Food Oils and Fats: Chemistry & Technology

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Module 11: By-products Utilization & Valorization of Oil Milling Industry Waste

Lecture 51 : Major By-products, their Composition and Uses

Hello everybody, Namaskar! Now, we are starting Module 11 of this course. The next five lectures of this module will be devoted on by-products utilization and valorization of oil milling industry waste.

Concepts Covered

- Composition, characteristics, properties and utilization of major by-products of oil milling industry
  - ✓ Oilseed cake
  - ✓ Gums
  - ✓ Edible oil waxes
  - ✓ Free fatty acids distillate
  - ✓ Soapstock
  - ✓ Biomass

In lecture 51 today, we will study about major by-products, their composition and uses. So, we will talk about composition, characteristics, properties and utilization of major by-products of oil milling industry that include oil seed cake that is popularly known as de-oiled meal, then gums, edible oil waxes, free fatty acid distillate, soap stock and other biomass.

Byproduct

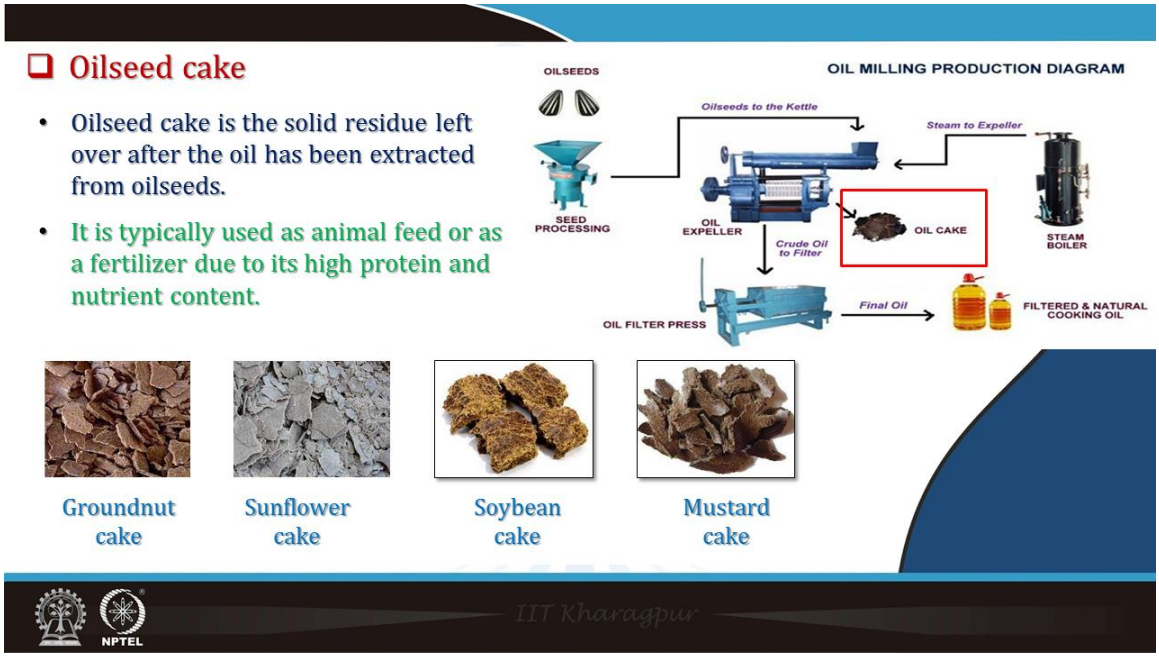
- In the food industry, a byproduct refers to a secondary or incidental product that is produced during the manufacturing or processing of a primary food product.
- It can be sold as a separate food product or used as an ingredient in other food products, or used in non-food applications.
- Byproducts are often considered to be waste, but finding new and innovative ways to use them can reduce waste and increase efficiency in the food industry.

Oilseed cake

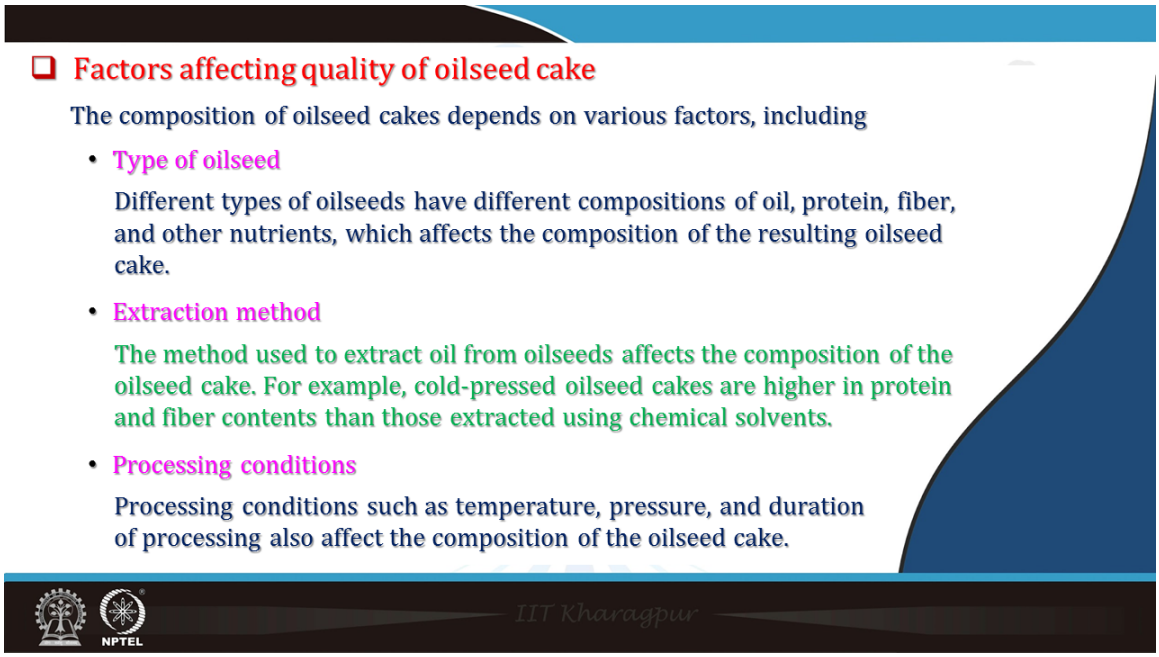
Soapstock

Lecithin

So, by-product in a food industry refers to a secondary or incidental product that is produced during the manufacturing or processing of the primary product. It can be a solid or liquid or any other form. It can be sold as a separate food product or used as an ingredient in other food product formulations or it can also be used in non-food applications. By-products are often considered to be waste, but finding new and innovative ways to use them can reduce waste and increase efficiency in the food industry. So, that is the three like oil seed cake, soap stock, etcetera. Oil lecithin is one of the very valuable by-product of oil milling industry. So, we will discuss in the classes to come about all these things.

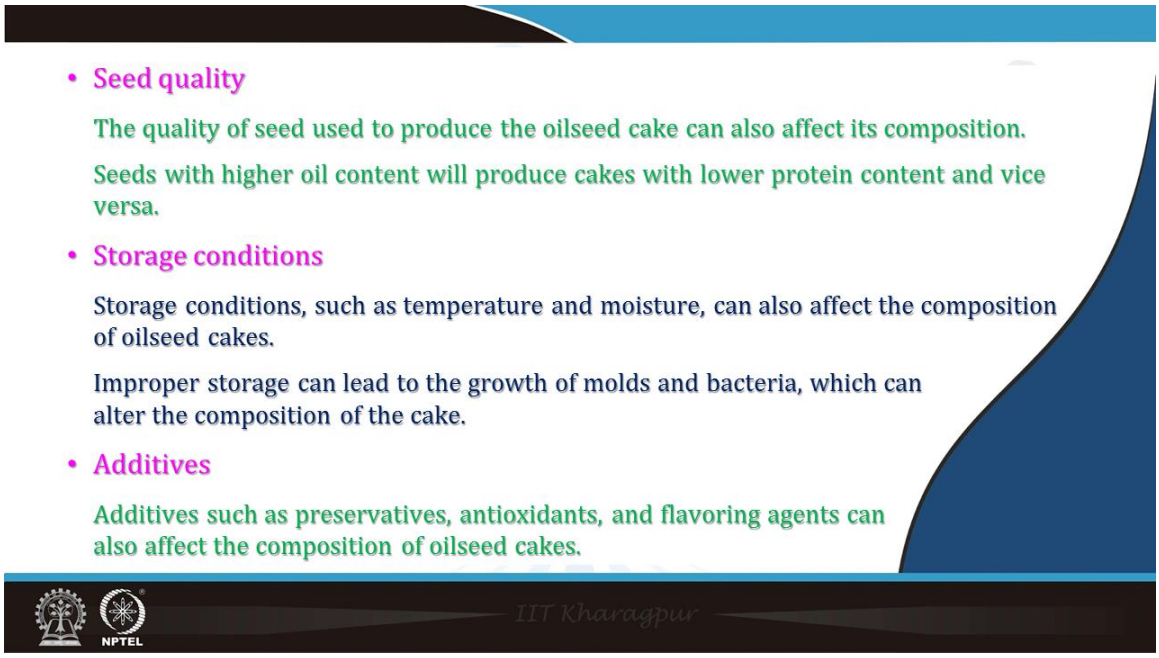


So, oil seed cake, first you see that, of course, in the earlier classes we have discussed that after the extraction of the oil that is we get a material pressed material or in the form of powder, sometime depending upon the process which is utilized. And the material remaining after the extraction of the oil is called mill or oil seed cake. So, the oil seed cake is the solid residue left over after the oil has been extracted from oil seed. It is typically used as animal feed or as a fertilizer due to its high protein and nutrient content. The popular oil seed cake, pressed cake which are used for these purposes include groundnut cake, sunflower cake, soybean cake, mustard cake, and so on. Mustard cake is popular very good ingredient in the feed, it is fed to the cows or other animals.

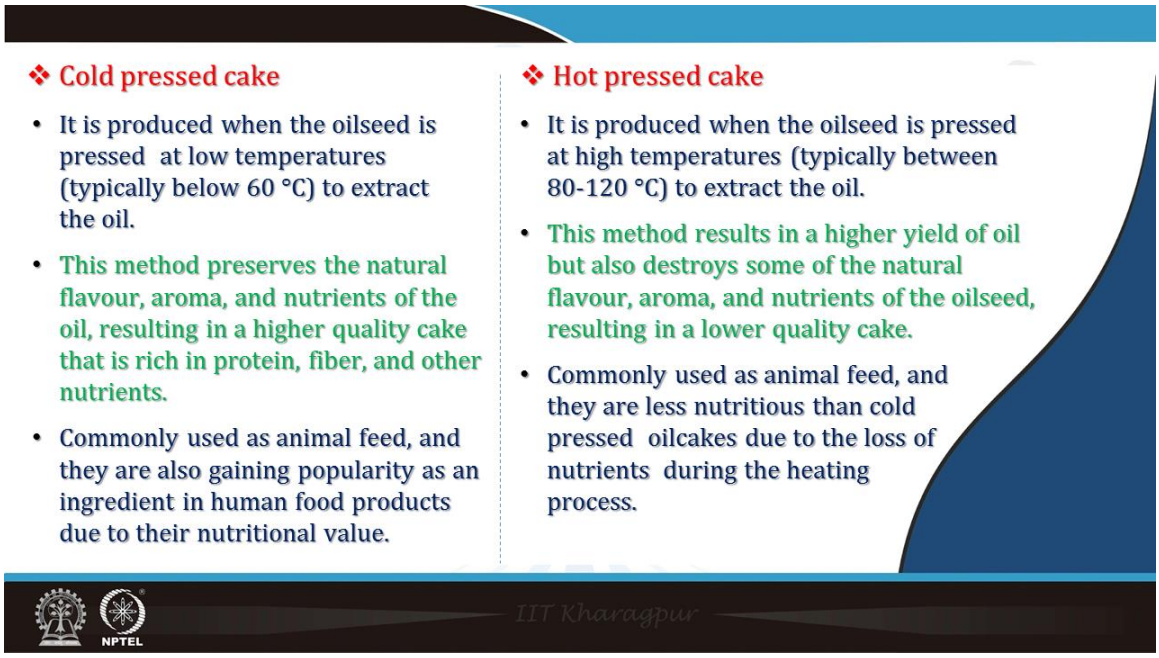


So, the first thing is the factors affecting the quality of the oil seed cake because sometime the cake which is obtained after the oil extraction it may not be in good quality depending upon the conditions that had been used during extraction or processing. So, this cake might be further required to be treated or processed in order to bring it into edible condition for that is edible for human or even for its utilization as a feed animal feed or such other purposes. So, let us talk about what are the various factors which affect the quality of oil seed cake.

And that though factors important factors are number of number one is the type of oil seed itself because different oil seeds have different composition particularly they have different content of oil protein fiber and other nutrients and which affect the composition of the resulting oil seed cake. Similarly, as I told you extraction method used to extract the oil from oil seed cake affect the composition of the pressed de-oiled cake. For example, the cold pressed cakes are higher in protein and fiber content than those extracted using chemical solvents. Processing conditions also influence the quality of the cake; the conditions like temperature, pressure, and duration of processing ok. It significantly influences the composition of oil cake and, it is, even the quality of the oil seed cake.



The quality of the seed used to produce the oil seed cake can also affect the composition. Seeds with higher oil content will produce cake with lower protein content and vice versa. Storage conditions such as temperature and moisture influence the composition of the oil seed cake. Improper storage can lead to the growth of molds and bacteria which can also alter the composition of the pressed cake. Then additives, sometime additives, are used for one or the other purposes like the preservatives, antioxidants, etcetera. They also influence the composition of the oil seed cake.



Now let us have a little comparison, that is, what is the quality of the cold pressed cake as well as hot pressed cake. Cold pressed cake is produced when the oil seed is pressed at low temperature typically below 60 degrees Celsius to extract the oil. And this method preserves the natural flavor, aroma, and nutrients of the oil resulting in a higher quality cake that is rich in protein, fiber, and other nutrients. Cold pressed cake is commonly used as animal feed and it is also gaining popularity as an ingredient for human food products due to their nutritional value. Hot pressed oil seed cake is produced when the oil seed is pressed at a higher temperature at a high temperature typically above 80 degrees Celsius or even 100 or 120 degree Celsius.

And this method results in a higher yield of the oil obviously, but it also destroys some of the natural flavor, aroma, components, and nutrients of the oil seed resulting in a lower quality cake. And because of its qualities little inferior quality than the cold pressed cake, the hot pressed cake is used as animal feed and they are less nutritious than the cold pressed oil seed cakes due to the loss of nutrients during the heating process.

Composition of oilseed cake

Common name	Oil content (%w/w)	Protein content (%w/w)	Fiber content (%w/w)	Average ash content (%w/w)
Groundnut	Varies depending upon the extraction process	20.9 – 25.3	1.4 – 3.9	1.2 – 2.3
Soybean		35.6	6.27	4.92
Rapeseed (Yellow)		30.7	7.14	6.32
Rapeseed (brown)		33.4	10.2	5.9
Mustard (black)		3.17	12.17	7.1
Mustard (yellow)		28.80	14.8	5.9
Mustard (brown)		23.11	9.34	3.22
Sunflower (dehulled)		33.82	17.93	5.20
Safflower		17	65	3.5
Castor		31.06	2.5	11.1
Sesame		33.91	5.63	4.04
Niger		25	18	4
Linseed		20	42	6.98

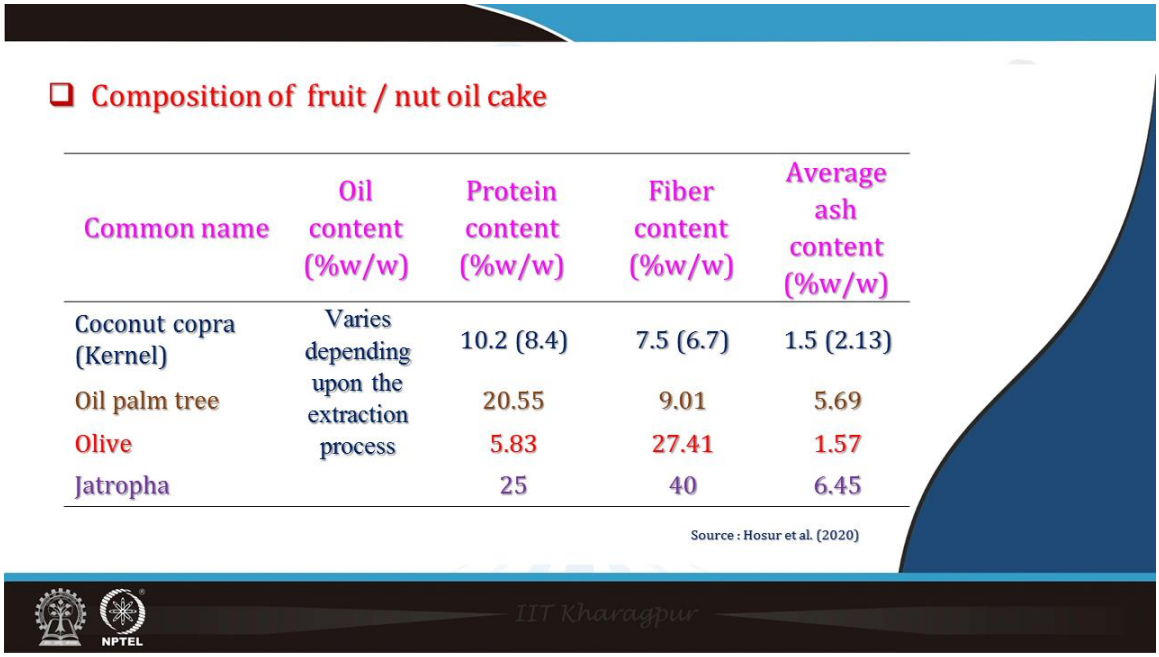
Source : Hosur et al. (2020)

So, in this table I have tried to give you a summary of the composition of the de-oiled cake ok, that we take, that, the groundnut, yellow rapeeed, brown rapeseed, mustard, mustard yellow, mustard brown, then sunflower dehulled, safflower whole, castor, sesame, niger and linseed. These are the cakes, cakes obtained from these materials after the extraction. So, the composition, let us say, that is the oil content in these obviously, it will vary depending upon the extraction process that is oil content on the cake whether it is a cold pressed, hot pressed or solvent extraction or by other method that is the cake might contain varying amount of oil.

So, protein content. Normally, the groundnut cakes has around 20 to 25 percent weight by weight whereas, soybean has around 35 to 40 percent protein. Even rapeseed and yellow or brown both have around 30, 33 or 31 ok, mustard 28. So, you can see that invariably all these oilseed cake, they are having protein content from even 20 to 40 percent ok. Here is the fiber content. Soybean has a 6.2 percent weight by weight fiber, rapeseed brown has 10.2 percent even mustard black has 12 percent or mustard yellow has 14 percent, even sunflower dehulled has around 18 percent fiber content ok, niger seed also has 18 percent; linseed has highest, that is, 42 percent fiber content.

So, here you can see again the fiber content also depends upon the commodity that is has been. So, average ash content. It ranges from 4, that is, in the soybean 4 to 5

percent in rapeseed 6 percent, mustard 6 percent, 11 percent in castor, 7 percent approximately in linseed and so on.



So, it also these are the values of the or composition of the oil cake. If you see the coconut or copra kernel ok, it has protein about 10 percent ok, fiber 7.5 percent and average ash content around 1.5 percent. Oil palm tree; it has protein 20, 21 percent, fiber 9 percent, and ash content around 6 percent. Olive has a protein 5.8 approximately, fiber content around 28 and 2 percent approximately ash content.

Jatropha, it has protein 25 percent, fiber content 40 percent weight by weight, and ash is about 6.5 or 7 percent. So, these are the composition, that is, the oil depending upon the extraction process and protein content, fiber content and ash content in the different oil cake of various materials varies depending upon the various methods, composition and so on.

Proximate composition of rice bran, copra and sesame de-oiled cakes, their water extracts & residual solids

Samples	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Crude fiber (%)	Carbohydrates (%)
RBP (100 %)	8.2±0.02^{a}	11.8±0.12^{a}	7.5±0.01^{a}	9.9±0.02^{a}	9.8±0.05^{a}	52.8
RBPR (66 %)	10.1±0.05^{b}	12.4±0.02^{a}	7.1±0.01^{b}	6.5±0.52^{b}	6.1±0.02^{b}	57.8
RBPE (34 %)	6.7±0.01^{c}	10.7±0.01^{b}	7.2±0.04^{b}	3.2±0.12^{c}	3.3±0.08^{c}	68.9
RBS (100 %)	0.9±0.1^{d}	16.1±0.25^{c}	7.6±0.02^{a}	10.4±0.4^{a}	10.5±0.01^{d}	54.5
RBSR (60 %)	21.6±0.32^{e}	10.3±0.08^{b}	6.4±0.08^{c}	5.9±0.1^{b}	5.8±0.06^{b}	50.0
RBSE (40 %)	12.8±0.44^{f}	15.8±0.32^{c}	7.3±0.24^{ab}	4.8±0.22^{d}	4.4±0.01^{e}	54.9
CC (100 %)	9.9±0.0^{ba}	9.4±0.01^{d}	4.9±0.06^{d}	17.8±0.1^{e}	10.3±0.08^{d}	47.7
CCR (74 %)	8.2±0.01^{a}	7.7±0.04^{e}	3.3±0.29^{e}	12.2±0.35^{f}	7.2±0.05^{f}	61.4
CCE (26 %)	27.4±0.06^{g}	0.0	7.3±0.24^{ab}	4.9±0.36^{d}	2.7±0.1^{g}	57.7
SC (100 %)	9.2±0.33^{ab}	9.3±0.14^{d}	8.9±0.16^{f}	34.0±0.22^{g}	8.2±0.08^{h}	30.4
SCR (83 %)	8.9±0.01^{ab}	10.4±0.08^{b}	9.0±0.44^{f}	25.4±0.42^{h}	6.1±0.2^{b}	40.2
SCE (17 %)	26.2±0.12^{h}	2.1±0.04^{f}	8.7±0.05^{f}	6.9±0.02^{b}	1.9±0.06^{i}	54.2

Values reported are mean ± SD (n=6). Values in columns followed by different superscripts are significantly different (p<0.05)

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract

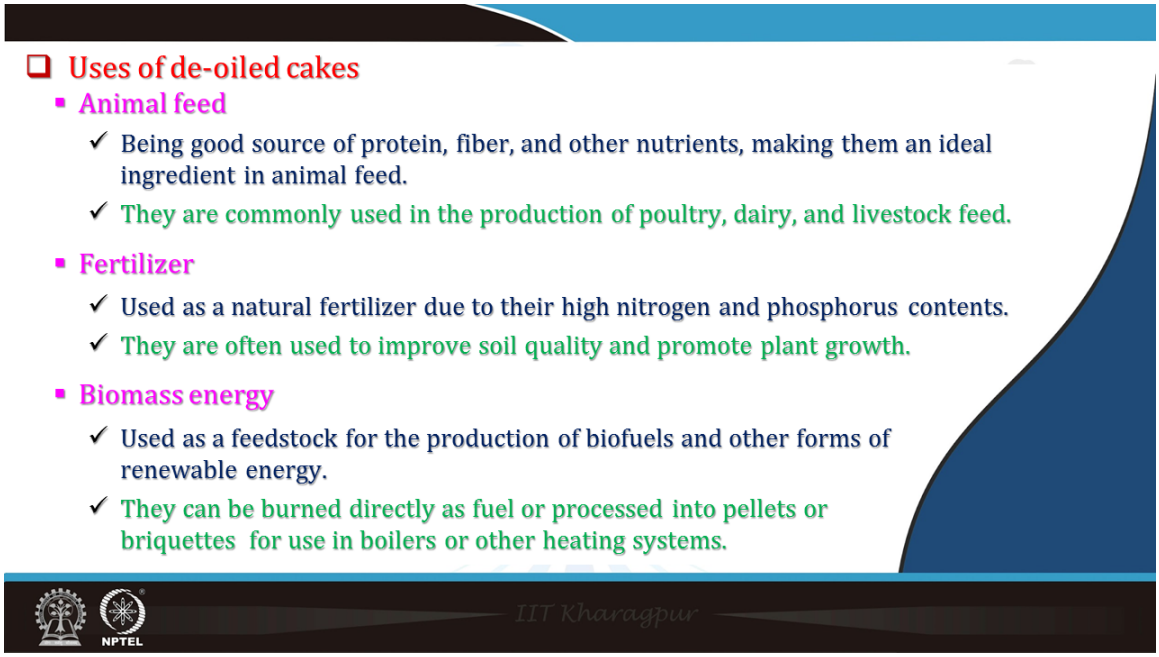
Source : Sunil et al. (2015)

So, now here I have tried to give you approximate composition of rice bran, copra and sesame deoiled cake, their water extract and residual solids content, ok. So, if you can see that RBP that is rice bran pellets, RBPR rice bran pellets residue and RBPE that is rice bran pellets extract, ok.

RBS is stand from rice bran stabilized, RBSR rice bran stabilized residue and RBSE that is rice bran stabilized extract. Similarly, the CC stand from copra cake, copra cake residue, copra cake extract or sesame cake, sesame cake residue or sesame cake extracts. In all these if you see that moisture content vary as low as 0.9 to 1 percent in RBS to about as high as 28 percent in CCE that is copra cake extract, ok. It that is the rice bran that is the rice bran stabilized extract; it has around 13 percent rice bran stabilized residue has around 22 percent moisture content.

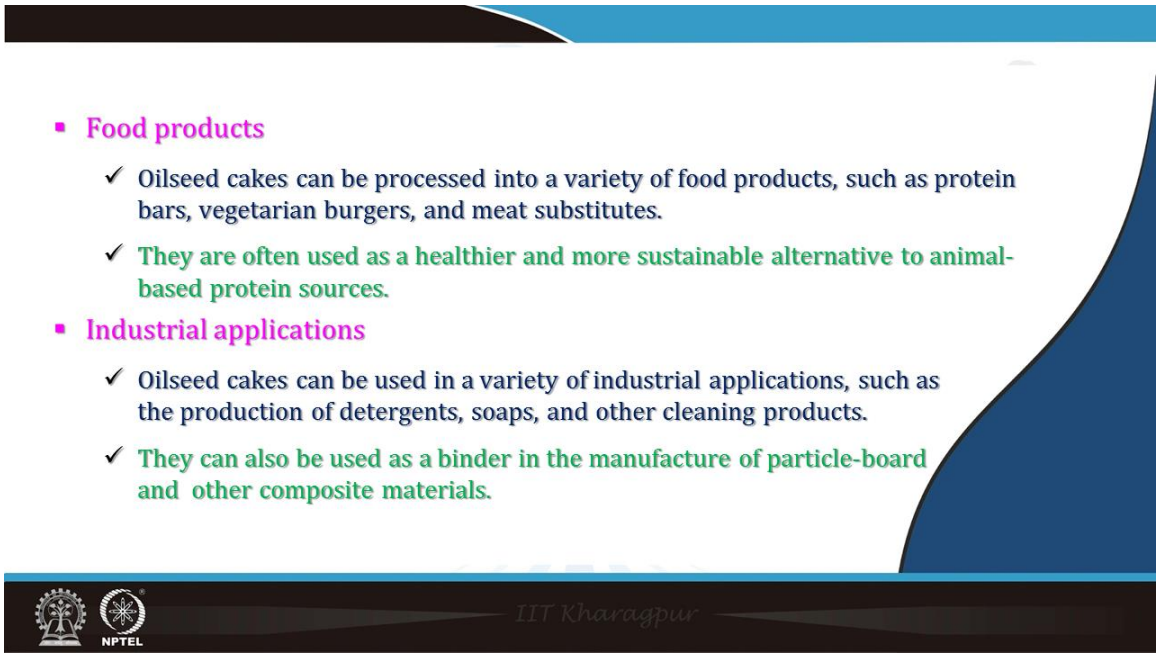
So, depending upon that is different materials they have different moisture content. Similarly, their fat content ash content also varies the fat content is the rice bran stabilized extract is around 15.8 percent whereas, there is the, in the case of sesame cake residue, it has around 11 percent ok. In rice bran pellets, also 11 percent rice bran pellet residue around 12 percent extraction rice bran that is a solid extract rice bran stabilized extract it has around 15.8 percent fat content, about 4.8 percent protein content are there in the rice bran stabilized extract copra cake has around 18 percent protein.

So, similarly that is now they have the in all these you can refer this table and you can find the details of the composition in various cakes.



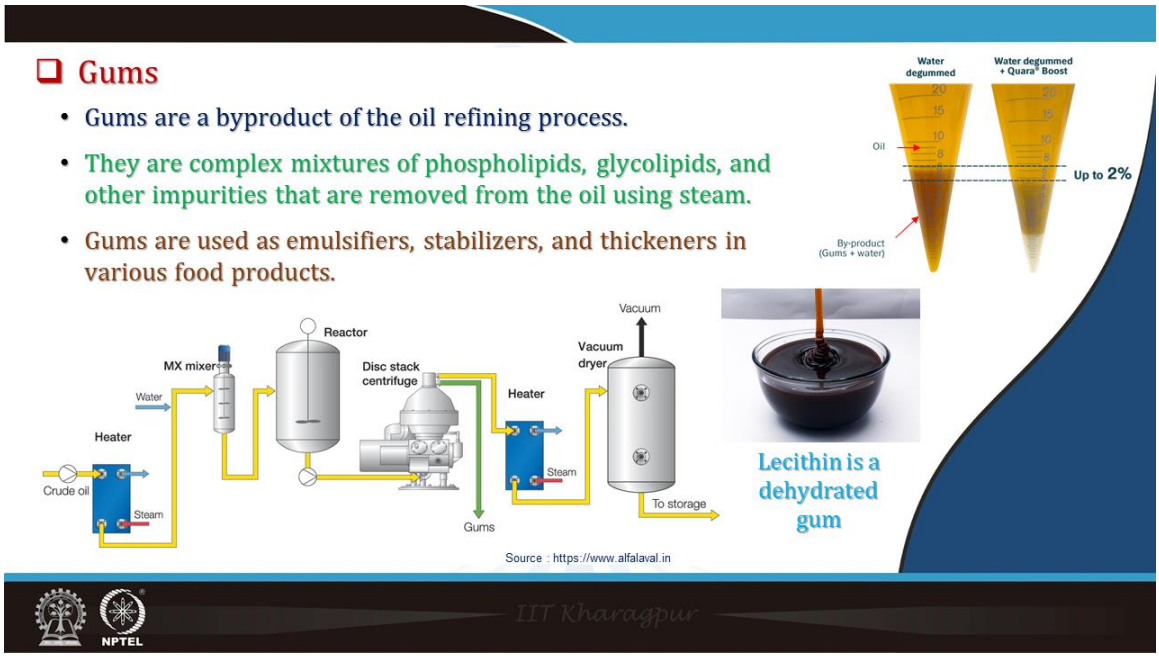
Now let us discuss about uses of this de-oiled cake, ok, that is, they are used as animal feed because they are good source of protein, fiber, and other nutrients and it make them an ideal ingredient in animal feed. They are commonly used in the production of poultry dairy and livestock feed formulations, ok. They are also used as fertilizer as a natural fertilizer due to their high nitrogen and phosphorus contents. They are often used to improve the quality of the soil as well as to promote the growth of the plant.

They are also used as a biomass energy, ok. They are used as a feedstock for the production of biofuels and other forms of renewable energy. They can be burned directly as fuel are processed into pellets or briquettes for use in boilers or other heating systems.



Pressed oilseed cake; they can also be, because they have good amount of protein, fiber, bioactives, etcetera. So, they can be refined as they can be processed further to be used in a variety of food products such as protein bars, vegetarian burgers and meat substitutes. They are often used as a healthier and more sustainable alternative to animal based protein sources.

As far as the industrial application of these de-oiled cakes is concerned, they can be used in a variety of industrial applications such as the production of detergents, soaps and other cleaning products. They can also be used as a binder in the manufacture of particle board and other composite materials, ok.



Now, after the cake, let us see another important byproduct of the oil milling industry, that is, gum, ok. And, these gums, you have seen in the refining process, when we were talking in the de-gumming process, a lot of about 3 to 4 percent of the gums are there and they are these gums during the refining process, they are removed from the oil and they are complex mixture of the phospholipids, glycolipids and other impurities that are removed from the oil during refining process using steam or such other methods this is de-gumming and other processes, we have discussed earlier in detail. Now, these gums which are obtained from the refining process during, that you can see that is this centrifuges and gums are removed; this is a just to refresh your memories, refining line is shown here and the step from where gums are obtained. So, these gums are used as a emulsifier. They can be used as a stabilizer and thickener in various food products. And I told you earlier also, I emphasized that, yes, lecithin is a very very valuable gum product byproduct which is processed and we will devote one lecture fully on the processing of the gum into its conversion into lecithin and the uses of lecithin. Lecithin is extensively used as an emulsifier in so many food products, ok.

❑ Composition of lecithin obtained from different oilseeds

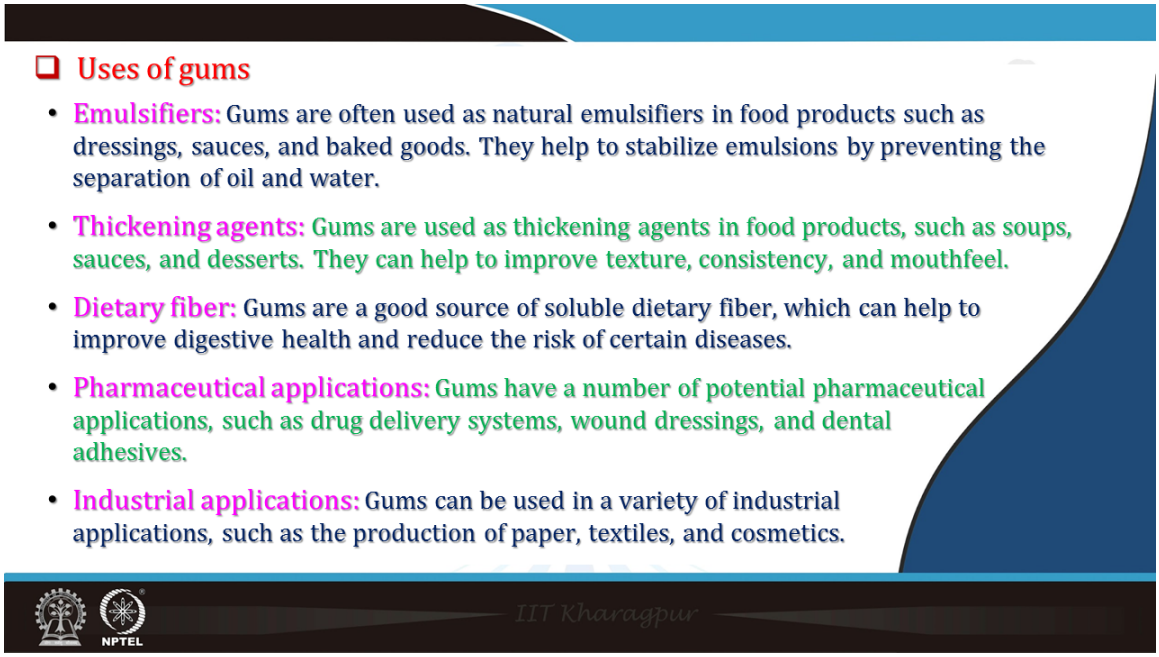
Compound	Soybean (%)	Cottonseed (%)	Corn (%)	Sunflower (%)	Rapeseed (%)	Peanut (%)	Rice Bran (%)
Phosphatidyl choline (PC)	29 – 39	34 – 36	30	13 – 27	16 – 24	49	20 – 23
Phosphatidyl ethanol-amine (PE)	20 – 26	14 – 20	3	15 – 18	15 – 22	16	17 – 20
Phosphatidyl inositol (PI)	13 – 18	—	16	7 – 8	8 – 18	22	5 – 7
Phosphatidyil serine (PS)	5 – 6	7–26	1	—	—	—	—
Phosphatidic acid (PA)	5 – 9	—	9	—	—	—	—
Phytoglycolipids (PGL)	14 – 15	—	30	—	—	—	—
Other phospholipids	12	—	8	—	—	—	—

So, the composition of lecithin obtained from the different oilseeds, you can see that and the like. Lecithin, it is basically phospholipids. So, various phospholipids like phosphatidylcholine, phosphatidylinacetyl, PE, phosphatidylethanolamine, phosphatidylserine, phosphatidic acid or phospholipids, in general, that is, phytoglycolipids or other phospholipids.

So, these are the different types of phospholipids which are generally found in the lecithin or other gums. So, if you can see the soybean contains the phosphatidylcholine about 29 to 39 percent, cotton seed has 34 to 36 percent, corn oil cake also contain about 30 percent of the phosphatidylcholine, ok. Sunflower oil it contains around 13 to 27 percent, rapeseed 16 to 24 percent. Peanut protein cake, peanut cake it has as high as 49 to 50 percent phosphatidylcholine, ok. Rice bran oil also has significant amount about 20 to 23 percent. So, you can see that these are the three major component like phosphatidylcholine, phosphatidylethanolamine, and phosphatidylinositol.

They are found in almost all these cake in very significant amount, and that is why that accordingly in the lecithin they also are carried over although in the lecithin, mainly phosphatidylcholine is the major component of the lecithin, ok. So, the cake which is obtained from the soybean, you can see, it has almost all forms of this phospholipids. Because the phospholipids whether it is choline, ethanolamine, inositol,

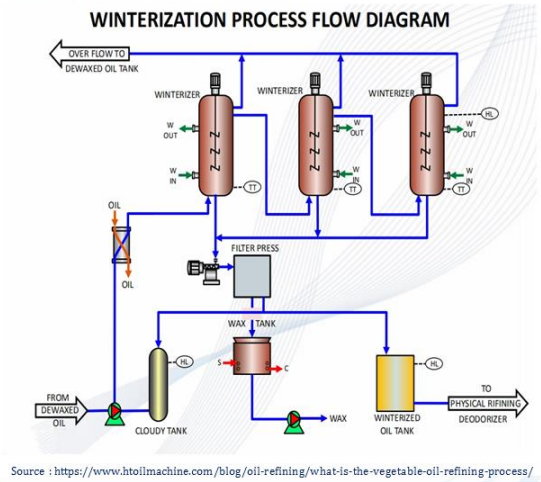
serine, phosphatidic acid and phytoglycolipids or other lipids are around 12 percent by weight in the soybean, ok. Even phytoglycolipids are around 14 to 15 percent. So, there are significant amount of these components in all these lipids, ok.



So, the uses of gums, if you talk about, these gums are used as emulsifier; they are as a natural emulsifier in food products formulation such as dressing, sausage, baked goods. They help to stabilize emulsions by preventing the separation of oil and water. In fact, lecithin is used in our most, more than 100s of the food products and it is used. It is one of the important emulsifier in product like margarine up to in margarine up to 10 percent of lecithin is there. Then it is used as a thickening agents in food products, in gravies, in sauces etcetera, in soup and desserts. They also help to improve texture, consistency, and mouth feel of these products when used.

The gums are used as a dietary fiber, soluble dietary fiber which can help to improve digestive health and reduce the risk of certain diseases. Gums are also used in various pharmaceutical applications, ok, such as in the drug delivery systems, wound dressings, and dental adhesive, these gums find use. Gums find use in variety industrial application in non-food uses, etcetera, such as, they are used in the production of paper, textiles as well as in cosmetics, ok.

Edible oil waxes



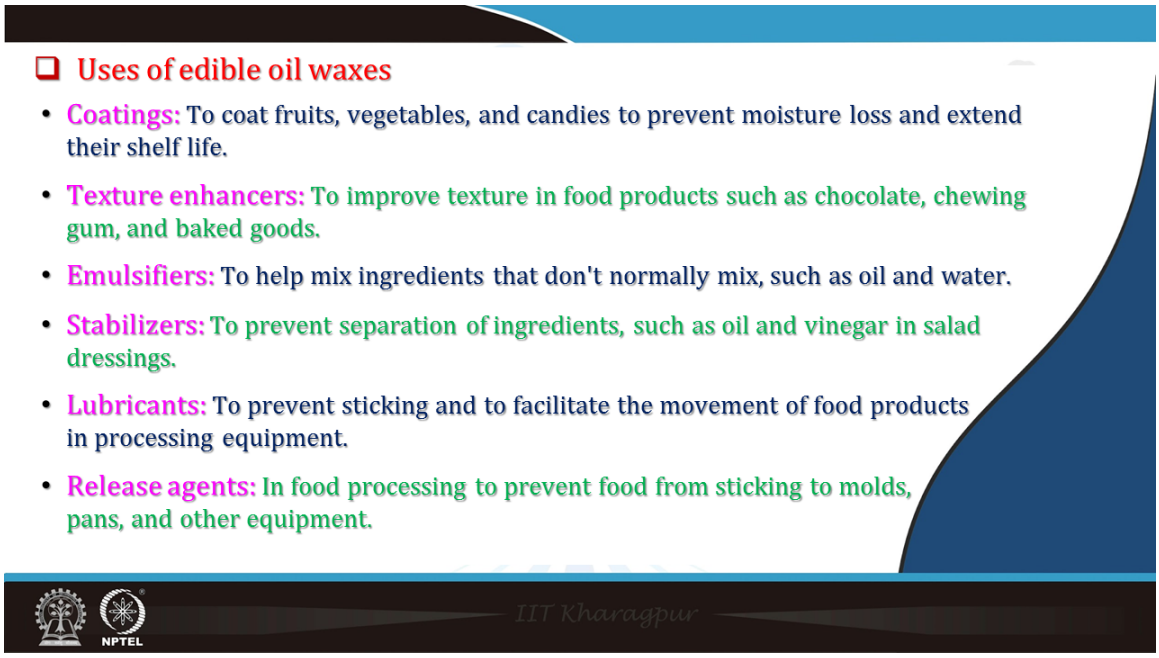
Source : https://www.htoilmachine.com/blog/oil-refining/what-is-the-vegetable-oil-refining-process/

- Edible oil waxes are a complex mixture of long-chain fatty acids and esters that are solid at room temperature and are separated from edible oils during the refining process.
- They are also known as "oil foots" or "oil feet".
- In winterization process, the waxes are removed from the oil.

Examples of waxes

Soy wax, palm wax, sunflower wax, rice bran wax

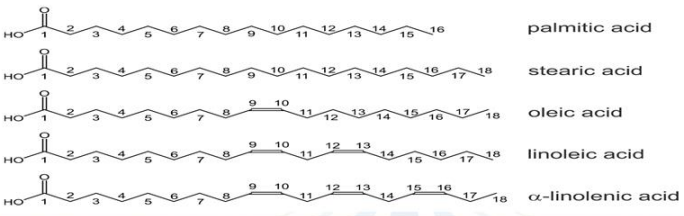
So, then, after gum let us talk about, little bit edible oil. These waxes are a complex mixture of long chain fatty acids and esters that are solid at room temperature and are separated from edible oil during the refining process. They are also known as oil foods or oil feed and in the winterization process, the normally gums, they settle down in the water, and then by either decontamination or by centrifugation they are removed. And, these gums, they are further processed into uses of various, like various applications, which we will discuss little later. So, examples of common waxes are soy wax, palm wax, sunflower wax, and even rice bran wax, etcetera it is obtained. So, this is the winterization process flow diagram is shown here in this figure and during this process, the gums are removed, that is, wax are removed. Here you can see from this and this winterization process in earlier lectures, we discussed in detail, ok.

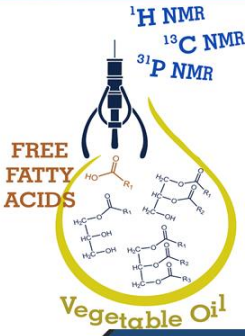


So, uses of these edible oil waxes include in coatings, that is, to use the coat of coating as a coating on the surface of fruits, vegetables, candies, etcetera to prevent moisture loss as well as to extend their shelf life by regulating the respiration processes in fruits, vegetables, etcetera. They can also be used as texture enhancers to improve the texture of the food product like chocolate, chewing gums, baked goods. They are, these, used as emulsifiers, that is, help mix ingredients that do not normally mix like oil and water, like in the margarine that is a peanut oil or other vegetable oil is mixed with water and there they are used as a stabilizer or emulsifier. Then, they can also be used as a lubricant to prevent sticking and to stabilize the movement of food products in processing equipment, ok. Then, these gums, waxes are also used as a releasing agent that is in food processing to prevent food from sticking to mold, pans or other equipments, etcetera, these waxes are used ok.

Free fatty acid distillate

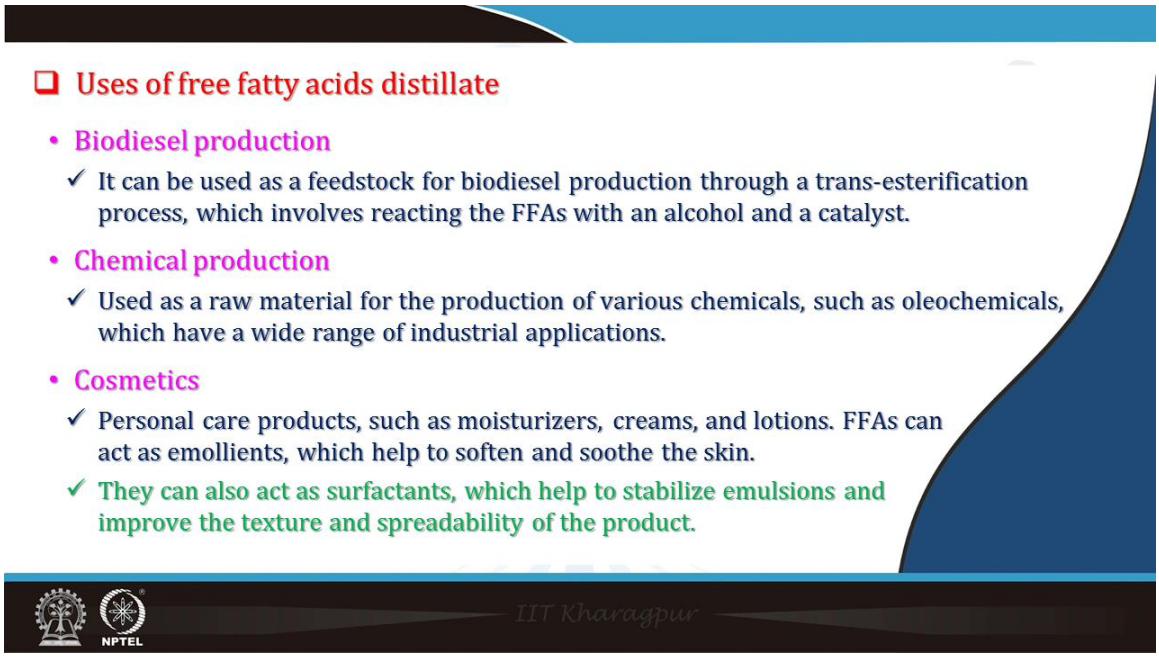
- Fatty acid distillates are a mixture of fatty acids, triglycerides, and other components that are removed from the oil during the deodorization process.
- Fatty acid distillates can be further processed to produce fatty acids, which have a variety of industrial applications.
- Free fatty acids (FFA) are hydrolysis products of triglycerides (TG) in vegetable oils.



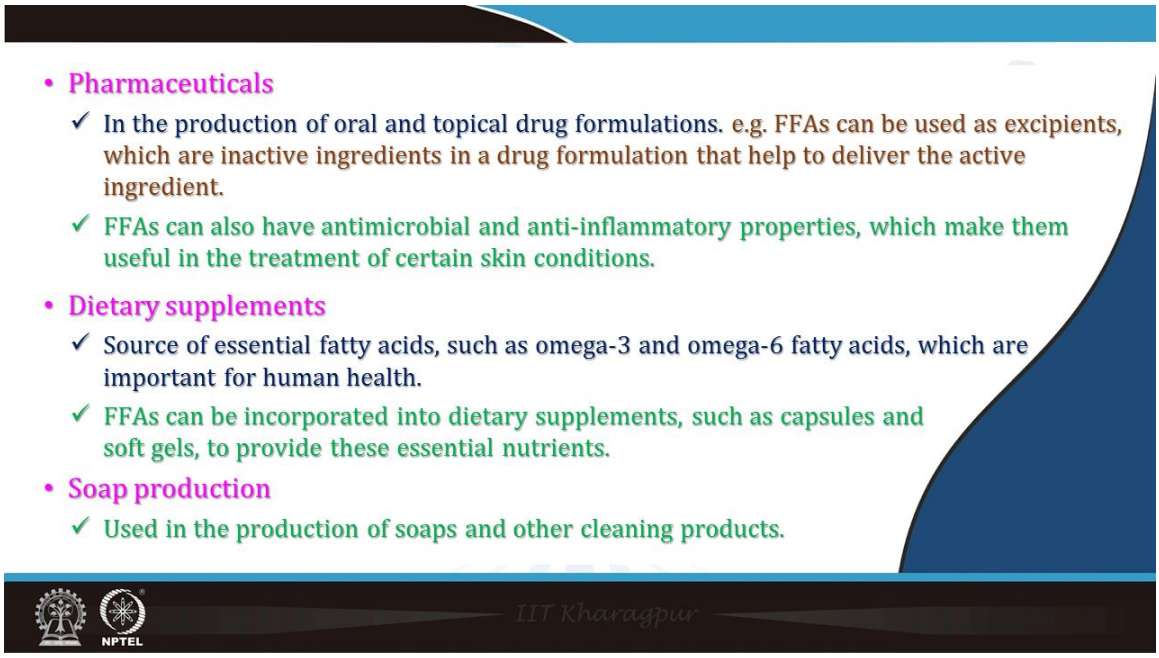


Source : Pietro et al. (2020)

Then other important byproducts of this is the free fatty acid distillate. The fatty acids, fatty acid distillates are a mixture of fatty acids, triglycerides, and other components that are removed from the oil during the deodorization process and these distillates can be further, that is, specific fatty acids for manufacture of glycerol, for manufacture of other important triglycerides. Triglycerides, they can be used to prepare, ok. That fatty acid distillates can be further processed to produce, as I told you, fatty acids which have a variety of industrial applications. Free fatty acids are hydrolysis product of triglyceride in vegetable oil in the various previous lectures. We have seen detail composition, that is, what is, how the free fatty acids are formed. So, all these free fatty acids particularly which are removed either in the deodorization process as a fatty acid distillate or even the soap stock, they can be further refined and pure pure fatty acids can be obtained.



So, these free fatty acids distillates can be used in the biodiesel production. It can be used as a feed stock for biodiesel production through the transesterification process which involves reacting the free fatty acids with an alcohol and a catalyst. Then in chemical production that is used as a raw material for the production of various chemicals such as oleochemicals which have a wide range of industrial applications. The free fatty acids distillates have found significantly usefulness in the cosmetics industry. In personal care products such as moisturizers, cream and lotions, free fatty acids can also act as emollients which help to soften and soothe the skin. They can also act as surfactant which help to stabilize emulsions and improve the texture and spreadability of the products.

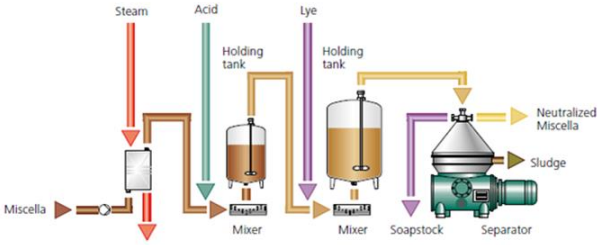


They are found used in pharmaceuticals, that is, in the production of oral and tropical drug formulations, like free fatty acids can be used as excipients, which are inactive ingredient in a drug formulation that help to deliver the active ingredient. Free fatty acids can also have an antimicrobial and anti-inflammatory properties which make them useful in the treatment of certain skin conditions. There is a dietary supplements, they may be a useful source of essential fatty acids, such as, omega 3 fatty acid, omega 6 fatty acids which are important for human health. FFA can be incorporated into dietary supplements such as capsules and soft gels etcetera to provide these essential nutrients. In soap production they are used, that is, and even they can be used for making other cleaning agents.

Soapstock

- Soapstock is a byproduct of the alkali refining process of edible oils.
- It is a dark brown, viscous material that contains residual oil, soap, and water.
- Soapstock can be further processed to recover the residual oil and to produce fatty acids, which have a variety of industrial applications.

Soapstock separation

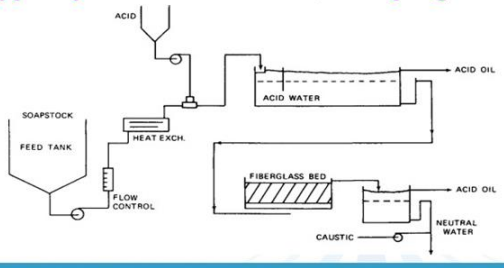


Source: https://lipidlibrary.aocs.org/edible-oil-processing/alkali-refining

Another important is the soapstock is a byproduct of alkali refining process of the edible oil, and it is a dark brown viscous material that contains residual oil, soap and water. Soapstock can be further processed to recover the residual oil and to produce fatty acids which have a variety of industrial applications. You see that is in the neutralization process, that is, when caustic is added into the oil, the caustic sodium it forms the sodium salts of various respect to fatty acid, that is, soapstock.

Acid oil

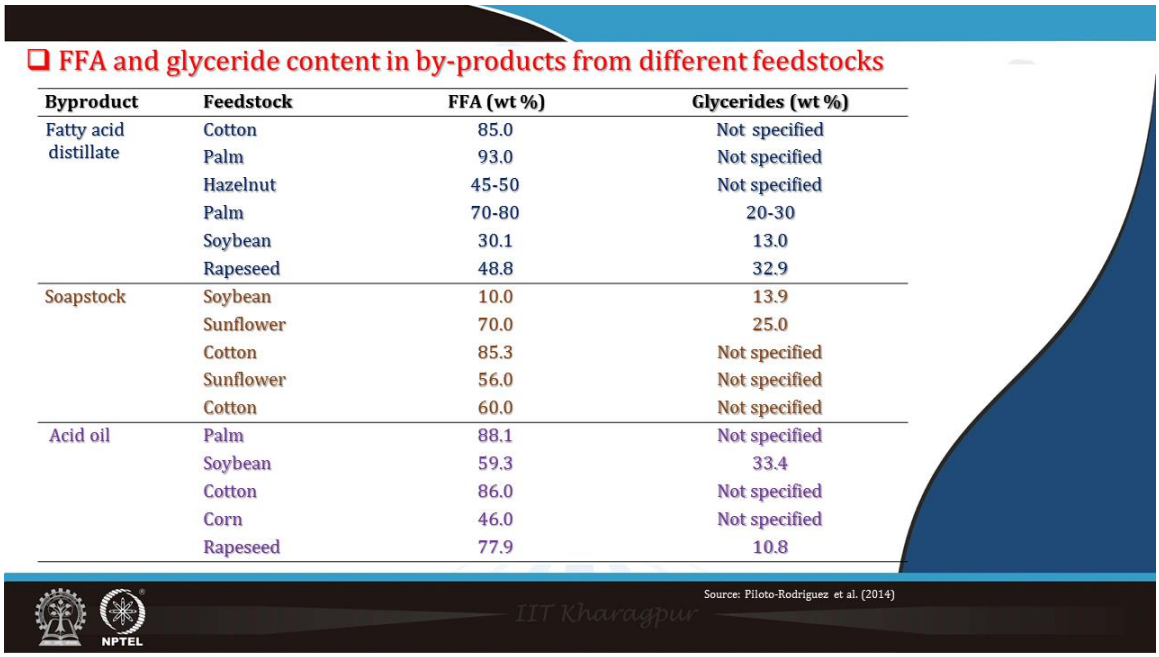
- The neutralization process results in the formation of soap stock and acid oil.
- Acid oil is formed by the reaction between the free fatty acids in the oil and the alkaline solution used for neutralization.
- It contains a high percentage of free fatty acids, and its composition depends on the type of oil being refined and the specific refining process.
- Acid oil is typically dark brown in color, has a pungent odor, and is highly acidic.



Source : O'Brien (2008)

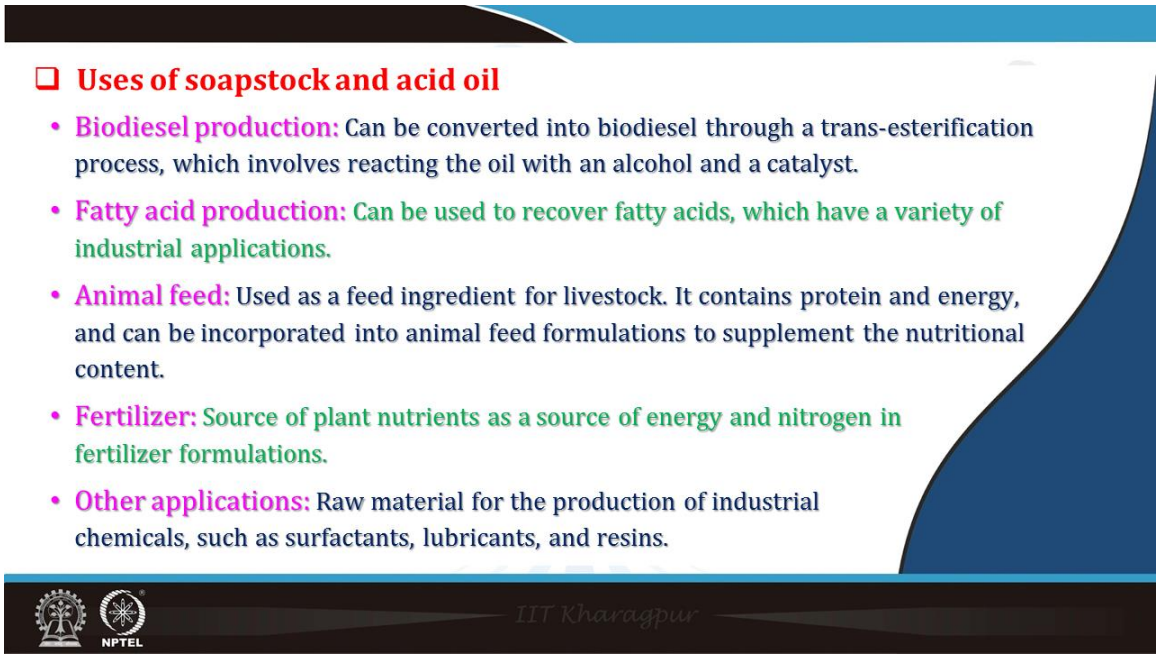
So, this, then there is another product acid oil. The neutralization process results in the formation of a soapstock and also an acid oil. Acid oil is formed by the reactions between the free fatty acids in the oil and the alkaline solutions used for neutralization.

So, it contains a high percentage of free fatty acids and its composition depends on the type of the oil being refined and the specific refining process. So, acid oil is a typically dark brown in color and it has a pungent odor and is highly acidic, ok. So, that you can see here, soapstock and feed tank and then it is acid reacted with acid and water, it gives acid oil or even fiberglass bed then acid oil can be formed, separated, ok.

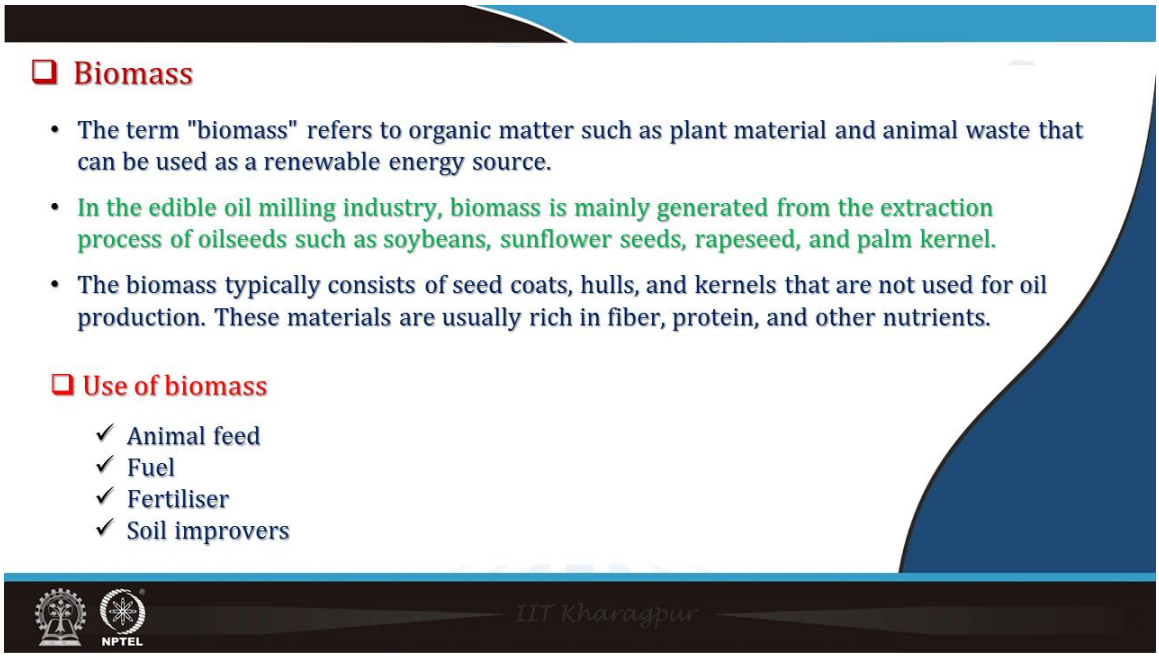


So, it is, in the stable free fatty acid and glyceride content in byproducts from different feedstocks, you can see, that is, it contains in the cotton seed oil cake as high as 85 percent in the fatty acid distillate in byproduct. So, it varies from 30 percent to as high as 30 percent in soybean, 48 percent in rapeseed to as high as 93 percent in palm oil that is the free fatty acid weight percent in the byproduct, ok. Similarly, glycerides they may be in the rapeseed around 32 percent weight percent, and also in the palm, the oil palm is about 20 to 30 percent, this is the fatty acid distillate. Similarly, is soapstock around from 10 percent in soybean to as high as 85 percent in cottonseed pressed cake. There is sunflower cake, contains 70 percent then this glycerides content is around 13 to 14 percent in soybean cake and sunflower cake has around 25 percent, ok. Then acid oil,

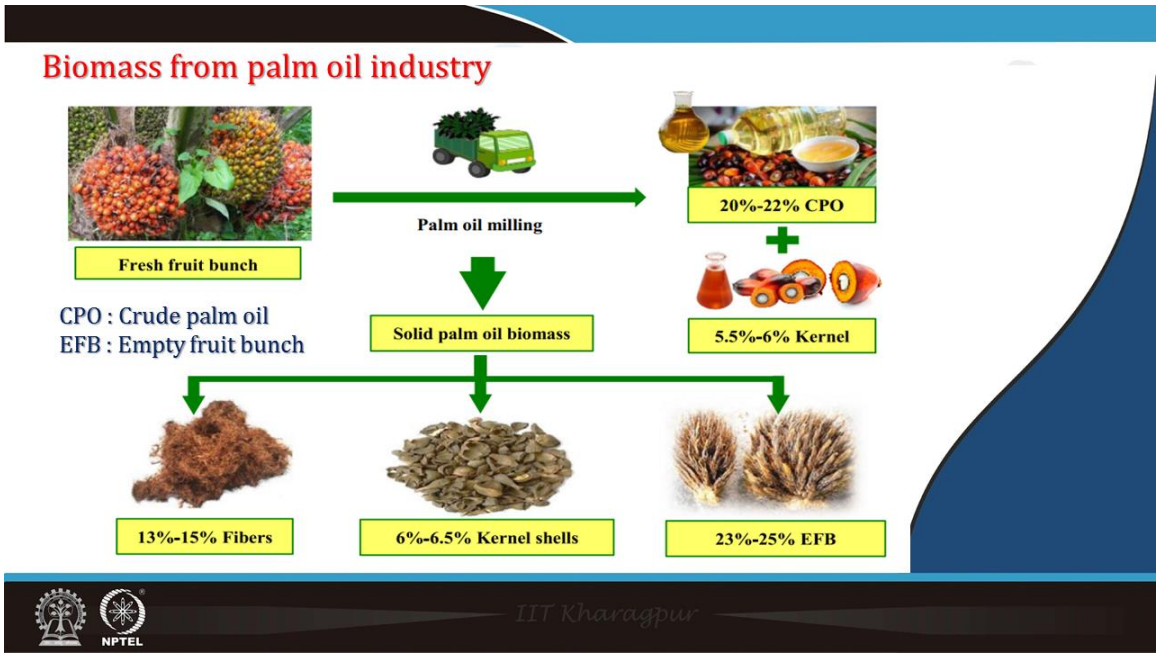
there is around, it can say corn cake has around 46 percent acid oil and then it varies up to as high as 88 percent in palm oil and 86 percent in cottonseed oil, 80 percent approximately in rapeseed acid cake. Then this glycerides are about in soybean it is contain 33 percent and this rapeseed feedstock it contains around 10.8 or 11 percent glycerides, ok.



So, this soap stock and acid oil can also be used in biodiesel production, fatty acid production. They can be used as animal feed. They can be used as fertilizer because sources of plant nutrients; as a source of energy and nitrogen in fertilizer formulations. And they can also, like other byproduct, they can be used in other material for production of industrial chemicals, surfactant, lubricants, resins, etcetera, ok.



Finally, the biomass, the term, biomass, refers to organic matter such as plant material and animal waste that can be used as a renewable energy source, that is, in the edible oil milling industry. Biomass is mainly generated from the extraction process of oilseeds such as soybeans, sunflower seed, rapeseed and palm kernel. The biomass typically consist of seed coats, hulls, and kernels, that are not used for the oil production like they are after dehulling process, another material outer covering, etcetera. So, these materials are usually rich in fiber, protein, and other application and they can be used again for the animal feed, fuel, fertilizer, soil improvers, etcetera.



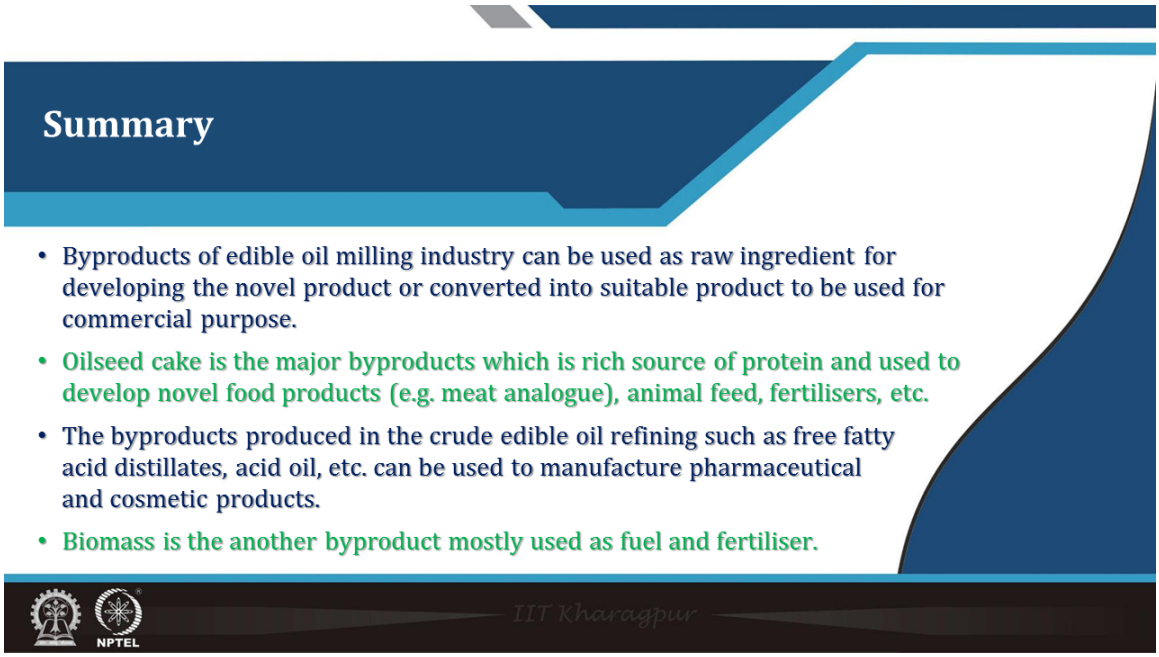
So, these biomass hulls, kernels, etcetera which are generated they can be further processed into, refined into different forms, and they can be used in this process, ok. So, here just a just for that biomass from the palm oil industry that is the fresh fruit you gave then palm oil milling, it gives around 20 to 22 percent of the crude palm oil and the remaining, you get about 5.5 to 6 percent kernel, ok. That is after the milling you get solid palm biomass, that is around 13 to 15 percent fibers, 6 to 6.5 percent kernel shells, and 23 to 25 percent empty fruit bunches. So, all these, that is, they constitute a huge quantity of biomass and they can be converted into various value added products, ok.

Proximate and ultimate analysis of palm fiber, shell and EFB

Parameters	Fiber	Shell	EFB
Proximate Analysis			
Moisture %	36.40	16.40	7.86
Ash %	5.34	2.68	4.77
Ultimate analysis			
Carbon %	30.02	43.80	44.72
Hydrogen %	3.81	5.27	6.58
Nitrogen %	0.89	0.50	0.80
Sulfur %	0.19	0.17	0.17
Oxygen %	23.35	31.18	42.96
Heating value (MJ/kg)	19.69	20.52	17.78

Source : Yan et al.(2019) and Abdullah et al. (2007)

And the proximate composition of these biomass, you can see palm fiber, shell and EFB includes, there is a moisture content they may, it may have partial moisture content in fiber around 36 percent, shell 16 percent, ash content it varies from 2 to 5 percent. Similarly, carbon percentage, they may have from 30 to about 44 percent, hydrogen is from 3 to 7 percent; even here there is oxygen also is a significant amount. They have a sulfur content and heating value of these fiber is around 19.69 MJ per kg. Shell has also a 20.52 MJ per kg and EFB, they have the 17.78 MJ per kg, ok.



So, finally, I summarize these lecture by saying that, yes, this is oil milling industry, produces a different byproducts and these byproducts, they can be further processed to and used in valuable various products. They can be used for developing novel products or converted into suitable products for use for commercial purposes like. And say, cake is the major product, which is rich in protein and used to develop novel food products like meat analogue, animal feed, fertilizers etcetera. The byproducts produced in the crude edible oil refining such as free fatty acid distillate, acid oil, etcetera can be used to manufacture a pharmaceutical and cosmetic product. Biomass is another. Significant quantity of biomass is produced in the oil milling industry and they can be used as either fuel or fertilizer or some other purposes.

These were the references used in the preparation of this lecture.

With this, thank you very much for your patience here. Thank you.