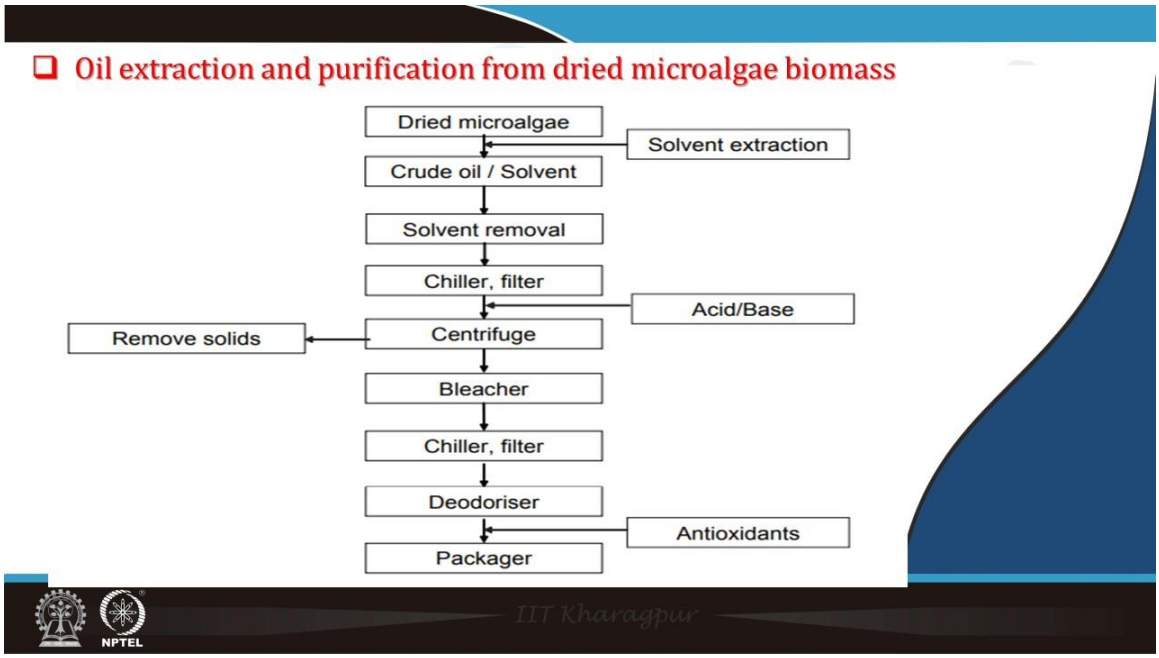
- Fish oils contain highly unsaturated fatty acids. They are easily susceptible to oxidation when exposed to air.
- Packaging material should have high barrier properties; should be moisture proof, oil resistant and impermeable to oxygen.
- Larger quantities of fish oil are mainly packed in LLDPE/Nylon films or in glass bottles.
- Bulk transportation in food grade flexi tanks made of 4 layered polyethylene and tubular Polypropylene (PP) is preferred.
- Advantages of using flexi tanks are that they can carry 50% more than bottles and, therefore, will save on storage space, packaging and transportation cost.

So, packaging material should have high barrier properties, should be moisture proof, it should be oil resistant and impermeable to oxygen. Larger quantities of fish oil are mainly packed in LLDPE/nylon films or in glass bottles. Bulk transportation in food grade flexi tanks made of 4-layered polypropylene tubes or polypropylene is preferred. Advantages of using flaxseed tanks are that they can carry 50 percent more bottles and therefore will serve on storage space packaging and transportation cost.

Algal oil

- Certain algae species are grown in agriculture specifically to produce algal oil.
- It can be made from a variety of species, including *Crypthecodinium*, *Nannochloropsis*, *Schizochytrium*, *Prototheca*, and *Ulkenia*.
- The fatty acids in the oil might reduce swelling and help with brain function.
- People use algal oil for improving thinking skills, physical performance, autism, depression, and for many other purposes, but there is no good scientific evidence to support these uses.

Then let us talk about algal oil, that is certain algae species are grown in agriculture especially to produce algal oil. It can be made from a variety of species including *Crypthecodinium*, *Nannochloropsis*, and *Schizochytrium*, *Prototheca* and *Ulkenia* etcetera. The fatty acids in the oil might reduce swelling and help with the brain function. Use algal oil for improved thinking skills, physical performance, autism, depression and for many other purposes, but there is no good scientific evidence to support these uses.



So, for the extraction and purification, first algae is dried using suitable technology, may be low temperature drying or vacuum drying may be preferred. Then dried microalgae is used for solvent extraction process using the standard protocol and the crude oil which is obtained, that is the solvent is removed and then it is added acid or base, centrifuge, bleach, deodorizer and package. So, other standard methods for the refining etcetera that we discussed in earlier. The process parameter may be of the refining and extraction etcetera may be a little bit changed.

❖ Algal oil fatty acid composition

Fatty Acid, %	Algal Oil	DHA Concentrate
C-10:0 Capric	0.58 ± 0.06	0.47 ± 0.04
C-12:0 Lauric	1.12 ± 0.05	0.51 ± 0.02
C-14:0 Myristic	14.92 ± 0.07	0.13 ± 0.02
C-14:1 Myristoleic	0.20 ± 0.03	0.16 ± 0.01
C-16:0 Palmitic	9.05 ± 0.12	ND
C-16:1 Palmitoleic	2.20 ± 0.08	0.25 ± 0.01

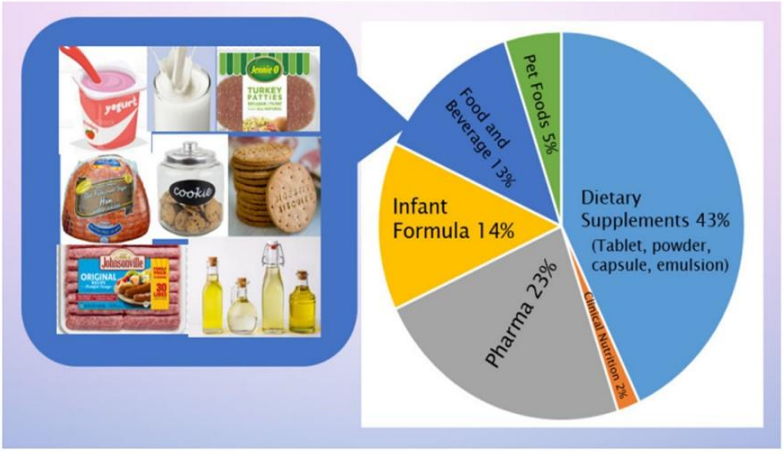
Characteristics	Typical	Range
C-18:0 Stearic	0.20 ± 0.01	ND
C-18:1 Oleic	18.95 ± 0.32	0.22 ± 0.01
C-18:2 Linoleic	1.01 ± 0.02	0.65 ± 0.03
C-22:5 Clupanodonic	0.51 ± 0.05	0.41 to 0.01
C-22:6 DHA	47.42 ± 0.15	97.1 ± 0.02
Iodine value, calculated	234.0 ± 1.3	436.8 ± 0.3

Note: ND = none detected.

Source: O'brien, R. D. (2008)

So, the algal oil fatty acid composition in this side contains around C10 caproic acid around 0.5, but the myristic acid are more in number, palmitic acid also 9.05 percent and palmitoleic acid is 2.2 percent. And this is a steric acid it is a very low, but oleic acid is about 19 percent linoleic 1 percent and DHA is around 47.42 and iodine value it is around 234 in the case of algal oil.

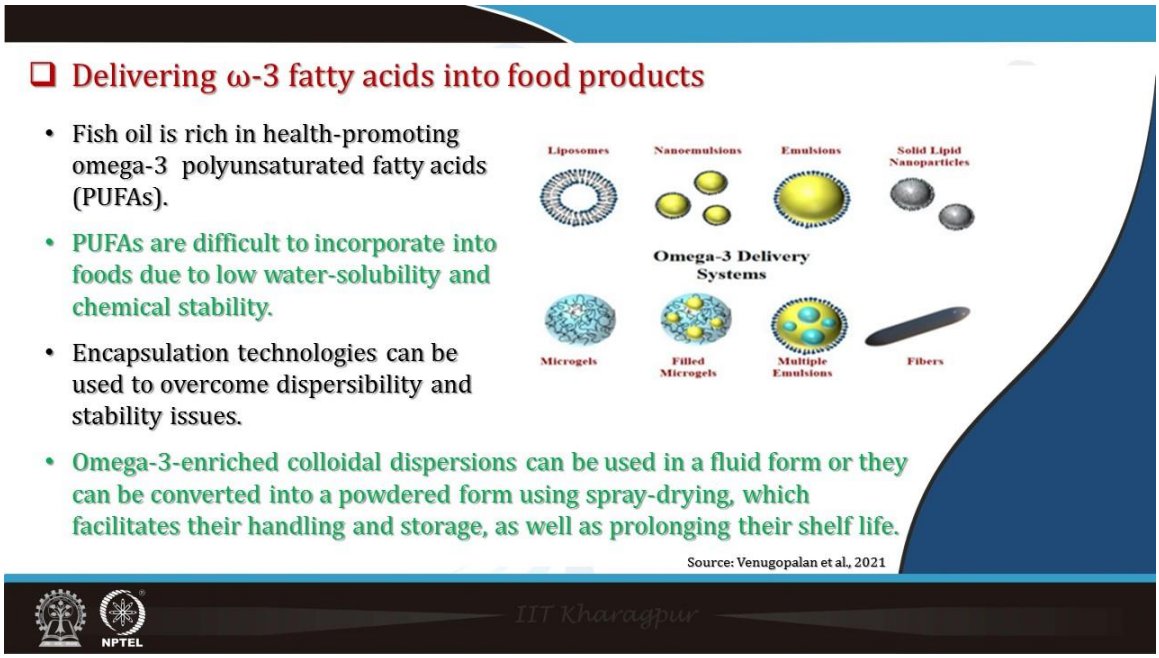
❖ Algal oil uses



Application category and proportion of microalgae-derived n-3 PUFA production (EPA/DHA) products in the global market

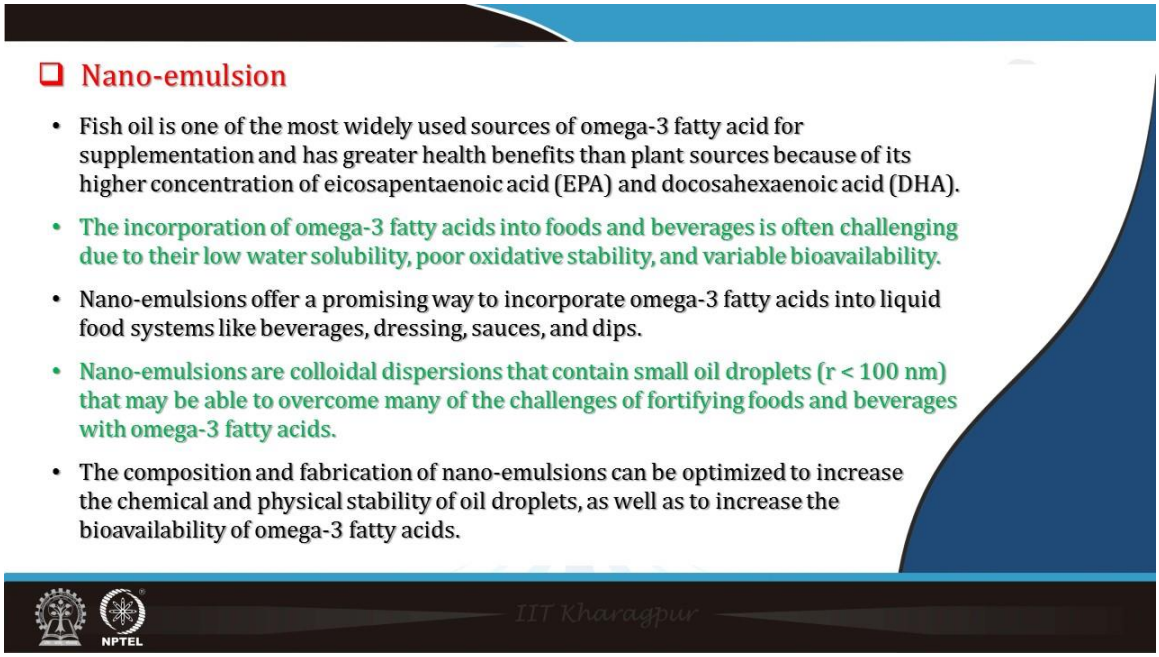
Source: Liu et al., 2022

So, as far as the usage of the algal oil corrosion that is application category and promotion for the microalgae derived omega 3 PUFA production that is EPA and DHA products in the global market that is it is used around infant formulation 14 percent, food and beverage usage 13 percent, pet food 5 percent and these algal usage are about 43 percent uses defined in the dietary supplements like in tablets, powder, capsules, emulsions etcetera and 23 percent in pharma and in clinical duties and about 2 percent.



Now delivering omega 3 fatty acids into food products, you know that fish oil is rich in health promoting omega 3 polyunsaturated fatty acids and these polyunsaturated fatty acids are difficult to incorporate into the foods due to low water solubility and chemical stability. So, the encapsulation technologies are used by which these fish oils are they are covered they are some sort of coating or covering is provided and this it is include that is the stability can be used to overcome the dispersibility and stability issue. Omega 3 in this colloidal dispersion can be used in a fluid form or they can be converted into a powdered form using a spray drying technology which facilitates their handling and storage as well as in prolonging their shelf life all right and different forms in which they can be liposomes or nano emulsions, emulsions, solid lipids, nano particles, there is micro gels, filled micro gels, multiple emulsions, fibers these are the various forms where omega 3 delivery system and of course, in that encapsulation technology making

the liposomes and converting it into powder we will take up separately may be in the next module separate lecture we will discuss on this particularly on the work which we have also done in this area.



And here in this case nano-emulsion is one such the fish oil is one of the most widely used sources of omega 3 fatty acids for supplementation and it has greater health benefits than plant sources because of its higher concentration of eicosapentaenoic acid and docosahexaenoic acid. The incorporation of omega 3 fatty acids into foods and beverages is often challenging due to their low water solubility, poor oxidative stability and variable bioavailability. Nano emulsions offer a promising way to incorporate omega 3 fatty acids into liquid food system like beverages, dressing, sauces and dips. Nano emulsions are colloidal dispersion that contain a small oil droplets that is of radius less than 100 nanometer and that may be able to overcome many of the challenges of fortifying foods and beverages with omega 3 fatty acids. The composition and fabrication of nano emulsions can be optimised to increase the chemical and physical stability of oil droplets as well as to increase the bioavailability of omega 3 fatty acids.

Summary

- Fish and algal oils are rich sources of ω-3 fatty acids and other bioactive.
- Fish oil has several health benefits. However, it is quite unstable due to more PUFA content.
- Materials that are impermeable to light, oxygen and moisture should be used to pack fish oil.
- Both fish and algal oils are good sources of delivering ω -3 fatty acids in food products.

So, with this now I will summarise this lecture that is fish and algal oils are rich sources of omega 3 fatty acids and other bioactives. Fissile has several health benefits. However, it is quite unstable due to more PUFA content. Materials that are impermeable to light, oxygen and moisture should be used to pack fish oils. Both fish and algal oils are good sources of delivering omega 3 fatty acids in food products.

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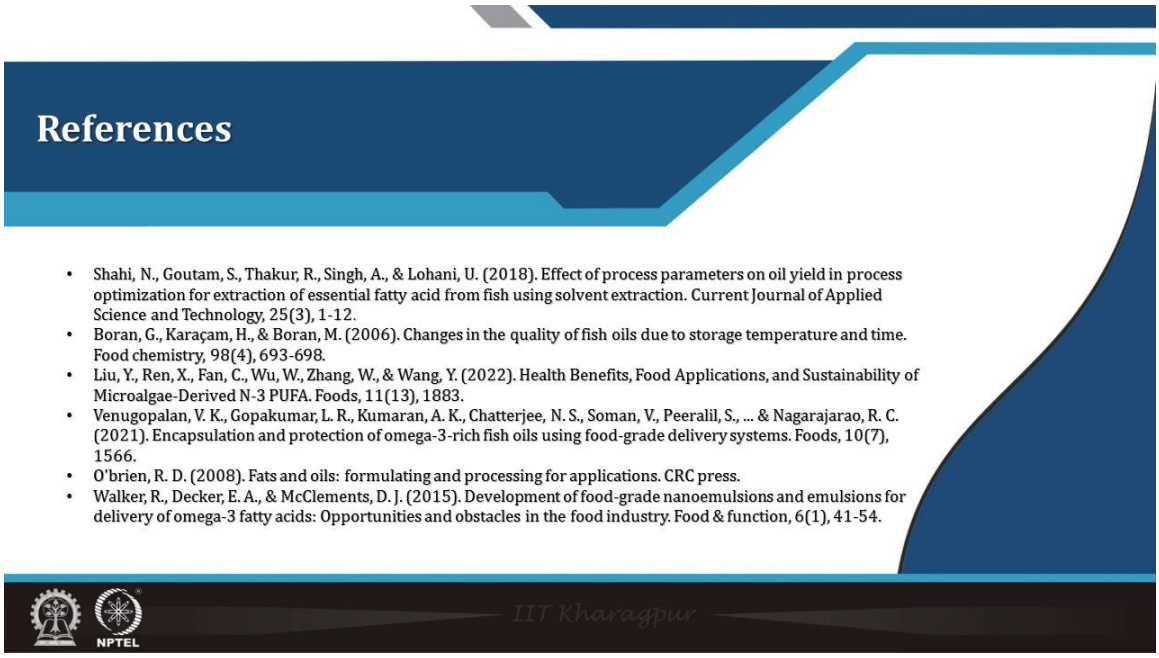

These are the references which are used in this.

Thank you very much.