Food Oils and Fats: Chemistry & Technology

Professor H N Mishra

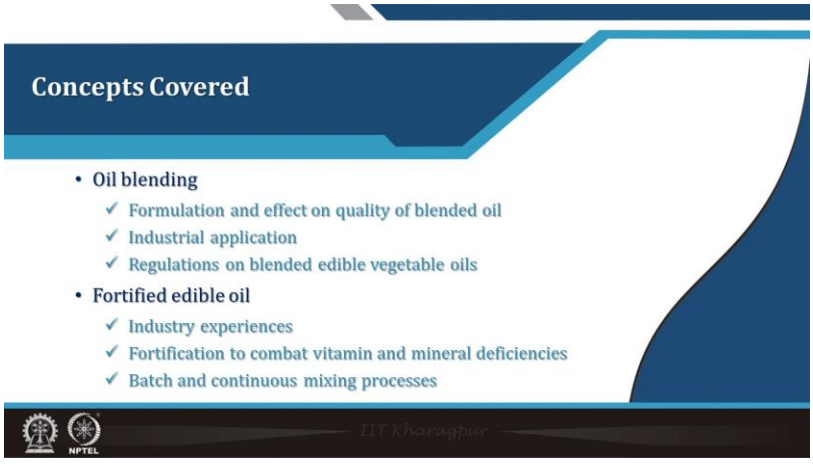
Agricultural and Food Engineering Department

Indian Institute of Technology Kharagpur

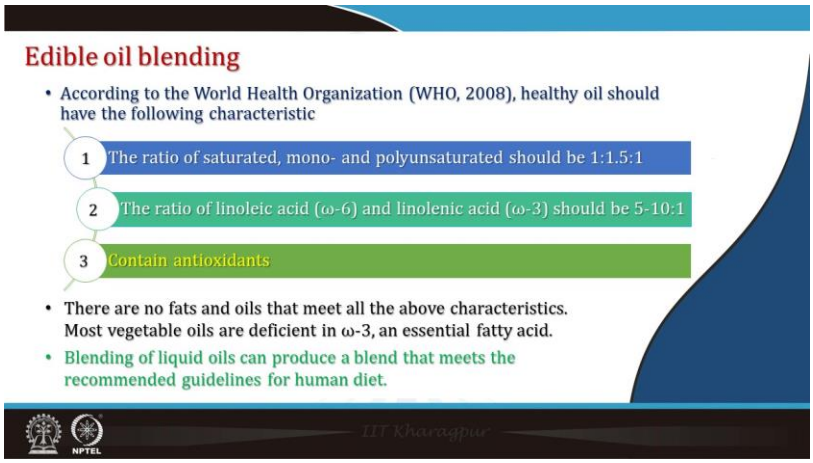
Module 12: Packaging, Storage & QA/QC of Food Oils and Fats

Lecture 56: Edible Oil Blending and Fortification

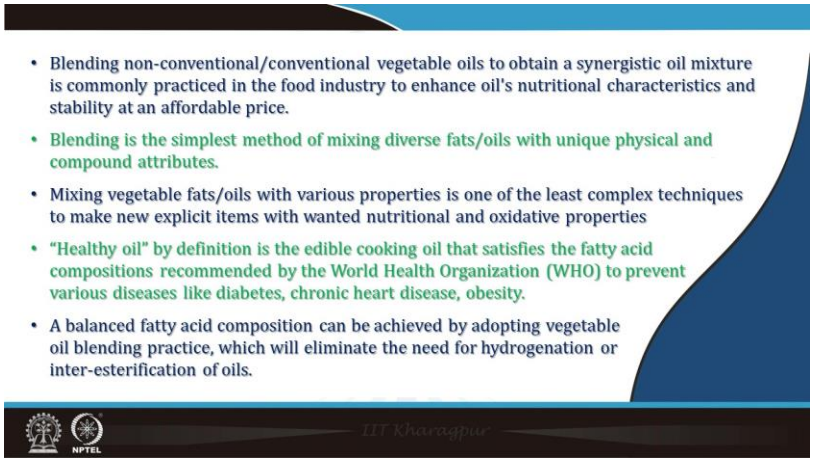
Hello everyone. Now, we are in the last module of this course that is module 12. In this module, the next five lectures, we will concentrate on packaging, storage and QA/QC of food oils and fats.



In today's lecture, we will talk about edible oil blending and fortification. We will cover oil blending that is formulation and effect on quality of blended oil, industrial application, and regulations on blended edible oil in the country. We will also discuss the industry experiences of fortified edible oil, fortification to combat vitamin and mineral deficiencies, and batch and continuous mixing processes.

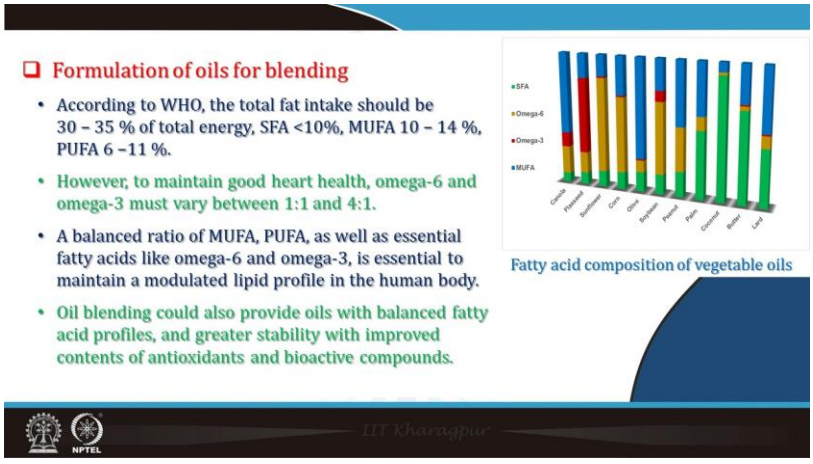


Blending of oil, according to the World Health Organization, healthy oil should have specific characteristics that is, it should have the ratio of saturated, monounsaturated and polyunsaturated fatty acids to the tune of 1:1.5:1, that is, it should have 1 saturated, 1.5 monounsaturated, and 1 polyunsaturated in this proportion. The second point is that the ratio of linoleic (omega-6) and linolenic (omega-3) fatty acid should be in the range of 5-10:1 that is anywhere between 5 to 10 is the omega-6 and 1 will be the omega-3. The third point is important thing that it should contain natural antioxidants. So, these are the characteristics which are present in the oil that make it a good healthy oil. There are no fats and oils that meet all the above characteristics. Most vegetable oil are deficient in omega-3 which is an important essential fatty acid. So, therefore, many times it is required to blend one oil with the other. Blending of liquid oils can produce a blend that meets the recommended guidelines for human diet.



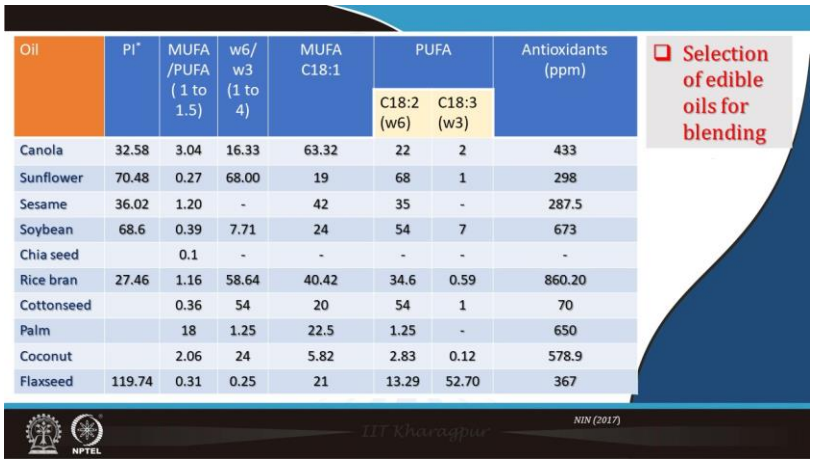
Blending non-conventional or conventional vegetable oils to obtain a synergistic oil mixture is commonly practiced in the food industry to enhance the oil's nutritional characteristics and stability at an affordable price. Blending is the simplest method of mixing diverse fats and oils with unique physical and compound attributes. Mixing vegetable fats or oils with various properties is one of the least complex techniques to make new explicit items and wanted nutritional and oxidative properties. The third

category of the oil by definition is the edible cooking oil that satisfies the fatty acid composition recommended by WHO to prevent various diseases like diabetes, chronic heart diseases, obesity, etc. So, a balanced fatty acid composition can be achieved by adopting vegetable oil blending practice which will eliminate the need for hydrogenation or even interesterification of the oils.



So, formulation for blending. In this figure, I have given you a fatty acid composition of some of the common vegetable oils like canola oil, flax seeds, and flower oil, etc. The composition of saturated fatty acid, monounsaturated fatty acids, omega-6, and omega-3. You can see here, canola oil contains higher amount of monounsaturated fatty acid, less proportion of saturated fatty acid. It also has a good amount of omega-6 fatty acid. The sunflower oil on the other hand, it has higher amount of omega-6 fatty acid, but less saturated and monounsaturated fatty acid. This coconut oil, if you see here, contains a higher amount of saturated fatty acid and very negligible or less amount of monounsaturated fatty acid as polyunsaturated fatty acids.

So, here as I told you for formulation of oil for blending, according to WHO, the total fat intake should be about 30 to 35 percent of the total energy, saturated fatty acid less than 10 percent, monounsaturated fatty acid between 10 to 14 percent, and polyunsaturated fatty acid between 6 to 11 percent. However, to maintain good health, omega-6 and omega-3 must vary between 1.1 to 1 is to 1 to 4 is to 1. So, a balance ratio of MUFA, PUFA as well as essential fatty acids like omega-6 and omega-3 is essential to maintain a modulated lipid profile in the human body. So, oil blending could also provide oils with balanced fatty acid profiles and a greater stability with improved content of antioxidants and bioactive compound.



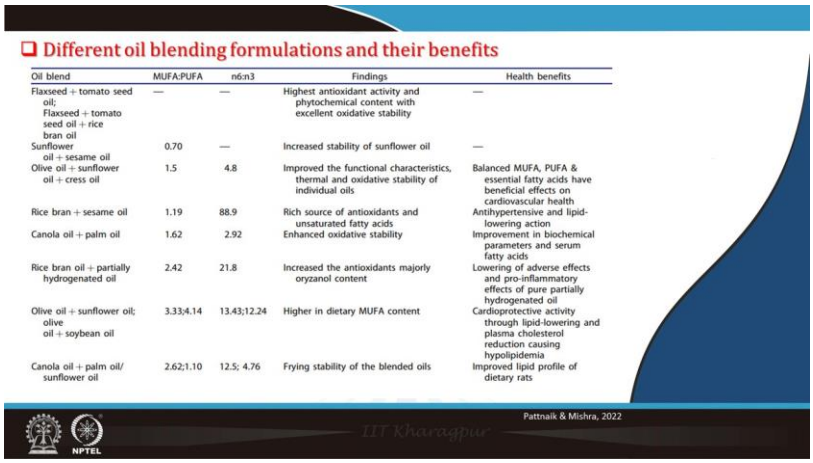
Oil	PI*	MUFA /PUFA (1 to 1.5)	w6/ w3 (1 to 4)	MUFA C18:1	PUFA		Antioxidants (ppm)
					C18:2 (w6)	C18:3 (w3)	
Canola	32.58	3.04	16.33	63.32	22	2	433
Sunflower	70.48	0.27	68.00	19	68	1	298
Sesame	36.02	1.20	-	42	35	-	287.5
Soybean	68.6	0.39	7.71	24	54	7	673
Chia seed		0.1	-	-	-	-	-
Rice bran	27.46	1.16	58.64	40.42	34.6	0.59	860.20
Cottonseed		0.36	54	20	54	1	70
Palm		18	1.25	22.5	1.25	-	650
Coconut		2.06	24	5.82	2.83	0.12	578.9
Flaxseed	119.74	0.31	0.25	21	13.29	52.70	367

So, here you can see, how to select the vegetable oil for blending. The various edible oils, their content of monounsaturated fatty acid, content of polyunsaturated fatty acids, ratio of MUFA, PUFA in a particular oil, and what is the content ratio of omega-6 and omega-3 in the oil and even the what is its antioxidant component. This data is available and if it is not available, one can analyze it like this and NIN 2017 data is there.

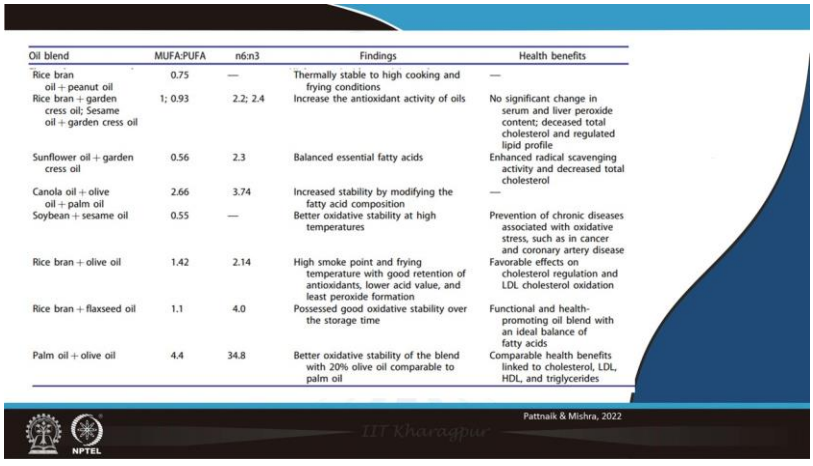
Common oils like canola, sunflower, sesame oils. Sunflower oil, it has a MUFA-PUFA ratio of around 0.27 whereas, it has omega-6 to omega-3 ratio of 68 percent. It has a MUFA (C18:1) 19 percent, and PUFA (C18:2) 68 percent, (C18:3) 1 percent and antioxidant content is 298 ppm. Similarly, the coconut oil, you can see coconut oil, it has a MUFA-PUFA ratio of about 2.06, it has omega-6 and omega-3 ratio of 24. MUFA content is 5.82 percent and PUFA content is 2.83, but you see, it has a very high antioxidant (ppm) like 578.9 ppm. Similarly, flaxseed, MUFA-PUFA ratio is less 0.31, omega-6 to omega-3 ratio 0.25, but MUFA that (C18:1), it has a 21 and PUFA (C18:2) 13.29 and (C18:3), it has more poly as 53 and antioxidant is 367 ppm.

So, once you know this information that is the different oils, what is their fatty acid profile, what is their omega content, what is the antioxidant value, etc., and you know that what you want, in which range, PUFA-MUFA ratio, omega-6 to omega-3 ratio and the antioxidant.

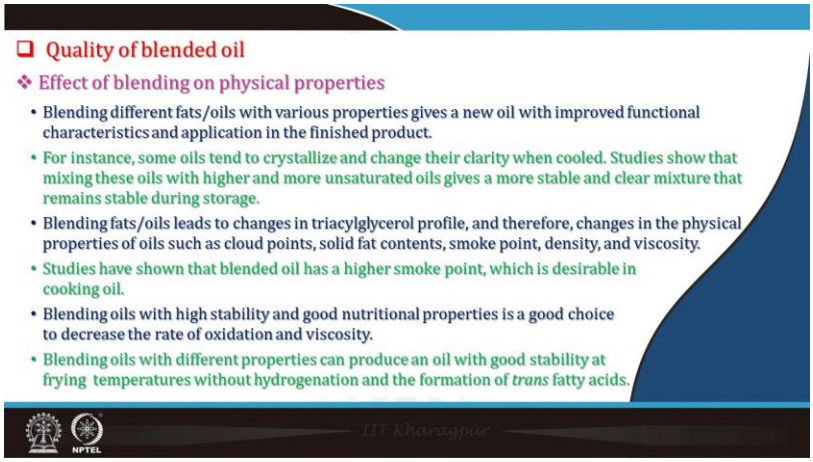
So, there are various mathematical tools like linear programming and such other programs one can use and find out and see that, which one is the best combination that gives the desired proportion of omega-6 to omega-3, and MUFA-PUFA ratio, and maximum amount of antioxidants. But there are also certain regulations by the government and that is, mixing of particular component, more than a particular quantity content is not permitted. So, that also should be taken into consideration while formulating the blend.



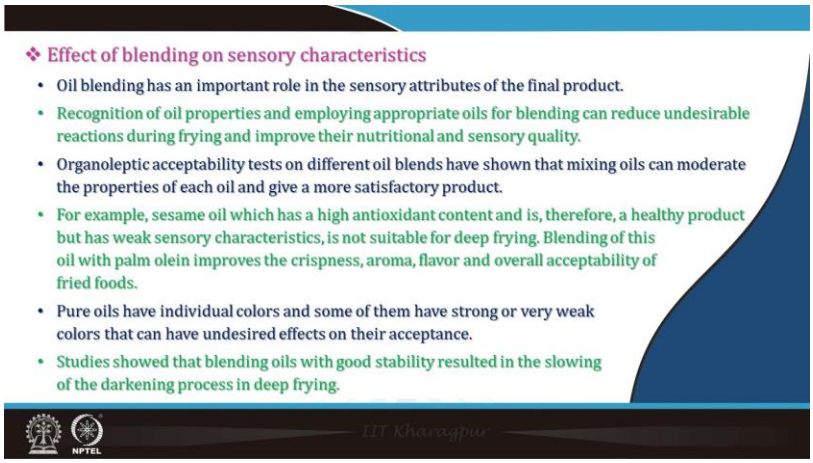
So, here different oil blend formulations and their health benefits are given like flaxseed and tomato seeds, if you get there is the highest antioxidant capacity and phytochemicals. If you check the olive oil + sunflower oil + cress oil, it has a MUFA-PUFA ratio, you will get 1.5, omega-6:omega-3, it will get 4.8, and it improved the functional characteristics, thermal and oxidative stability of individual oils, and its health benefits are because you are getting a balanced MUFA-PUFA and essential fatty acids, they have beneficial effect on cardiovascular health. There is the rice bran oil and partially hydrogenated oil like you get here MUFA-PUFA 2.42, and omega-6:omega-3 is 21.8. It has increased the antioxidant majorly oryzanol content. It has oryzanol as the antioxidant. So, health benefits are lowering of adverse effects and pro-inflammatory effects of partially pure hydrogenated oils etc. So, even olive oil plus sunflower oil plus cress oil or rice bran oil and sesame oil, if you see rice bran oil and sesame oil blend, you will get MUFA-PUFA 1.1 and you can get omega-6:omega-3 as high as 88.9. So, it gives a finding and is a source of antioxidant and unsaturated fatty acids, but it gives antihypertensive and lipid lowering action. Canola oil and palm oil accordingly MUFA-PUFA 1.62 and omega-6:omega-3 you can get 2.92 and it gives an enhanced oxidative stability.



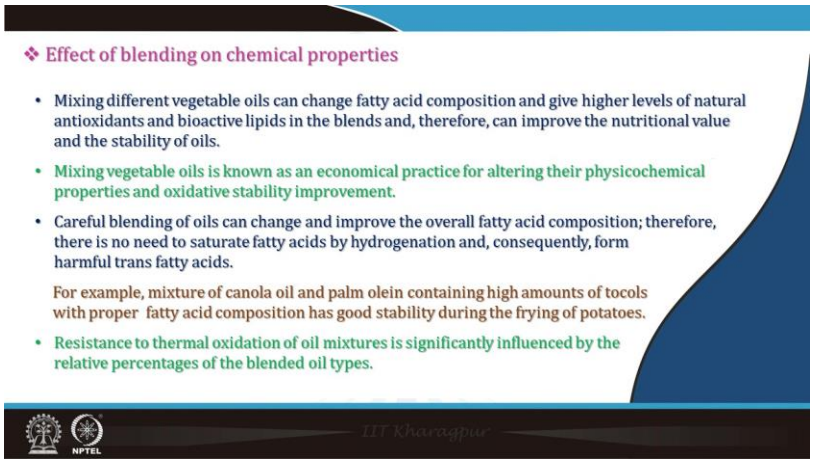
Similarly, sunflower oil and garden cress oil, one can get MUFA-PUFA 0.56 and omega-6:omega-3 2.3 and it gives a balanced essential fatty acids in the proper proportion and enhanced radical scavenging activity and decreased total cholesterol content. Similarly, rice bran oil and olive oil, if you mix, you can get 1.42 as a MUFA-PUFA ratio and omega-6:omega-3 as 2.14. It gives high smoke point and frying temperature with good retention of antioxidants, lower acid value, and least peroxide formation. So, it has favorable effect on cholesterol regulation and LDL cholesterol oxidation. Similarly, rice bran oil, flaxseed oil, palm oil, and olive oil can be blend. Palm oil and olive oil, it is made, one can get more MUFA-PUFA like 4.4 with the ratio and omega-6: omega-3 ratio can get 34.8. So, it has a better oxidative stability of the blend with 20 percent olive oil comparable to the palm oil. It has comparable health benefits linked to cholesterol, LDL, HDL, and triglycerides etc. So, in this way these are from the literature that is various oil blend you can find out keeping the characteristic property into it and one can mix in the proper proportion to get the desired benefits.



Then the effect on quality that you have to see is very important thing that the quality of the blended oil it should be maintained. The effect of blending on physical properties. Blending different fats and oils with various properties gives a new oil with improved functional characteristics and application in the finished product. For instance, some oils tend to crystallize and change their clarity when they are cooled. Studies show that mixing these oils with higher and more unsaturated oils gives a more stable and clear mixture that remains stable during storage. Similarly, blending fats and oils leads to changes in triacylglycerol profile, and therefore, changes in the physical properties of the oil such as cloud points, solid fat content, smoke point, density, viscosity and so on. Studies has shown that the blended oil has a higher smoke point, which is desirable in cooking process. Blending oils with high stability and a good nutritional property is a good choice to decrease the rate of oxidation and viscosity. Blending oils with different properties can produce an oil with good stability at frying temperature without hydrogenation and the formation of trans fatty acids can be avoided here.

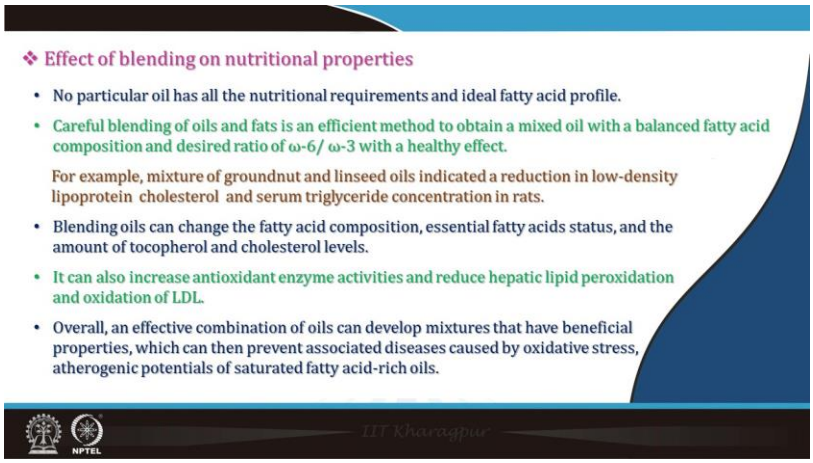


Effect of blending on sensory characteristics is a very important property. Oil blending has an important role in the sensory attributes of the final product particularly the product in which this oil is used for frying purposes, cooking purposes and so on. So, recognition of oil properties and employing appropriate oils for blending can reduce undesirable reactions during frying and improve their nutritional and sensory quality. Organoleptic acceptability tests on different oil blends have shown that mixing oil can moderate the properties of each oil and give a more satisfactory product. For example, sesame oil which has a high antioxidant content and is, therefore, a healthy product, but has weak sensory characteristics. It is not suitable for deep frying. Blending of this sesame oil with palm oil improves the crispiness, aroma, flavor, and overall acceptability of the fried foods. Pure oils have individual colours. Some of them have strong and some have very weak colour that can have undesired effect on their acceptance. Studies showed that blending oils with good stability resulted in slowing the darkening process in deep-fry.

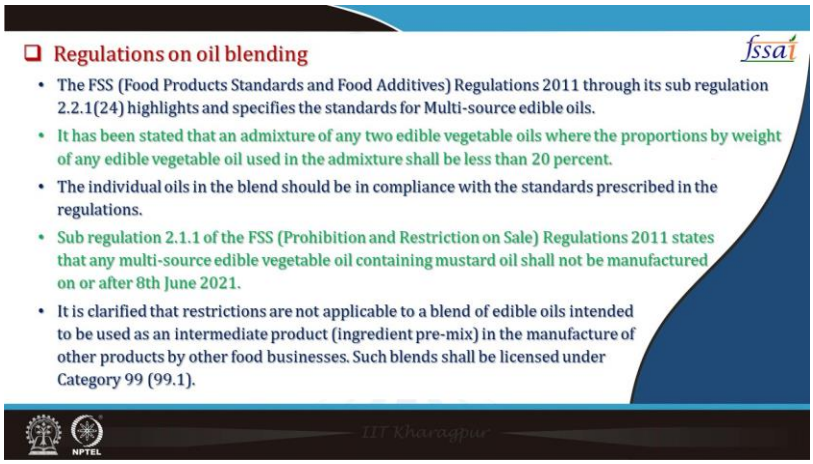


Then, effect of blending on chemical properties of the oil as well as the product. Mixing different vegetable oils can change fatty acid composition and give higher levels of natural antioxidants and bioactive lipids in the blends. Therefore, it can improve the nutritional value and stability of oil. Mixing vegetable oils is known as an economical practice for altering their physicochemical properties and oxidative stability

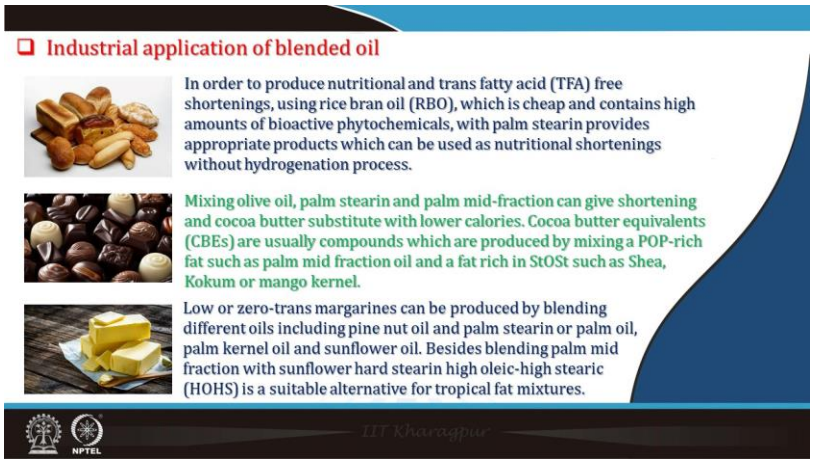
improvement. Careful blending of oils can change and improve the overall fatty acid consumption; therefore, there is no need to saturate fatty acids by hydrogenation and consequently form harmful trans fatty acids. For example, mixture of canola oil and palm oil containing high amounts of tocols with proper fatty acid composition has good stability during the frying of potatoes. Resistance to thermal oxidation of oil mixtures is significantly influenced by the relative percentage of the blended oil type.



Effect of blending on nutritional properties of the oil. No oil has all nutritional requirements and ideal fatty acid profile. Careful blending of fats is an efficient method to obtain a mixture of oil with a balanced fatty acid composition and desired ratio of omega-6 and omega-3 with a healthy effect. For example, mixing groundnut and linseed oils indicated a reduction in low viscosity, lipoprotein cholesterol and serum triglyceride concentration in rats. Blending oils can change the fatty acid composition, essential fatty acid status, and the amount of tocopherol and cholesterol levels. It can also increase the antioxidant enzyme activity and reduce hepatic lipid peroxidation and oxidation of LDL. Overall, an effective combination of oils can develop mixtures that have beneficial properties, which can help prevent associated diseases caused by oxidative stress, atherogenic potentials of saturated fatty acids rich oils.

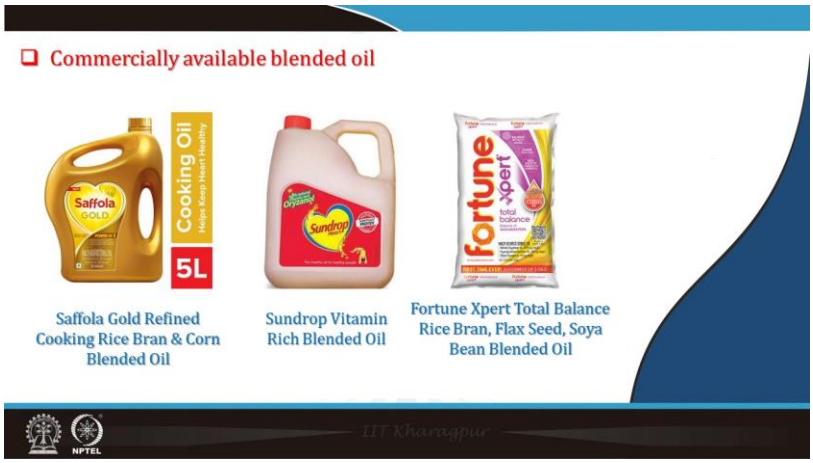


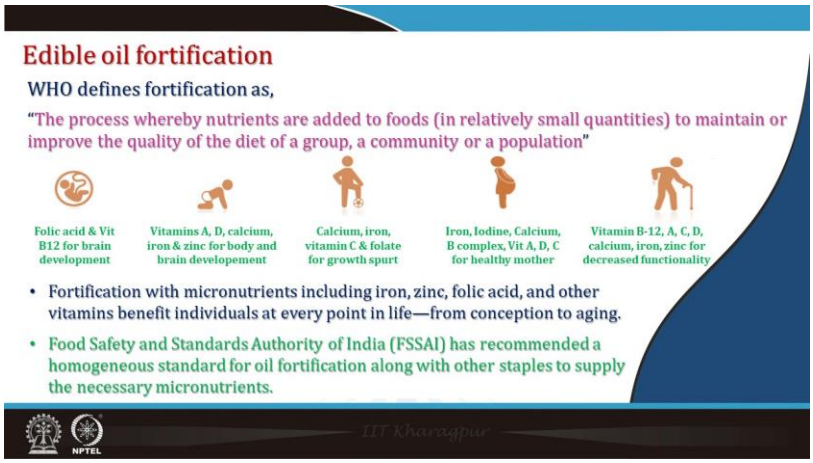
Let's talk about regulations on oil blending. The FSS that is Food Products Standards and Food Additive Regulation 2011 through its sub regulation 2.2.1 of 24 highlights and specifics the standards of multi-source edible oils. It has been stated that an admixture of any two edible oils where the proportion by weight of any edible oil used in the admixture shall be less than 20 percent that is a particular oil. If you are mixing oil A into oil B, then proportion should not be less than 20 percent. The individual oils in the blend should be in compliance with the standards prescribed in the regulations. Sub regulations 2.1.1 of the FSS (Prohibition and Restriction on Sale) Regulations 2011 states that any multi-source edible vegetable oil containing mustard oil should not be manufactured on or after 2021. After that day, blending of mustard oil is not permitted. It is clarified that restrictions are not applicable to a blend of edible oil intended to be used as an intermediate product that is ingredient premix in the manufacture of other products by other food business. Such blends shall be licensed under category 99, rule 99.1.



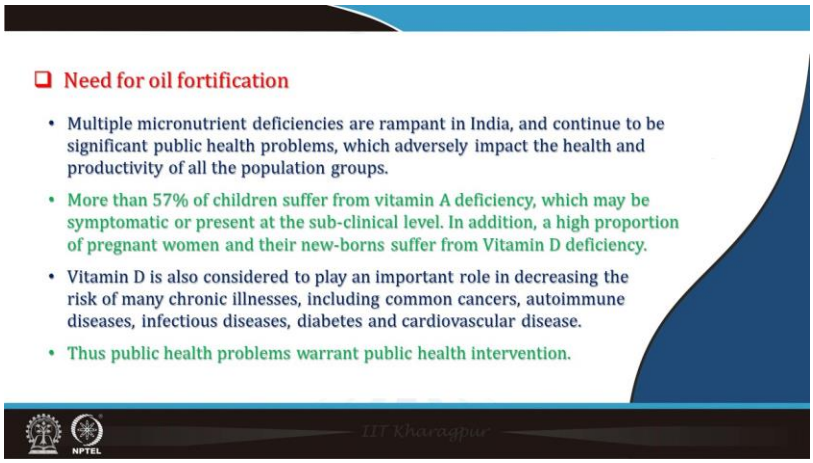
Industrial applications of blended oil. In order to produce nutritional and trans fatty acid free shortening, using rice bran oil, which is cheap and contains high amount of bioactive phytochemicals, with palm stearin provides appropriate products which can be used as a nutritional shortenings without hydrogenation process. Mixing olive oil, palm stearin, and palm mid-fraction can give shortening and cocoa butter substitute with lower calories. Cocoa butter equivalents are usually compounds which are produced by mixing a POP-rich fat such as palm kernel fraction, palm mid fraction oil and fat rich in StoSt, such as Shea, Kokum or mango kernel. Low or zero-trans margarine can be produced by blending different oils including pine nut oil and palm stearin or palm oil, palm kernel oil, and sunflower oil. Besides blending palm mid fraction with sunflower hard stearin, high oleic-high stearic is a suitable alternative for tropical fat mixtures.

The commercially available blended oil in the market are Saffola gold refined cooking rice bran and corn blended oils, Sundrop vitamin rich blended oil, Fortune xpert total balance rice bran, flax seed, soya bean blended oil and so on.

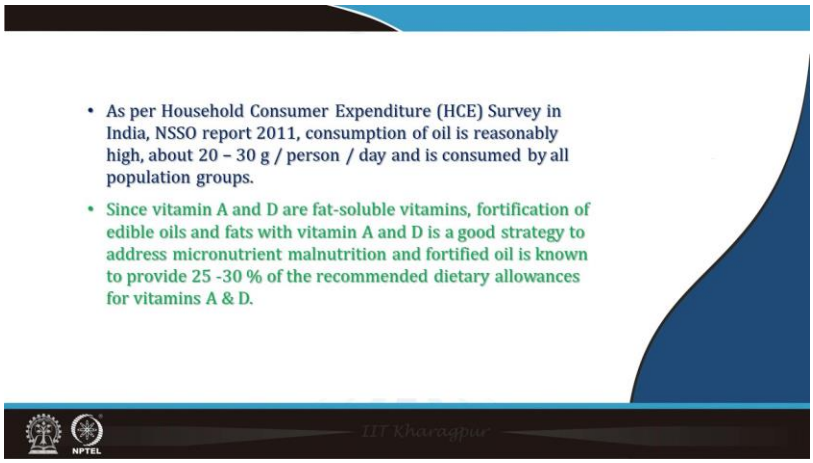




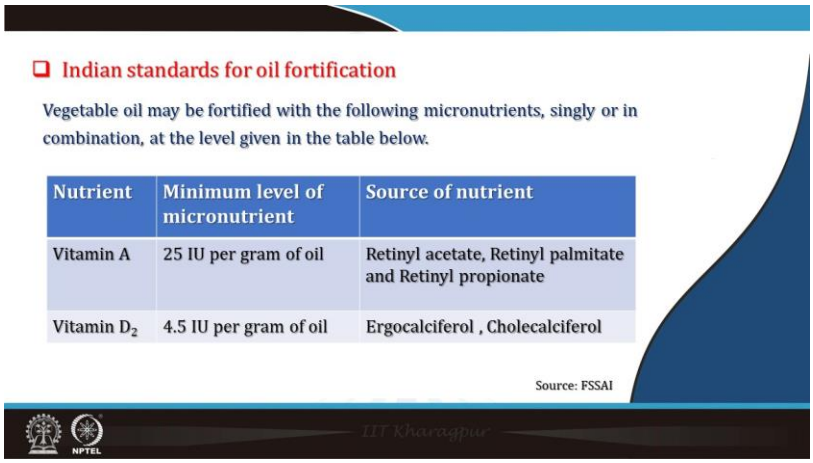
Now, let's talk about edible oil fortification. World Health Organization defines fortification as "the process whereby nutrients are added to food (in relatively small quantities) to maintain or improve the quality of the diet in a group, a community or a population". This fortification with micronutrients including iron, zinc, folic acid, and other vitamins benefit individuals at early point in life that is from conception to aging like folic acid, vitamin B_{12} is required for brain development, vitamin A, D, calcium, iron and zinc are required for body and brain development, calcium, iron, vitamin C, folate are required for growth, iodine, iron, calcium, B complex, vitamin A, D, C they are needed by a healthy matter, vitamin B_{12}, A, C, D, calcium, iron, zinc for decreased functionality or for aging during old age. So, these are the various vitamins and minerals micronutrients required. Food Safety and Standard Authority of India has recommended a homogeneous standard for oil fortification along with other staples to supply the necessary micronutrients because the micronutrient deficiency is one major problem in our country. So, to tackle this problem, certain micronutrients are recommended to be mixed in the oil, that is fortified oil, then fortified oil should be set in the market.



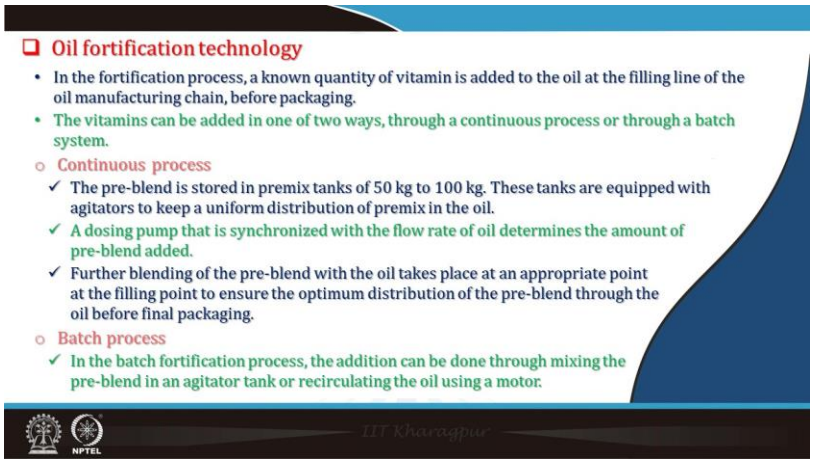
These multiple micronutrients, this deficiency is rampant. So, more than 57 percent of children suffer from vitamin A deficiency, which may be symptomatic. Vitamin D is also considered to play an important role in decreasing the risk of many chronic diseases, public health problems warrant, public health interventions etc.



So, as per the Household Consumer Expenditure Survey in India, NSSO report 2011, consumption of oil is reasonably high, about 20 to 30 gram per person per day and is consumed by all population groups. Since vitamin A and D are fat-soluble vitamins, fortification of edible oil with vitamin A and D is a good strategy to address micronutrient malnutrition and fortified oil is known to provide 25 to 30 percent of the recommended dietary allowances for vitamin A and vitamin D.



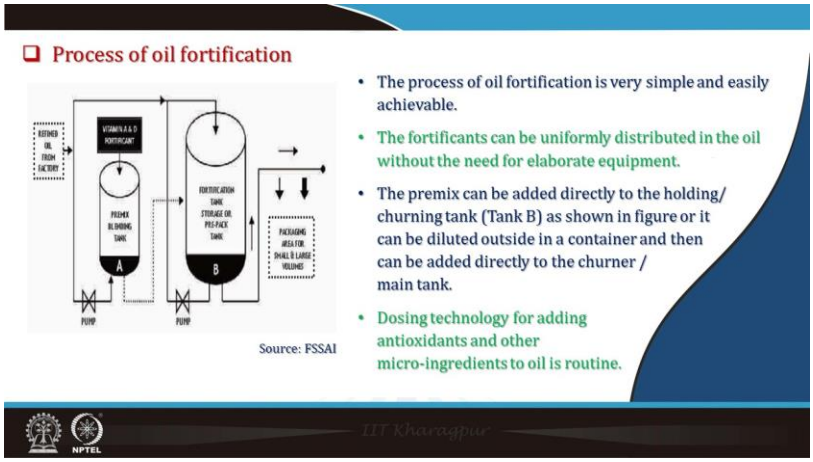
As per the Indian standard FSSAI, the oil may be fortified with the following micronutrients like vitamin A in the level 25 international unit per gram of the oil and the source of the vitamin A used may be retinyl acetate, retinyl palmitate and retinyl propionate. Vitamin D_2 should be fortified to the level of 4.5 international unit per gram of oil and the form is ergocalciferol and cholecalciferol.



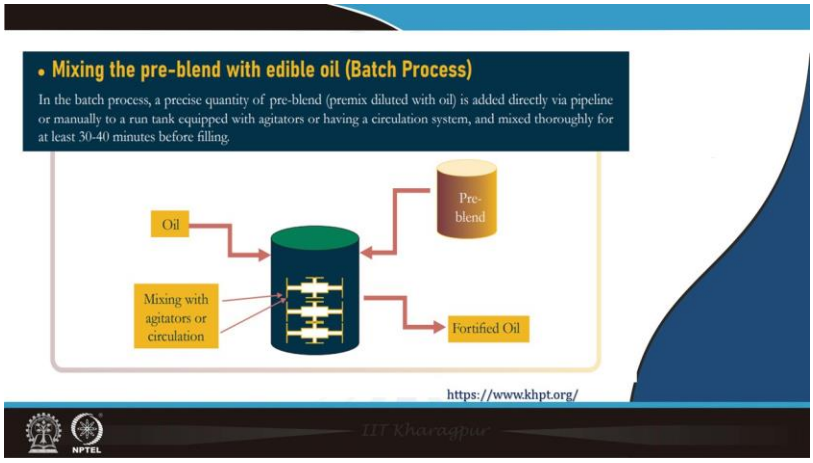
As far as the technology of oil fortification is concerned, that is, in the fortification process a known quantity of vitamin, level is already recommended by FSSAI, you know the oil quantities accordingly there is known quantity of vitamin is taken and it is added to the oil directly in the filling line in the packaging line of the oil manufacturing chain that just before packing these are blended/mixed with the oil. The vitamins can be added in one or one of the two ways through a continuous process or through a batch process.

In the continuous process, the pre-blend is stored in a premixed tanks of 50 to 100 kg capacity and these tanks are equipped with agitators to keep a uniform distribution of premix in the oil. A dosing pump that is synchronized with the flow rate of oil determines the amount of pre-blend added. Further blending of the pre-blend with the oil takes place at an appropriate point at the filling point to ensure the optimum distribution of the pre-blend through the oil before final packaging. In the batch process, the addition can be

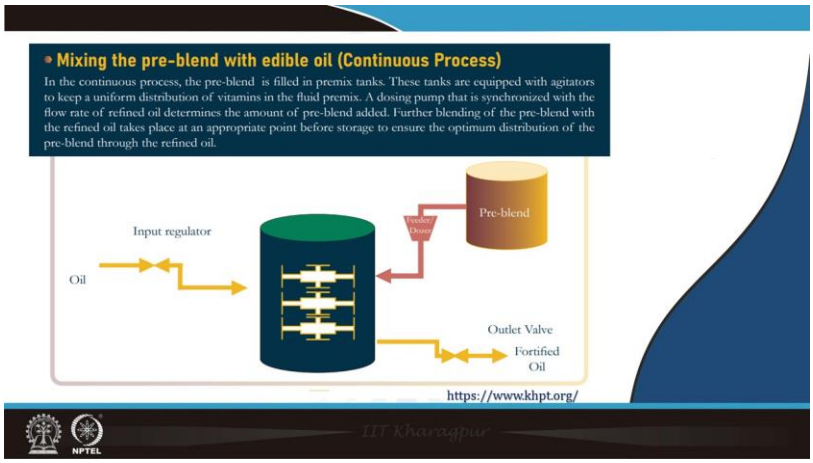
done through mixing the pre-blend in an agitator tank or recirculating the oil using a motor.



So, here the process of oil fortification is very simple and is easily achievable. The fortificants can be uniformly distributed in the oil without the need of elaborate equipment etc. The premix can be added directly to the holding/ churning tank that is here. The holding tank (B) the premixed can be as shown in the figure or it can be diluted outside in a container and then it can be added directly into the churner or the main tank. Dosing technology for adding antioxidant and other micro-ingredients to oil is a routine process. Now in India, in fact, there are many companies they are adding these micronutrients and selling it to the market the micronutrient and fortified oil.

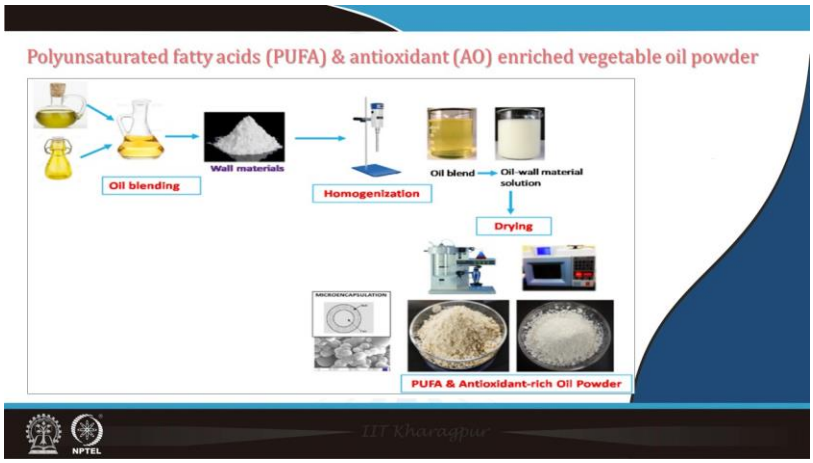


Here, mixing the pre-blend with edible oil batch process. It is a mixture of the oil and the pre-blend. The mixing with the agitator and circulation and you get the fortified oil that is in the batch process, a precise quantity of the pre-blend (premixed diluted with oil) is added directly by a pipeline or manually to a run tank equipped with agitators or having a circulation system, and it is mixed thoroughly for at least about 30 to 40 minutes before filling and then fortified oil is sent to the filling line.

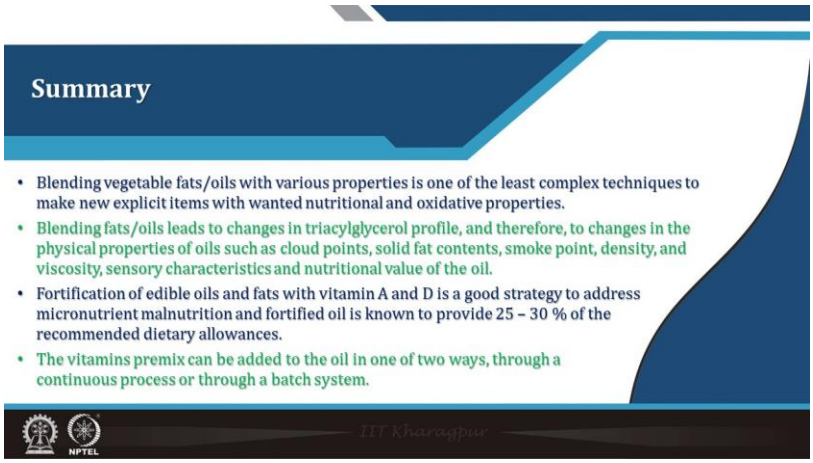


Mixing the pre-blend with edible oil in the continuous process. In the continuous process, the pre-blend is filled in premixed tanks. These tanks are equipped with agitators to keep uniform distribution of vitamins in the fluid premix. A dosing pump that is synchronized with the flow rate of the refined oil determines the amount of the pre-blend added. Further blending of the pre-blend with the refined oil takes place at an appropriate point before storage to ensure the optimum distribution of the pre-blend oil through the refined oil. So, here oil is going in the input regulator and the pre-blend that is from the blower and it is mixing and the process is continuous.

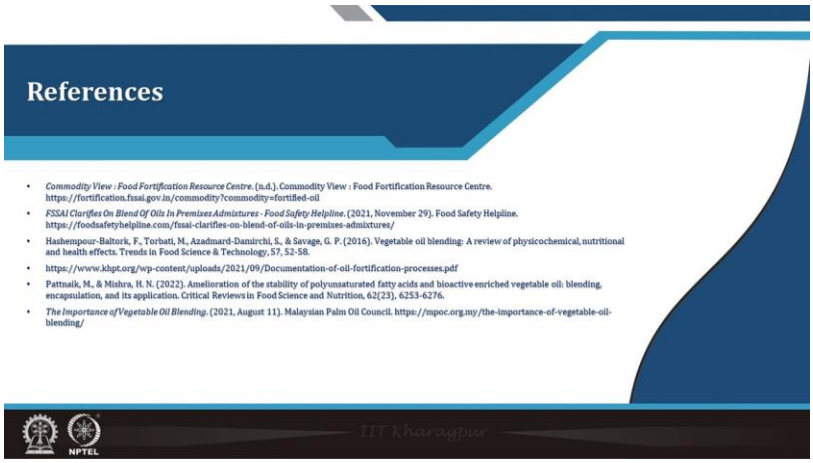
The commercially available fortified oil includes Dhara, V Brand, Surya, Anupam, Patanjali, Gold Winner, ADM, Cargill etc. These are all the companies in India which fortify the oil before sending it to the market.



So, polyunsaturated fatty acid (PUFA) and this antioxidant vegetable oil powder we did in our lab and that was in earlier lecture I have elaborated on this, that is, we had a blended oil as per the American health directive requirement that blended oil with PUFA MUFA proportion and this was converted into emulsion and we made it into a stable powder and this powder is a rich source of micronutrients that is in the solid form. It has potential, we have used this in bakery products, muffins as well as in ice cream and frozen desserts is used and it gives a very good quality polyunsaturated fats with stability.



With this, I will summarize this lecture that is blending vegetable oil or fats with various properties is one of the least complex techniques to make new explicit items with wanted nutritional and oxidative properties. Blending fats and oils leads to changes in triacylglycerol profile, and therefore, to change in the physical properties of the oil such as cloud point, solid fat content, smoke point, density, viscosity, sensory characteristics of the nutritional value of the oil etc. The fortification of vegetable oils and fats with vitamin A and D is a good strategy to address micronutrient malnutrition and fortified oil is used to provide 25 to 30 percent of the recommended dietary allowances. The vitamin mix can be added in the oil in one of the two ways that is continuous process or through a batch process just before the packing of the oil packaging of the oil.



So, with this I end my lecture with this references.

Thank you very much for your patience hearing. Thank you.