Food Oils and Fats: Chemistry & Technology

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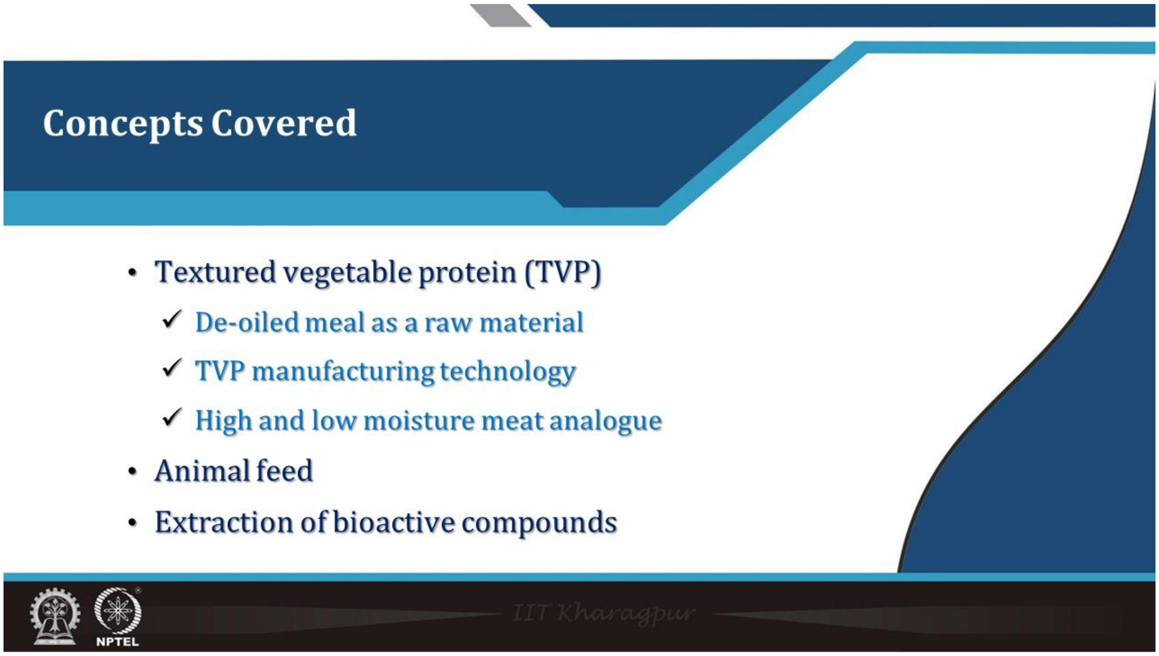
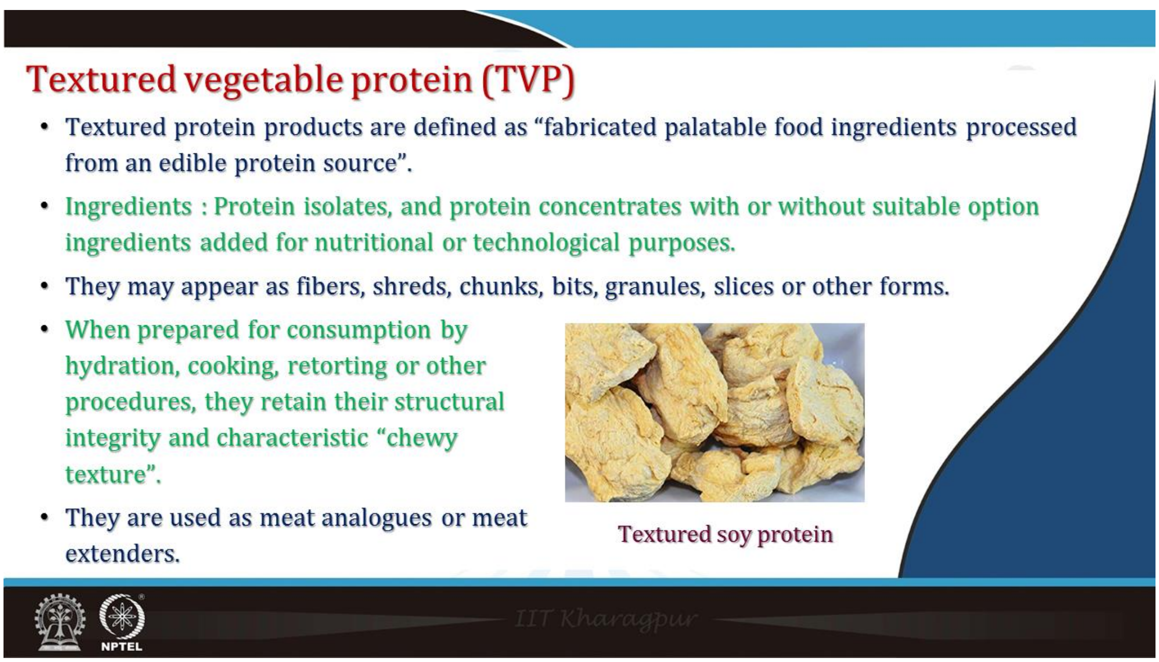
Module 11: By-products Utilization & Valorization of Oil Milling Industry Waste

Lecture 53 : By-products Utilization – Part II

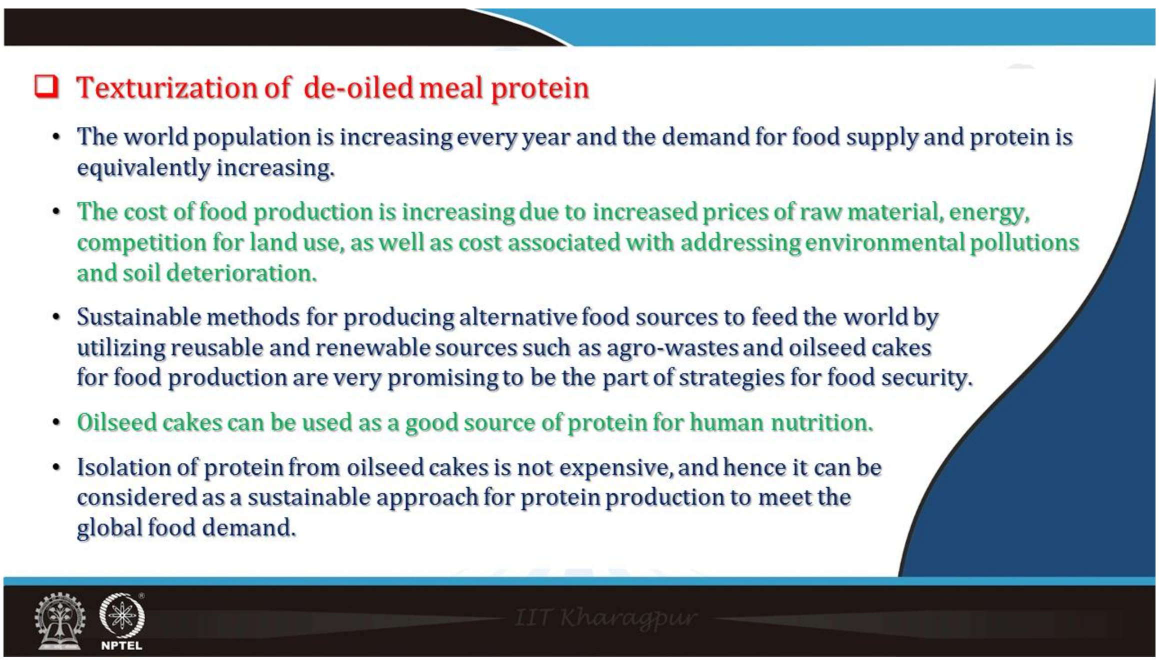
Hello everyone, Namaskar. Now, in this 53rd lecture, we will also take up one or two byproduct utilization. In the earlier class, we saw, that is, how protein powders can be made.



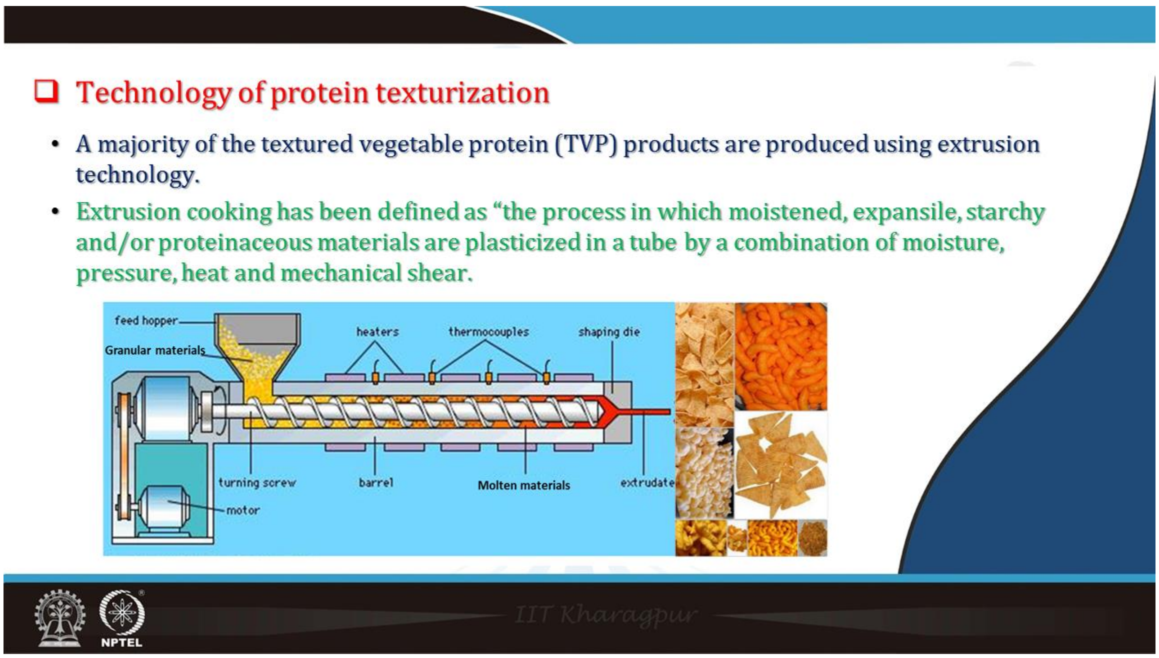
Then, let us discuss how these protein powders, that is, the oilseed floors can be converted into value added product, that is, for texturization of protein textured vegetable protein.



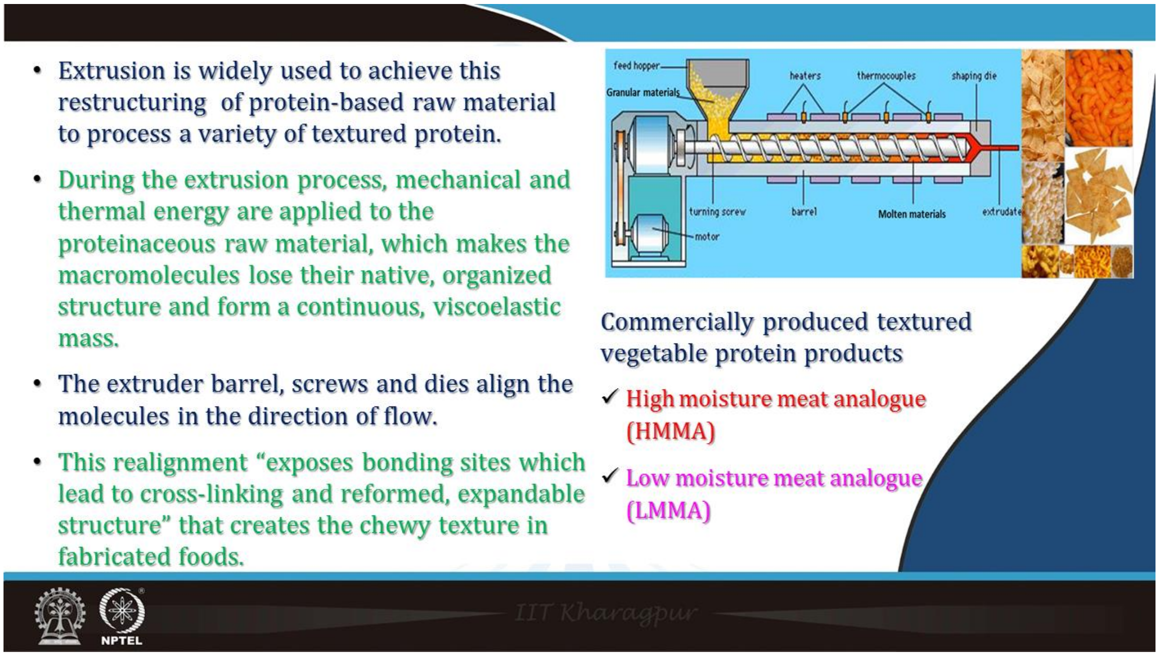
So, here, that is, for preparation of textured vegetable protein, de-oiled meal as a raw material. We will see then TVP manufacturing process manufacturing technology. We will study that high and low moisture meat analogues because now there is a lot of emphasis on being made on the texturization of vegetable protein, animal protein, and conversion, its in textured protein products to be used as a meat analogue or meat extenders, etcetera. Then, even they can be used as animal feed, and then this, from de-oiled flours, they contain lot of bioactives. They can be used for extraction of bioactive compounds. Let us first talk about texturization of vegetable protein, that is, which is, popularly known as TVP. These textured protein, vegetable protein or protein products they are defined as fabricated palatable food ingredients processed from an edible protein source. And the ingredients, normally, it can be taken protein isolate, protein concentrate with or without suitable optional ingredients added for the nutritional and technological purposes. They may appear as fibres, shreds, chunks or bits, granules, slices or in other forms. Even they can resemble, that is, fresh animal meat or flesh. When prepared for consumption by hydration, cooking, retorting or other processes, they retain their structural integrity and characteristic chewy texture and they resemble the normal meat. They are used as meat analogue or meat extenders.



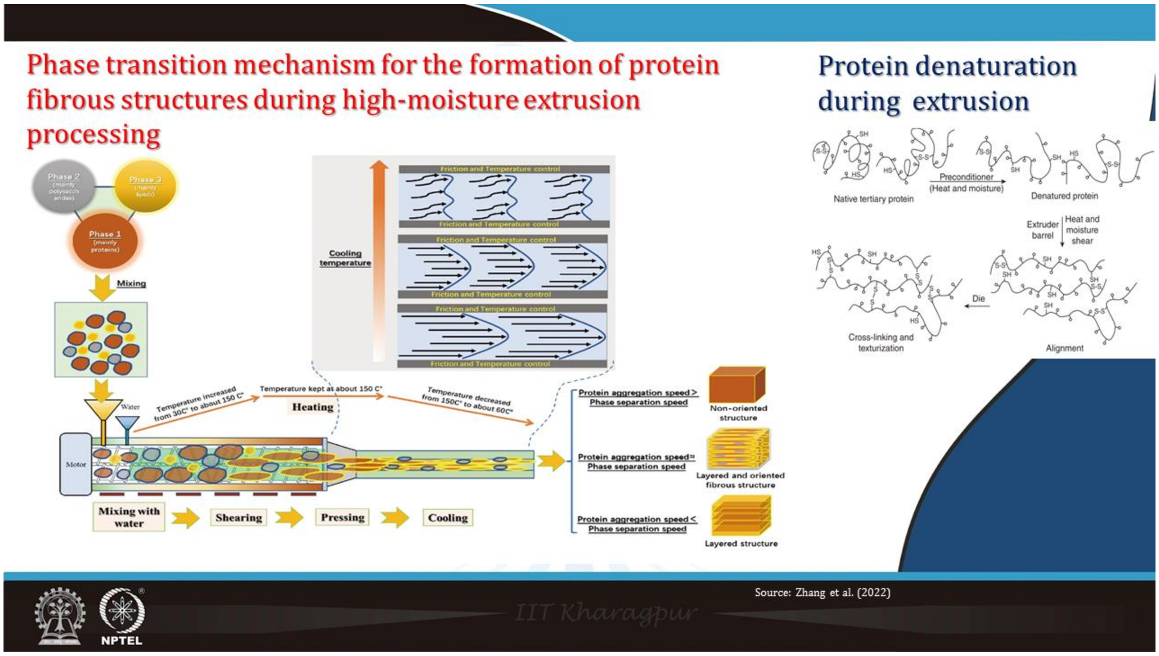
So, texturization of de-oiled meal, that is, even though you know that world population is increasing every year, and the demand for food supply and protein is equivalently increasing. So, the cost of food production is increasing due to increased prices of raw materials, energy, competition for land use, as well as the cost associated with addressing environmental pollution, soil deterioration, etcetera. So, sustainable method for producing alternative food sources to feed the world by utilizing reusable and renewable sources such as agro wastes, oil seed cakes, etcetera they offer promise. So, oilseed cakes can be used as a good source of protein for human utilization. We have studied in the earlier class. So, isolation of protein from cake is not expensive and hence it can be considered as a sustainable approach for protein production to meet the global food demand.



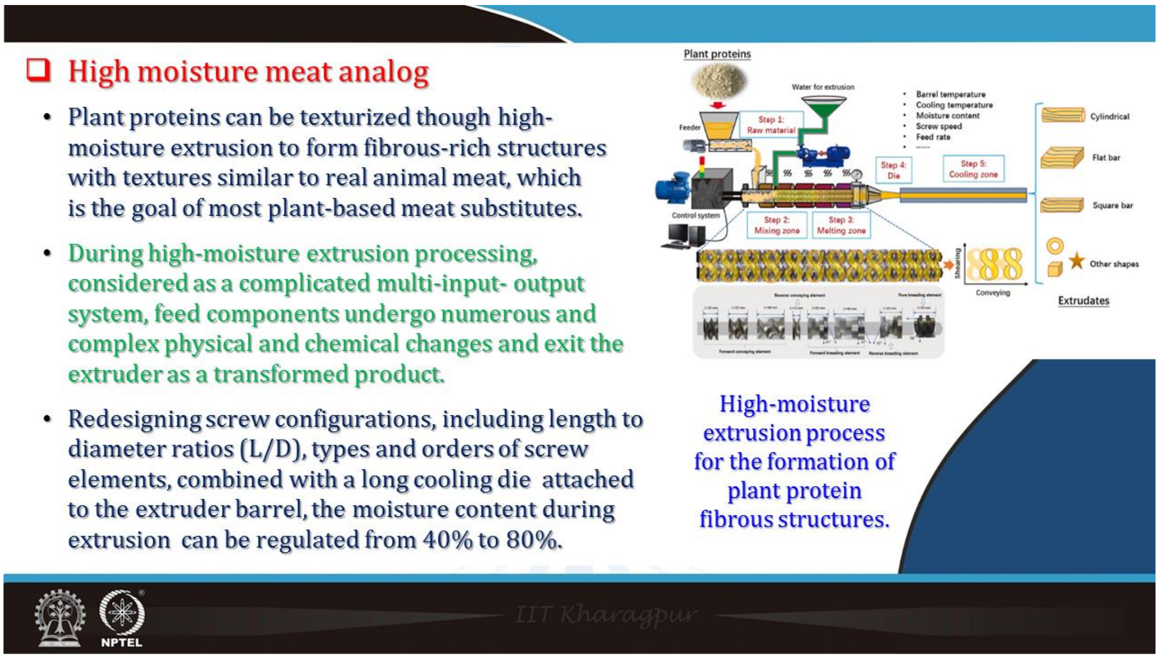
So, technology of protein texturization include, that is, majority of the textured vegetable protein products available in the markets. They are produced using a technology called extrusion. That is, extrusion cooking has been defined as the process in which the raw materials are there is fibres, flours, etcetera. They are moistened, expansile, starchy and other proteinaceous materials. They are, there is the, plasticized in a tube by a combination of moisture, pressure, heat and mechanical shear. You can see here, in the extruder, it contains, that is, a screw, the material is coming. That. There are different screw barrel, that is, heaters are provided, thermocouples are there, it is meaning die. Then, the material, when comes to the extruder, in it becomes almost thermoplastic melt, and then a die can be inculcated, it is forced through a die, and various products of various shapes, sizes, etcetera are obtained.



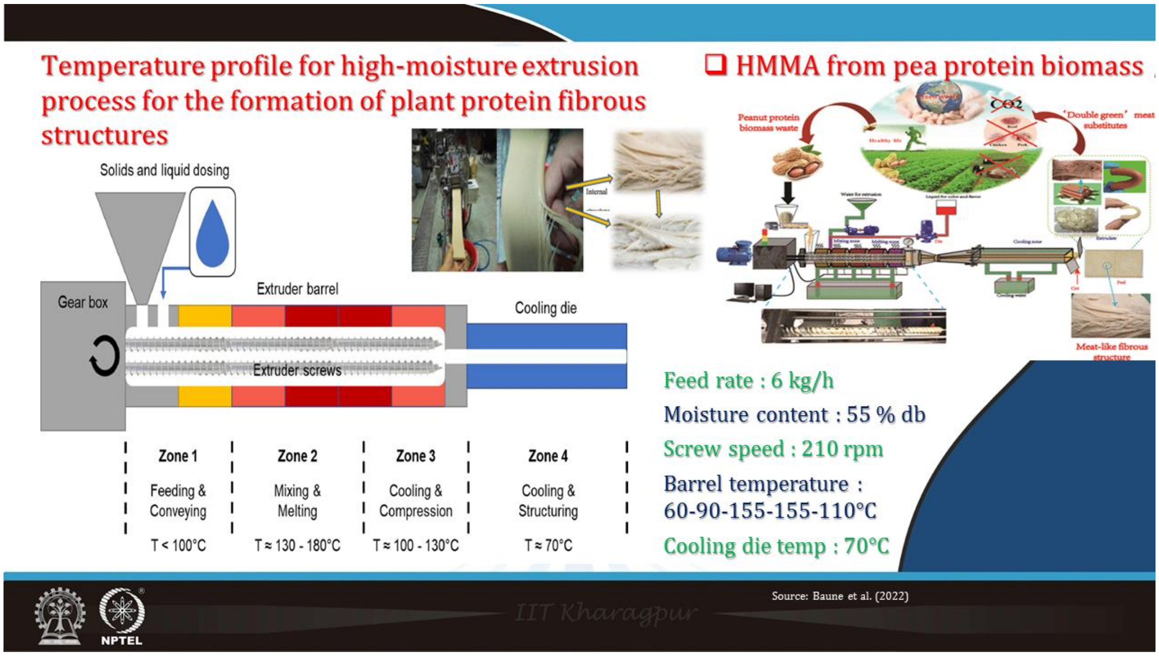
So, that is the extrusion technology. So, extrusion is widely used to achieve this restructuring of protein based raw material to process a variety of textured protein. During the extrusion process, mechanical and thermal energy are applied to protein material, which makes the macromolecule lose their native organized structure and form a continuous viscoelastic mass. The extruder barrel screws and dies, they align the molecules and then in the direction of the flow. This realignment exposes bonding sites, which lead to cross linking and reformed expandable structure that creates a chewy texture in the fabricated food. That is, how, that is whole thing, the philosophy behind this extrusion and its conversion. So, commercially using specific dies and specific processing conditions, these materials are converted into two types of meat analogues, that is, high moisture meat analogue or low moisture meat analogue, popular HMMA or LMMA.



So, what happen, what we discussed, that is, you see the phase transition mechanism for the formulation of protein fibrous structure during high moisture extrusion processing. And you can see, basically here, the material, when it may be that is the protein molecule, lipid molecule or carbohydrate molecules, that is, the yellow portion that is the deep red portion is mainly the protein, yellow is in the oil and other is the carbs. So, they are mixed together and then when you put to the extruder barrel then it is mixed, water is added, appropriate quantity mixed with water, then it is passed through the air, shearing action is there, pressing is there, cooling is there, and in the various, when the cooling die, that is, high moisture for high moisture meat analogue, the long cooling die is there, and during actually this cooling process, in the cooling die, when the material goes from here, that is, the temperature may be in initially, may be around 30 to 150, then in heating about it is about 100 degree Celsius, and then finally, in the cooling section it comes from 150 to about 100 to about 60 degree Celsius temperature and the various transformation takes place. There is denaturation of the protein, you can see here the native protein; how it is converted into denatured protein, and then in the denatured protein, then heat and moisture and shear inside the extruder barrel, they act and they cause the realignment of these proteins, and then it is forced through the die, then there is a cross linking and texturization. So, you get a non-oriented structure or layered and oriented fibrous structure or layered structure depending upon that: when the protein aligned speed is more than the phase separation speed you get basically a non-oriented structure. When the protein alignment speed is equal to the phase separation speed, it gives a layered and oriented fibrous structure. When protein alignment a protein aggregation, that is, aggregation speed is less than the phase separation speed, you get a layered structure. So, the conditions inside the extruder and in the cooling die can be maintained accordingly to get the desired structure, ok.



So, the high moisture extrusion process, that is, plant proteins are texturized through a high moisture extrusion process to make, to form fibrous rich structures with texture similar to real animal meat, which is the goal of the most plant based meat substitute. During high moisture extrusion processing, which are considered as a complicated multi-input output system, feed components undergo numerous and complex physical and chemical changes and exit the extruder as a transformed product. So, redesigning screw configurations, including length to diameter ratios, types and orders of the screw elements combined with a long cooling die attached to the extruder barrel, the high moisture during the extrusion can be ranged from up to as high as 40 to 80 percent, ok. And you get different product like a step 1, then step 2 mixing zone, melting zone, then die heat comes cooling zone and finally, you get the different products.



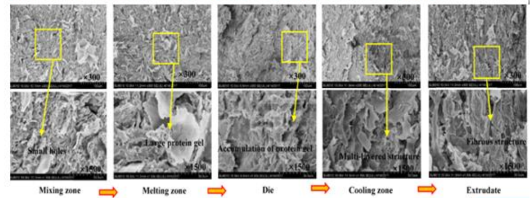
So, here you see the temperature profile for high moisture extrusion process for the formation of plant protein fibres, ok. And this, I already showed you in the earlier case, that is, in the zone 1 temperature is less than 100 degree Celsius; in the zone 2, which is mixing and melting, temperature may be around 130 to 180 degree Celsius; in zone 3, which is cooling and compression, temperature may be 100 to 130 degree Celsius; and finally, cooling and structuring zone, that is, last zone 4, here the temperature is brought finally, to 70 degree Celsius. So, this is the process flow for a high moisture meat analogue from the pea protein biomass. The feed rate is maintained at 6 kg per hour; moisture content is around 55 percent dry basis; the screw speed is 210 rpm; barrel temperature may be, in different section, may be 60, 90 then 155 early 110, and in the cooling die, the temperature is 70 degree Celsius, ok.

Textural properties of the high moisture extruded-texturized peanut protein, peanut protein-based dry tofu, peanut protein-based vegetarian sausage, and some commercial meat products

samples	hardness (kg)	springiness	chewiness	tensile strength (kg)	lengthwise strength (kg)	crosswise strength(kg)	fibrous degree
high-moisture extruded-texturized peanut protein	27.80 ± 0.82	0.83 ± 0.01	13.32 ± 0.33	0.90 ± 0.11	0.44 ± 0.06	0.48 ± 0.03	1.10 ± 0.13
chicken breast meat	27.60 ± 1.64	0.67 ± 0.02	10.07 ± 1.03	-	-	-	-
beef tenderloin	15.09 ± 0.03	0.79 ± 0.05	58.21 ± 0.07	-	-	-	-
pork tenderloin	17.94 ± 7.35	0.70 ± 0.03	4.49 ± 0.01	-	-	-	-
peanut protein based-dried tofu	21.81 ± 1.09	0.95 ± 0.03	14.34 ± 0.53	-	-	-	-
commercial dried soybean tofu	5.79 ± 0.79	0.94 ± 0.02	4.58 ± 0.57	-	-	-	-
peanut protein based-vegetarian sausage	9.58 ± 0.37	0.89 ± 0.03	5.24 ± 0.22	-	0.51 ± 0.07	0.52 ± 0.07	1.03 ± 0.23
commercial ham sausage	8.10 ± 0.37	0.84 ± 0.02	4.03 ± 0.10	-	0.36 ± 0.02	0.35 ± 0.05	0.98 ± 0.09

[a]"-" means that the indicator is not detected.

Microstructure analysis using SEM images



Small holes → Large protein gel → Accumulated protein gel → Multi-layered structure → Multi-layered structure

The SEM images also confirmed that the fiber orientation in the cooling zone exhibited a multilayered structure, which then formed the fibrous structure in the extrudate.

Source: Zhang et al. (2019)

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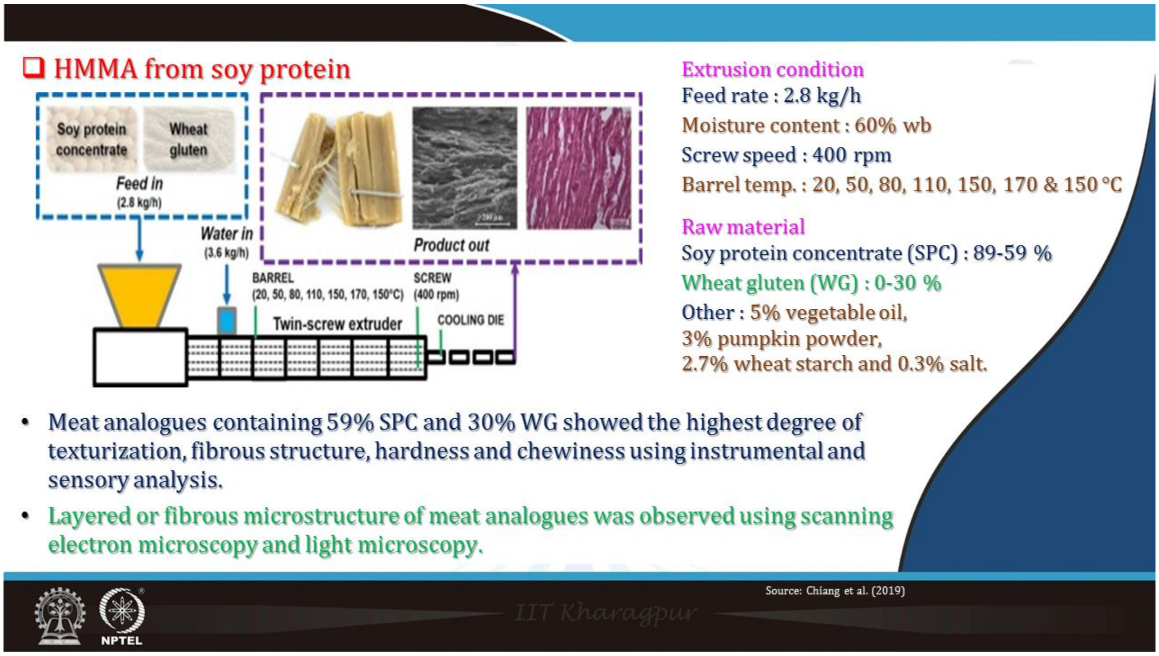
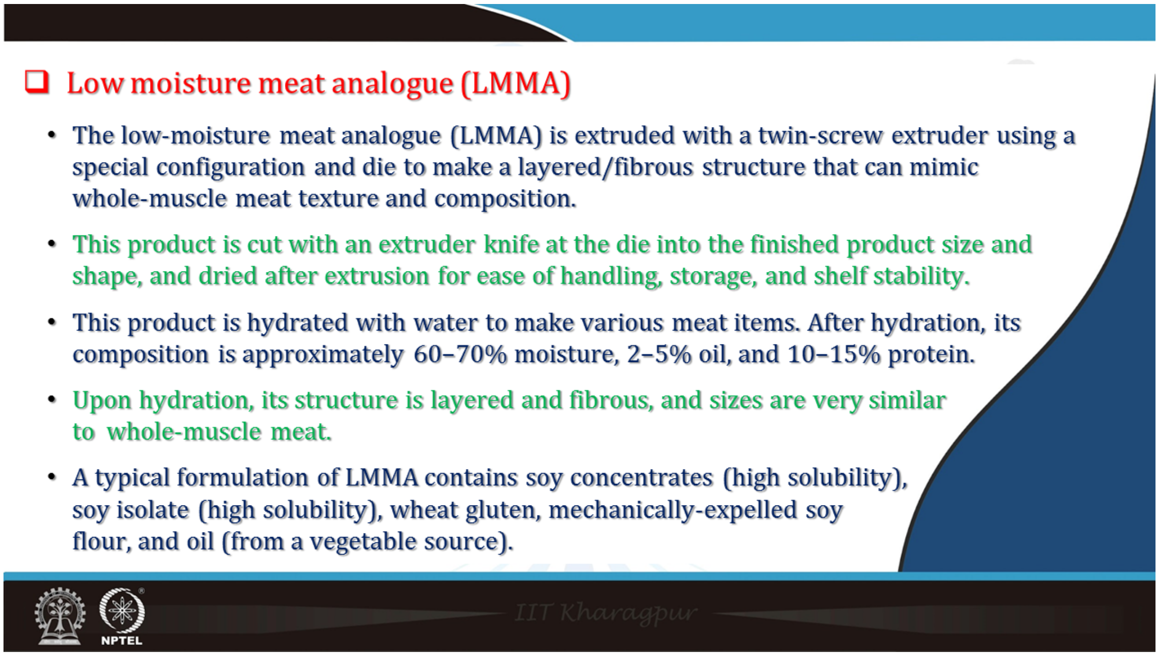
So, you can see the typical properties of the high moisture extruded texturized pea protein is obtained then peanut protein, peanut protein based dry tofu, peanut protein based vegetarian sausage, and some other commercial meat products is shown here, that is, you see, that high moisture extruded texturized peanut protein, it is hardness, springiness, chewiness, tensile strength, long wise strength, cross width strength and fibrous degree etcetera is shown here, given here. It has a hardness of about 28 kilogram, springiness 0.8, chewiness 13.32 and these values, that is hardness, springiness and chewiness of high moisture extruded texturized protein, they compare very values as you can see with the same values of the chicken breast meat, that is, hardness of the high moisture meat texturized peanut protein is about 27.8 and here in the chicken breast meat it is 27.6 and other value also, ok. And this even peanut protein based vegetarian sausage it is also the value is given. So, that is, means that is the, here by combining a proper extrusion conditions, cooling die designs, and all those things, we can simulate the process in such a way that it can produce a meat type product, which resembles the fresh meat. In this figure, it is the microstructure analysis using SEM image. SEM image confirm that the fiber orientation in the cooling zone exhibit a multilayered structure, which then formed the fibrous structure in the extrudate. You can see, that is, there are small holes in the mixing zone, then the large protein gel is formed in the protein gel in the melting zone, then accumulated protein gel multilayered structure is formed in cooling zone, and finally the extrudate which is obtained, ok.

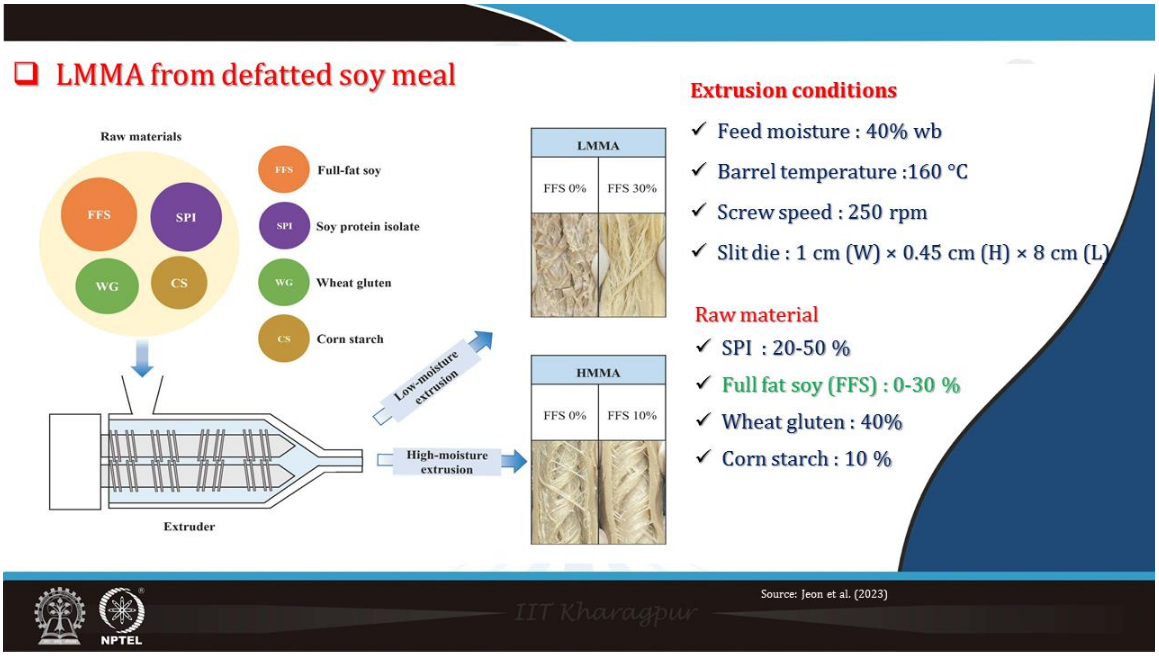


Then, it is another case study, where the high moisture meat analogue is formed from the soy protein, ok. There is soy protein as well as wheat glutens are used, ok. The feed rate is used about 2.8 kg per hour and moisture content of the mixture is maintained at 60 percent wet basis. Screw rpm is 400 and there is screw speed 400 rpm, and the barrel temperature in different sections are, that is, 20, 50, 80, 110, 150, 170 and again 150 degree Celsius. Raw material, as I told you, it is the soy protein concentrate is the 89 to 59 percent and the gluten may be 0 to 30 percent. Other ingredient may be 5 percent vegetable oil, 3 percent pumpkin powder, 2.7 percent wheat starch and 0.3 percent salt. So, this were experiment reported by Cheng et al 2019, and what they found that meat analogue containing about 59 percent soy protein concentrate and 30 percent wheat gluten showed the highest degree of texturization, fibrous structure, hardness and chewiness using instrumental and sensory analysis. The layered or fibrous microstructure of meat analogues was observed using scanning electron microscopy and light microscopy.



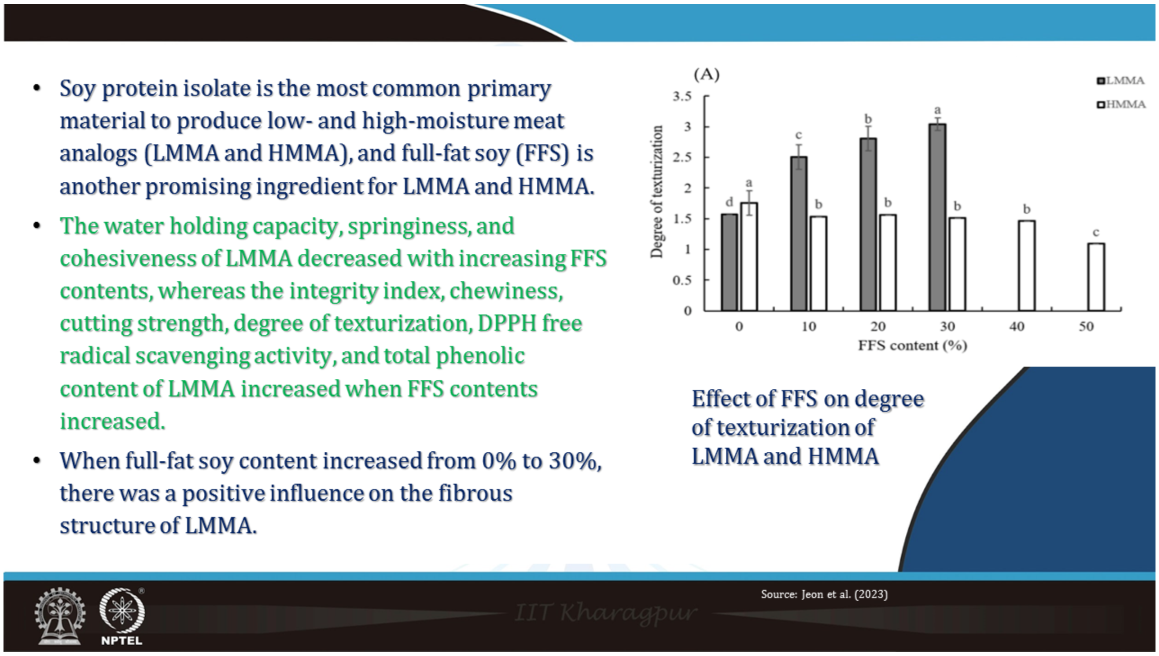
The low moisture meat analogue, they, it is found extrusion with twin extruder using a special configuration and die to make a layered fibrous structure that can mimic whole muscle meat texture and composition. Normally, the low moisture meat analogue, that is, die, they can be used sometime at the meat extender high moisture meat analogue, that be used as a just meat replacer. This LMMA is cut with an extruder knife at the die into the finished product size and shape, and dried after extrusion for ease of handling, storage, and shelf stability.

This product is hydrated with water to make various meat items. After hydration, its composition is approximately 60 to 70 percent moisture, 2 to 5 percent oil, and 10 to 15 percent protein. Upon hydration, its structure is layered and fibrous, and sizes are very similar to whole muscle meat, or they are very similar to whole muscle meat. A typical formulation of a low moisture meat analogue contains soy concentrate, soy isolate, wheat gluten and mechanically expelled soya flour, and oil, ok. That is, oil is the vegetable source, ok.

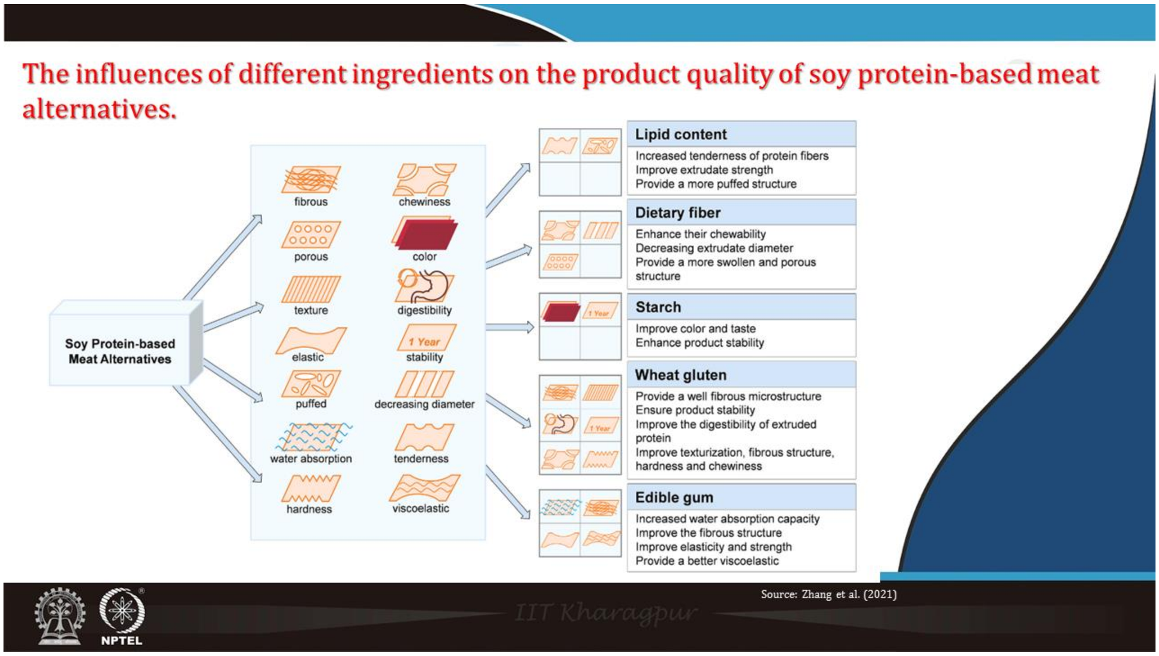


So, you see here, that is, raw material, that is, full fat soy flour, soy protein isolate, wheat gluten and this corn starch is used, ok. And then in the proportion, that is, soy protein isolate, may be 20 to 50 percent, full fat soy flour 0 to 30 percent, wheat gluten 40 percent, and corn starch was 10 percent. This is the result reported by John et al in 2023, ok. And then, these material in proper proportion, they are fed into the extruder, ok. And this is, even for both the high moisture and low moisture analogue.

In high moisture meat analogue, that is, FFS is 0 percent, you can see the texture which you are getting fibrous layer, and when FFS is 10 percent, layers you can see you can see the difference between this. Similarly, in the low moisture analogue material also, when the full fat soy flour content varies, it has significant effect on the textural and fibre layer configuration of the product, ok. So, feed moisture was maintained as 40 percent wet basis, barrel temperature was 160 degree Celsius, screw speed was 250 rpm and slit die was 1 centimeter width, 0.45 centimeter height, and 8 centimeter length, ok.

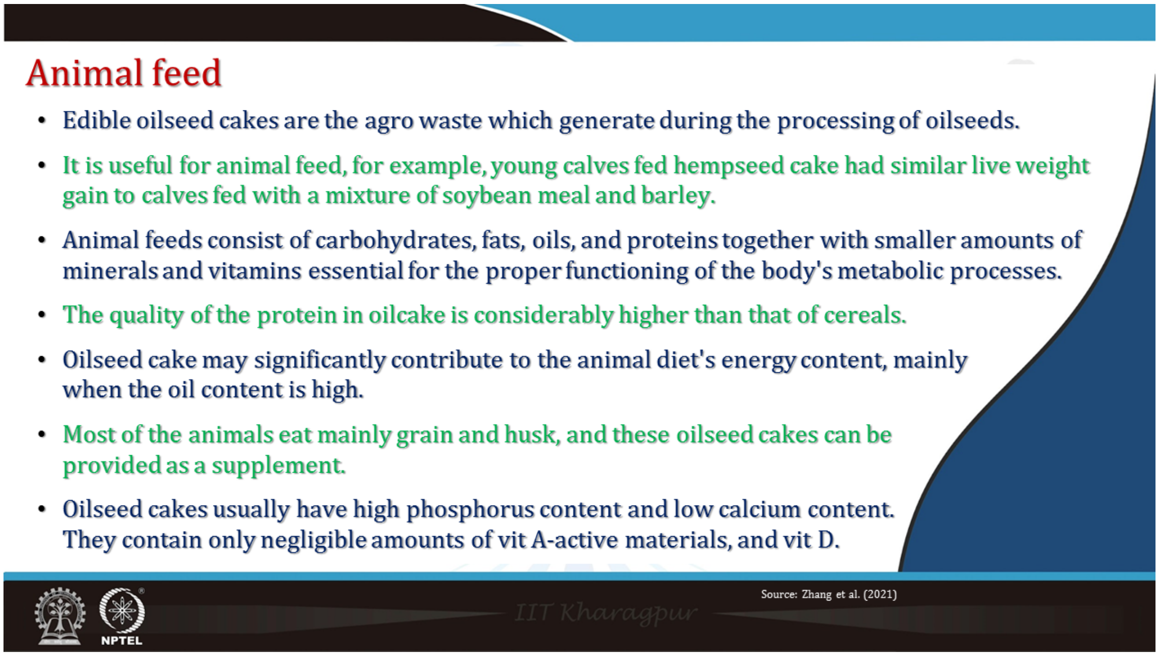


So, you can see here that is the soy protein isolate is the most common primary material to produce low moisture or high moisture meat analogue. And the full fat soy flour is another promising ingredient for the these two products. However, the water holding capacity, springiness, cohesiveness of LMMA decreased with increasing the FFS content, that is, full fat soy flour content, ok. Whereas, the integrity index, chewiness, cutting strength, degree of texturization, DPPH free radical scavenging activity, and total phenolic content of low moisture meat analog increased when the FFS content, full fat soy flour content increased, ok. So, when full fat soy flour content increased from 0 to 30 percent, there was a positive influence on the fibre formation or fibrous structure of low moisture meat analogue, ok. And you can see here, there is degree of texturization, and when you are getting, that is FFS content up to 30 percent, that is, the texturization conditions were better in the low moisture meat analogue, ok. Whereas, in the high moisture meat analogue, there was not. It is conditions, that is you see, it is lower down, that is, degree of texturization is not very, it is, rather decreasing then it does not have much effect, ok.



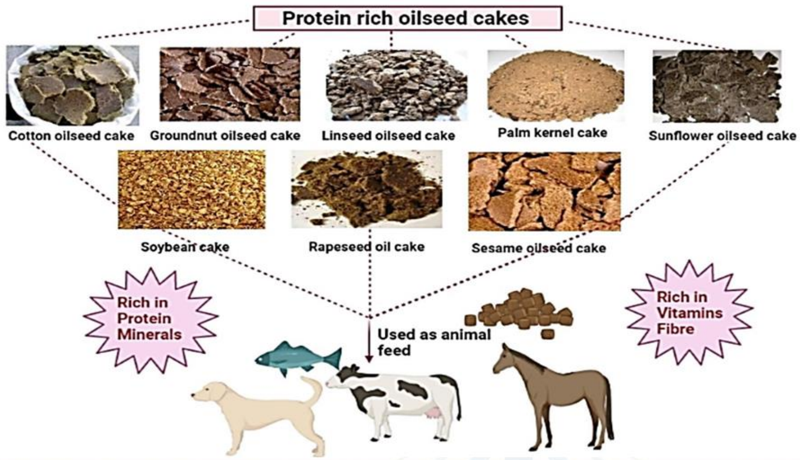
Then influence of different ingredient on the product quality of soy protein based meat alternatives. You can see, there is the various like the soy protein based meat alternative, if you, lipid content, ok. The increased lipid content contributes to increased tenderness of protein fibres, improved extrudate strength and it is provides a more puffed structure. Whereas, dietary fibre enhances the chewability, ok, decreases extruder extrudate diameter and it provide more swollen and porous structure. Starch content of, starch improves the colour and taste, or it enhances the product stability. There is soy based meat alternative products.

Wheat gluten provide a well fibrous microstructure. It ensures the product stability. It improves the digestibility of the extruded products protein, improve texturization, it improves or impart more fibrous structure, ok. It improves the hardness and chewiness of the product. Vegetable gums, when they are used, they result in increased water absorption capacity. They improve fibrous structure, improve elasticity and strength, and they provide better viscoelastic properties in the product, ok. Now, after that, texturization. So, this is, using extrusion technology, the meat analogue can be produced and they can be used as in the place of real cooking. Now let me tell you that, even in India also, so many companies and at the global level that is, trend towards conversion or making of the vegetable meat protein, meat analogue, etcetera is increasing and so many companies are now involved with this process. India, many startup are coming in this direction, ok.



Then other important application is the animal feed. Animal feed, vegetable oil based cakes are the agro waste, which generate during the processing of oilseed. It is useful for animal feed, for example, young calves fed hempseed cake had similar live weight gain to calves fed with a mixture of soybean meal and barley. Animal feed consist of carbohydrates, fats, oils, and protein together with smaller amounts of minerals and vitamins which are essential for the proper functioning of the body metabolic processes. The quality of the protein in oilcake is considerably higher than that of the cereals. So, oil cake may significantly contribute to the animal diet's energy content mainly when the oil content is high. Most of the animals eat grain and husk, and these oilseed cakes can be provided as a supplement. Oilseed cakes usually have high phosphorus content and low calcium content. And they contain only negligible amounts of vitamin A-active materials as well as vitamin D, ok.

❑ Various kinds of protein rich oilseed cakes used as animal feed



So, these are the various, in this picture, various kinds of oilseed protein rich oilseed cakes that are used as animal feed like cotton oilseed cake, groundnut cake, bean seed cake, palm kernel cake, sunflower cake, soya cake, rapeseed cake, sesame, and these are used as, these are rich in protein and minerals as well as rich in vitamins and fibers. And they are processed, and they are used in various feed formulations, etcetera. And they are used to feed cows, particularly, milk animal, cows, buffalo, etcetera.

Composition of cow feed containing pressed oilseed cake from various sources

Intake of dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF) and non-fiber carbohydrates (NFC) of pasture and supplemented pressed oilseed cakes

Intake of nutrients (kg/day)	Byproducts pressed oilseeds supplemented				SEM	*P*-value
	Soybean mean	Peanut cake	Sunflower cake	Palm kernel cake		
Dry matter	14.41	14.18	14.64	13.48	3.19	0.2996^{ns}
Crude protein	1.48 a	1.45 a	1.47 a	1.26 b	0.01	<0.0001*
Ether extract	0.19 b	0.20 b	0.20 b	0.23 a	0.00	0.0006*
Neutral detergent fiber	8.78	8.62	8.99	9.03	1.57	0.7654^{ns}
Acid detergent fiber	5.40	5.31	5.58	5.61	0.62	0.6766^{ns}
Nonfiber carbohydrates	3.32 a	3.29 a	3.31 a	2.25 b	0.07	<0.0001*

Means followed by the same letter were not significantly different in the Tukey test at a probability levels of *5% ($P < 0.05$), **10% ($P < 0.10$) and ns = no significance. SEM, standard error of means.

- Cow : 16 crossbred Holstein × Zebu with an average body weight of 544 ± 57 kg
- The supplements used as peanut cake, sunflower cake and palm kernel cake for replacement of soybean meal.

So, we will take up one or two case studies. Here, in this, I have tried to give you composition of the cow feed containing pressed oil seed cake from various sources, ok. And, then the, there are, that is, because this provide intake of dry matter, crude protein, etheric extract, neutral detergent fiber, NDF, acid detergent fiber, ok, and nonfiber carbohydrates of pasture and supplemented pressed oil seed cakes. So, these, in the cake, they are, these are the various ingredient, and you, they are supplemented with. So, what are the proportion they, you see that is, dry matter in the soybean cake, peanut cakes, sunflower, palm cake, etcetera, the dry matter may be around 14 percent, almost in all the cake, 14 to 15 percent, ok. Crude protein content may vary from 1.1 to 1. 5 or 2 percent, etheric extract is 0.19 to 0.23 in all the cake, and neutral detergent fiber is around 8 percent to 9 percent in palm kernel cake, and acid detergent fiber is 5.4 in almost, that is, in the same range and nonfiber carbohydrate around 3 percent and 2.25 in the palm kernel cake, ok. So, the cows, these were feed, feed they were fed to the cows, that is, the cows were 16 crossbred Holstein and Zebu with the average body weight of around 544 plus minus 57 kg. This is the result reported by Oliverira et al in 2016. And the supplements used as a peanut cake, sunflower cake and palm kernel cake for replacement of soya bean meal etcetera.

Milk production and the chemical constituents of milk from cows grazing on pasture and feed supplemented with pressed oilseed cakes

Variables	Byproducts pressed oilseeds supplemented				SEM	*P*-value
	Soybean mean	Peanut cake	Sunflower cake	Palm kernel cake		
Milk production (kg/day)	8.10	8.33	8.04	7.73	0.72	0.2730^{ns}
Fat (%)	2.85	2.66	2.65	2.81	1.62	0.4632^{ns}
Protein (%)	3.26	3.17	3.24	3.16	2.13	0.3281^{ns}
Lactose (%)	4.73	4.78	4.77	4.73	1.96	0.1537^{ns}
Total solids (%)	11.81	11.59	11.65	11.69	1.13	0.4323^{ns}
Solids not fat (%)	8.96	8.93	9.01	8.88	1.38	0.2648^{ns}

Means followed by the same letter were not significantly different in the Tukey test at a probability levels of *5% ($P < 0.05$), **10% ($P < 0.10$) and ns = no significance. SEM, standard error of means.

Source: Oliveira et al. (2016)

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And this, when this cows were fed, the whatever their effect on the milk production and the chemical constituent of the milk from those cows were grazing on pasture and feed supplemented with the pressed oilseed cakes, ok. And you can see, the milk production in almost, there is where these were there, except in the palm kernel cake little lesser, but in other case 8 percentage. Fat content in the milk varied from 2 to 3 percent, protein again in the 3 percent, the lactose there was less variation and total solid around 11 percent, and solid not fat around 9 percent or 8 percent. So, however, that is, in the case of palm kernel cake, that is the, even it has the similar value.

Fatty acid profile of milk from cows fed with feed containing pressed oilseed cake

FA (g/100 g of milk fat)		Byproducts pressed oilseeds supplemented				SEM	*P*-value
		Soybean mean	Peanut cake	Sunflower cake	Palm kernel cake		
$C_{4:0}$	Butiric	0.67b	4.2a	3.56a	3.8a	0.56	0.0333*
$C_{6:0}$	Caproic	2.44	2.43	1.89	2.00	0.33	0.0451*
$C_{8:0}$	Caprylic	1.72a	1.73a	1.61a	1.38b	0.12	0.0729**
$C_{12:0}$	Lauric	4.23ab	4.13b	4.01b	5.02a	0.59	0.0141*
$C_{14:0}$	Myristic	15.74	15.35	14.28	15.62	2.20	0.4072^{ns}
$C_{14:1}$	Myristoleic	1.43	1.01	1.33	1.39	0.32	0.2751^{ns}
$C_{16:0}$	Palmitic	38.18a	35.19ab	36.18ab	33.11b	4.51	0.0727**
$C_{16:1}$	Palmitoleic	1.40a	0.95b	1.33a	1.65a	0.07	<0.0001*
$C_{17:0}$	Margaric	0.77	0.61	0.38	0.60	0.40	0.5262^{ns}
$C_{18:0}$	Stearic	8.1	9.00	7.41	8.29	4.97	0.2243^{ns}
$C_{18:1}$	Oleic	23.14b	23.11b	26.21a	25.01ab	5.10	0.0135*
$C_{18:2}$	Linoleic	0.50	0.87	0.29	0.57	0.37	0.1667^{ns}
$C_{18:3}$	Linolenic	0.52	0.75	0.52	0.55	0.37	0.7620^{ns}
$C_{20:0}$	Arachic	0.97	0.45	0.8	0.87	0.75	0.5002^{ns}
CLA		0.19 a	0.22a	0.22a	0.14b	0.23	0.0356*

Means followed by the same letter were not significantly different in the Tukey test at a probability levels of *5% ($P < 0.05$), **10% ($P < 0.10$) and ns = no significance. CLA, conjugated linoleic acid; SEM, standard error of means.

Source: Oliveira et al. (2016)

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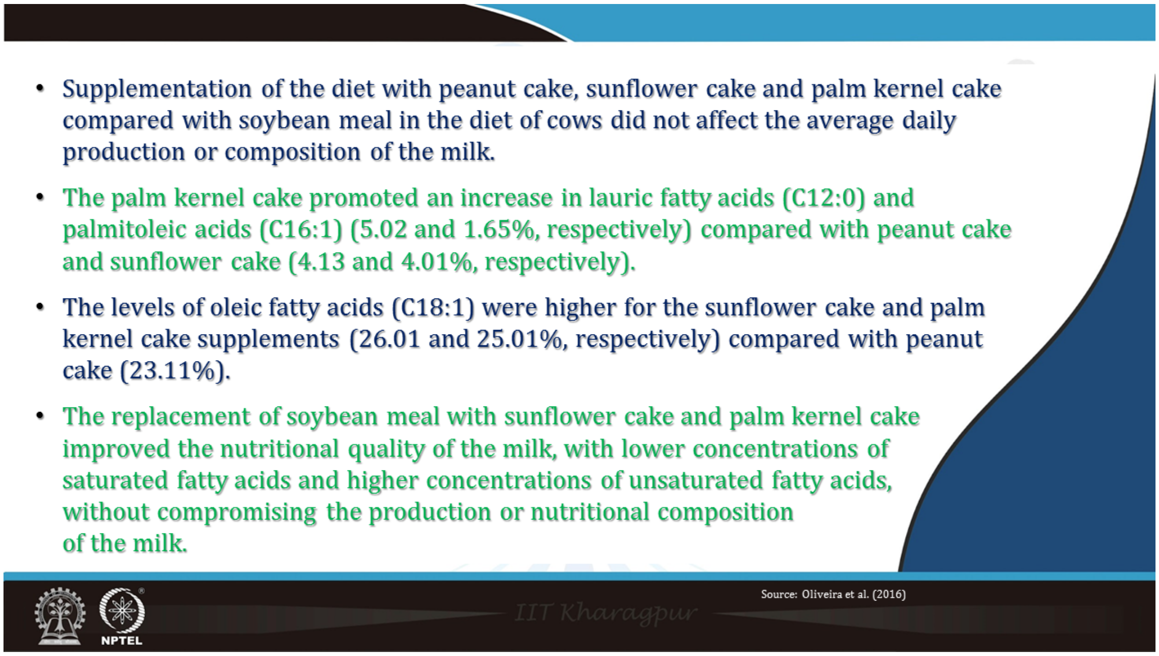
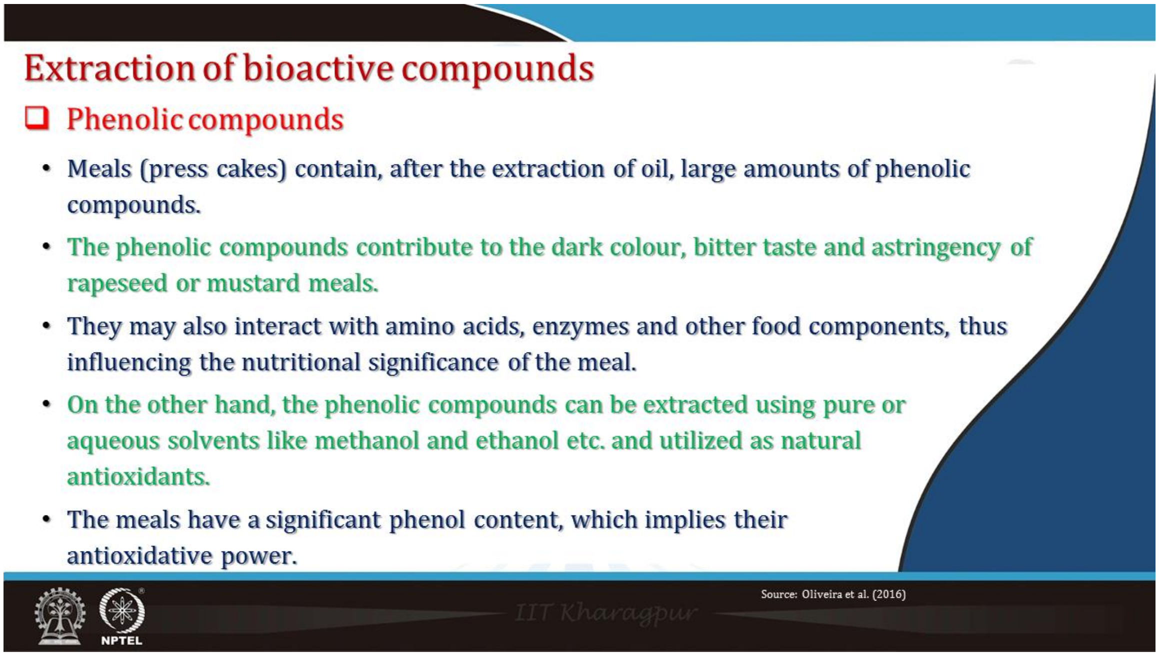
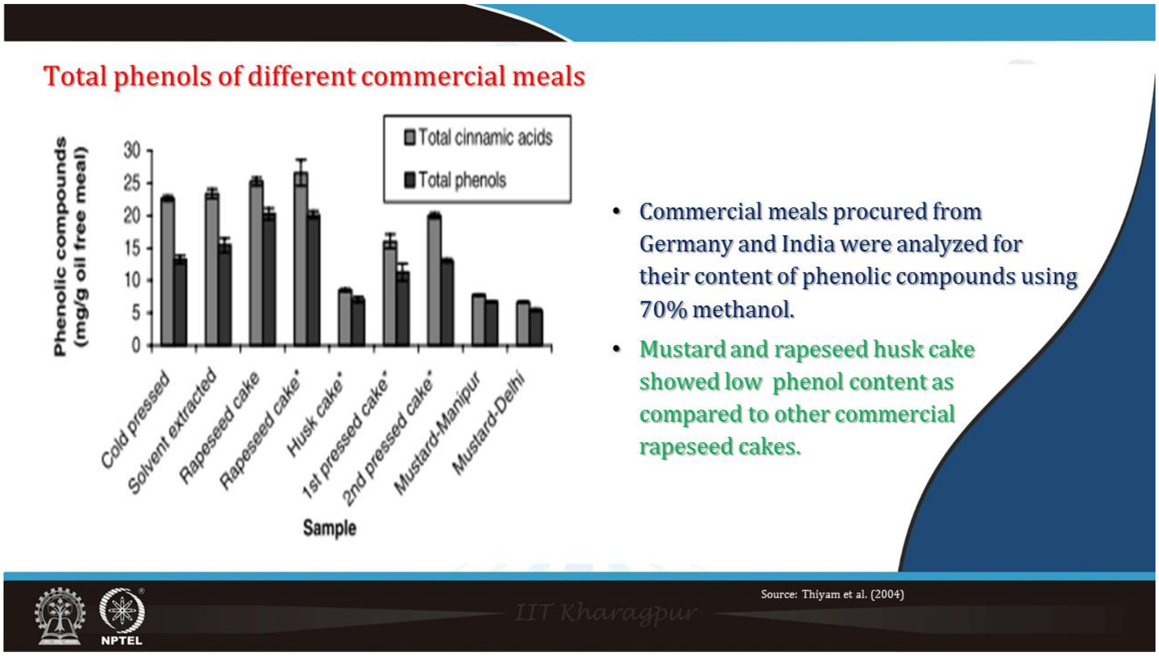
And similarly fatty acid profile of the milk which were fed with the feed containing pressed oilseed cake. Consider about that lauric acid has a significant quantity, palmitic acid around 35 to 38 percent in palm kernel it was 33 unit weight. Then oleic acid also has been significant amount in all these cakes, ok. And the other, even myristic acid, in all the cases, around 14 to 15 percent, lauric acid to percent. So, there were these variations, these type of different fatty acids, which were found in the milk, when they were fed with the depending upon what was the pressed cake given.



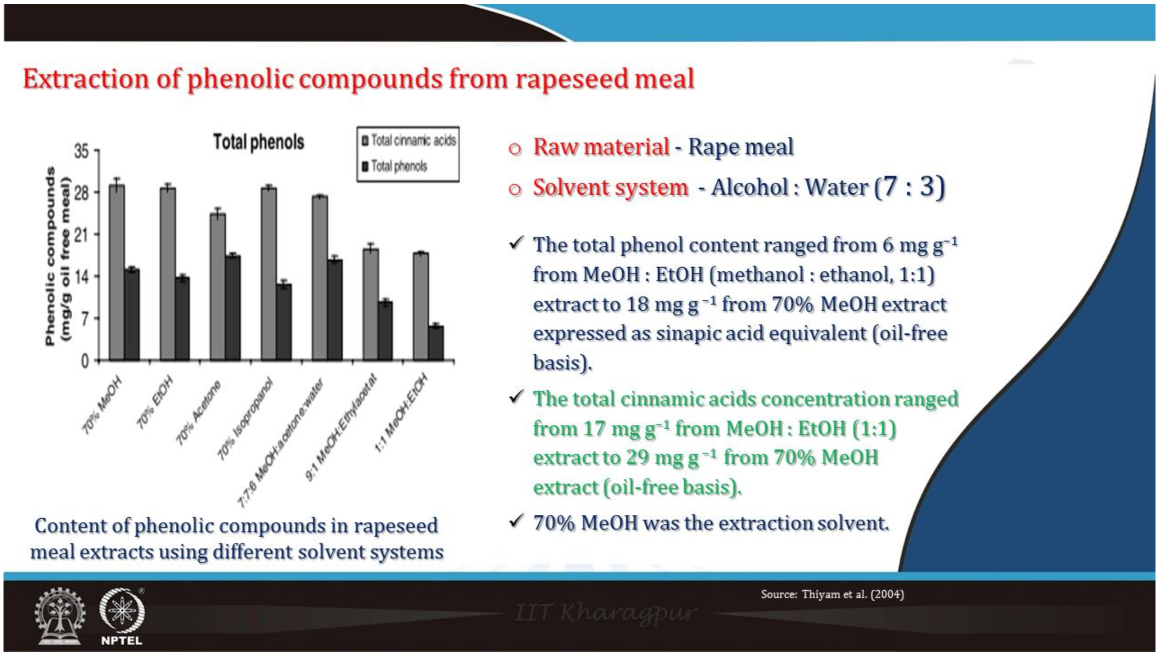
So, you can say that supplementation of the diet with peanut cake, sunflower cake, and palm kernel cake compared with soybean meal in the diet of cows did not affect the average daily production or consumption of the milk and it remains almost different. The palm kernel cake promoted an increase in the lauric fatty acids and palmitoleic acids, ok. And compared with the peanut cake and sunflower cake, the level of oleic fatty acids were higher for the sunflower cake and palm kernel cake supplements compared with the peanut cake. The replacement of soybean meal with sunflower cake and palm kernel cake improved the nutritional quality of the milk, as you could see in the, because earlier although production were almost similar, but the quality, nutritional quality with the lower concentration of saturated fatty acids and higher concentration of unsaturated fatty acids without compromising the production or nutritional composition of the milk. So, by feeding the cows with the these cakes, there is content of the unsaturated fatty acid is significantly improved.



Then, now, let us briefly talk about the extraction of various bioactive compound because these meals contain various phenolic compound, flavonoids, etcetera, ok. So, after extraction of the, large amount of phenolics are there, these phenolic compounds contribute to the dark colour, bitter taste, and astringency of the rapeseed meal or mustard meal. They may also interact with amino acids, enzymes, and other food components, thus influencing the nutritional significance of the meal. On the other hand, these phenolic compounds can be extracted using pure or aqueous solvents like methanol or ethanol etcetera, and utilized as natural antioxidant. The meals have a significant phenol content which implies their antioxidant power, ok.



Here in this table, I have shown, that is, the different, the phenolic components found in the different meals like cold pressed, solvent extracted and rapeseed cake, husk cake, first pressed cake, second pressed cake, mustard which is from from Manipur or in India or from Germany. So, commercial meals prepared from Germany as well as in India were analyzed for their content of phenolics compound using 70 percent methanols in the experiment reported by Thiyam et al, and the mustard and rapeseed cake, husk cake showed low phenol content as compared to other commercial rapeseed cakes, ok.



So, this was some study, was again conducted by Thiyam et al, for the extraction of phenolic compound from the rapeseed meal, ok. And the solvent system used was alcohol and water, and you can see in the figure diagram, here. The total phenol content ranged from 6 milligram per gram from MeOH or methanol ethanol in the 1 to 1 extract to 18 milligram per gram from 70 percent methanol extract, ok, oil free basis. And it is, it is expressed as sinapic acid equivalent. The total cinnamic acid concentration ranged from 17 milligram per gram from MeOH EtOH 1 is to 1 extract to 29 milligram per gram from 70 percent MeOH extract, which is oil free basis. So, 70 percent MeOH methanol extract was the found as the better extract better solvent.

Flavonoids

Extraction of flavonoid compounds from oilseed meals

Total flavonoids (mg LUE/100 g fresh weight)

Solvent	Seed Cakes		
	Hemp	Flax	Canola
Methanol	3.86 ± 0.06^{cB}	3.47 ± 0.06^{cC}	28.13 ± 0.06^{dA}
Ethanol	0.81 ± 0.06^{fB}	0.58 ± 0.08^{fB}	25.28 ± 0.42^{eA}
Hexane	0.23 ± 0.10^{gB}	0.08 ± 0.05^{gB}	20.27 ± 0.57^{fA}
Acetone	4.31 ± 0.06^{dB}	4.33 ± 0.09^{dB}	28.63 ± 0.09^{dA}
Acetone 80%	8.04 ± 0.07^{bB}	5.36 ± 0.11^{bC}	36.05 ± 0.12^{bA}
Methanol 80%	7.61 ± 0.04^{cB}	5.01 ± 0.18^{cC}	35.03 ± 0.05^{cA}
Methanol:acetone:water (7:7:6 v/v/v)	27.41 ± 0.04^{aB}	9.18 ± 0.17^{aC}	37.79 ± 0.04^{aA}

Results are expressed as mean ± standard deviations; $n = 3$. $^{a-g}$ Means in the same column followed by different lowercase letters are significantly different ($P < 0.05$). $^{A-C}$ Means in the same row followed by different uppercase letters are significantly different ($P < 0.05$).

- The flavonoid content in the seed cakes extracted by different solvents was significantly different ($p < 0.05$).
- The order of solvents used in extracting phenolic compounds : MAW > acetone 80% > methanol 80% > acetone > methanol > ethanol > hexane.

(MAW : Methanol : Acetone : Water)

Source: Teh et al. (2014)

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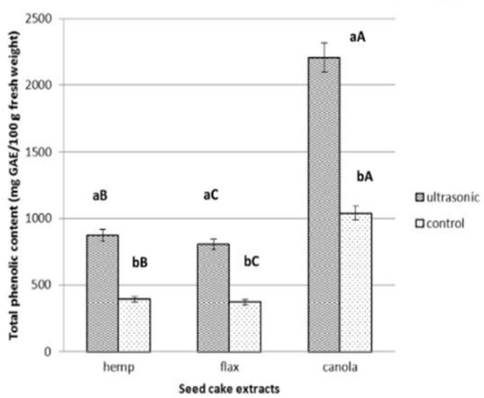
Similarly, flavonoid contents, ok. The extraction of flavonoid compound from oilseed meal, the flavonoid content in the seed cake extracted by different solvents were significantly different. And the order of solvents used in the extracting phenolic compounds were methanol, acetone and water mixture would more than acetone pure, acetone 80 percent, with higher than the methanol 80 percent higher than the acetone, methanol, ethanol, and hexane, ok.

Effect of ultrasonic treatment on polyphenol content



Total phenolic content of the seed cake extracts by ultrasonic treatment and the control

Raw material : Hemp, flax, canola cake meal

Solvent system : Methanol : Acetone : Water (MAW, 7:7:6 v/v/v)

Instrument used : US bath (fixed power 200 W)

Process parameters :

Solvent volume (25, 50, 75, 100 mL),

Extraction time (20, 30, 35 min)

Temperatures (40, 50, 60, 70 °C)

Design : Orthogonal design test

Source: Teh & Birch (2014)

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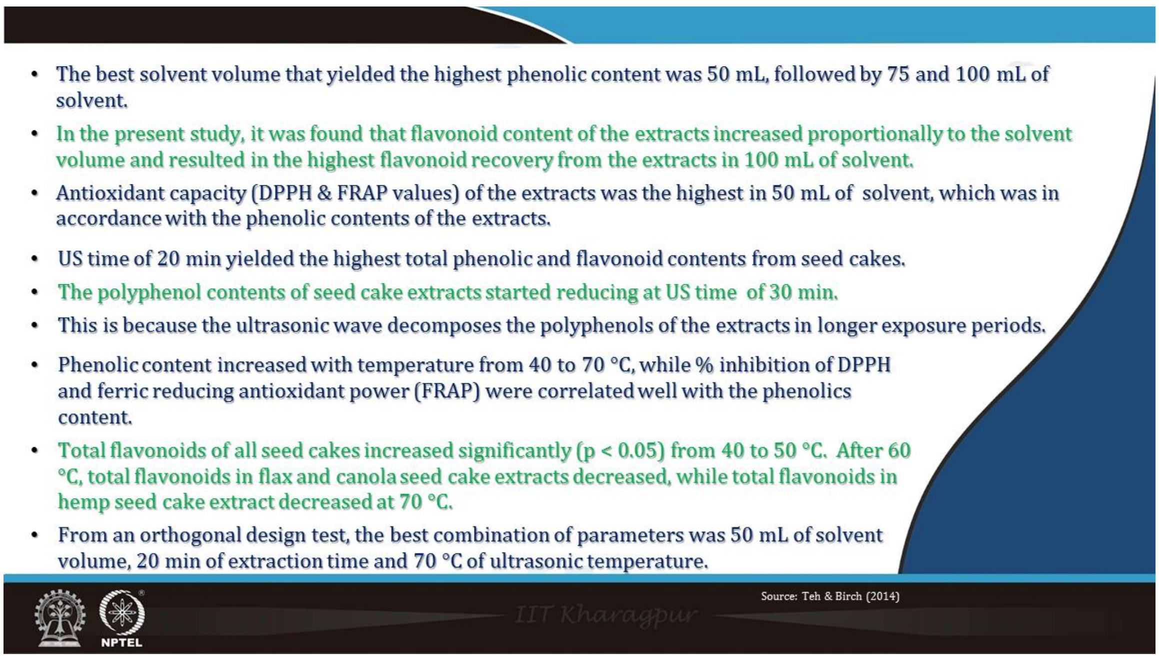
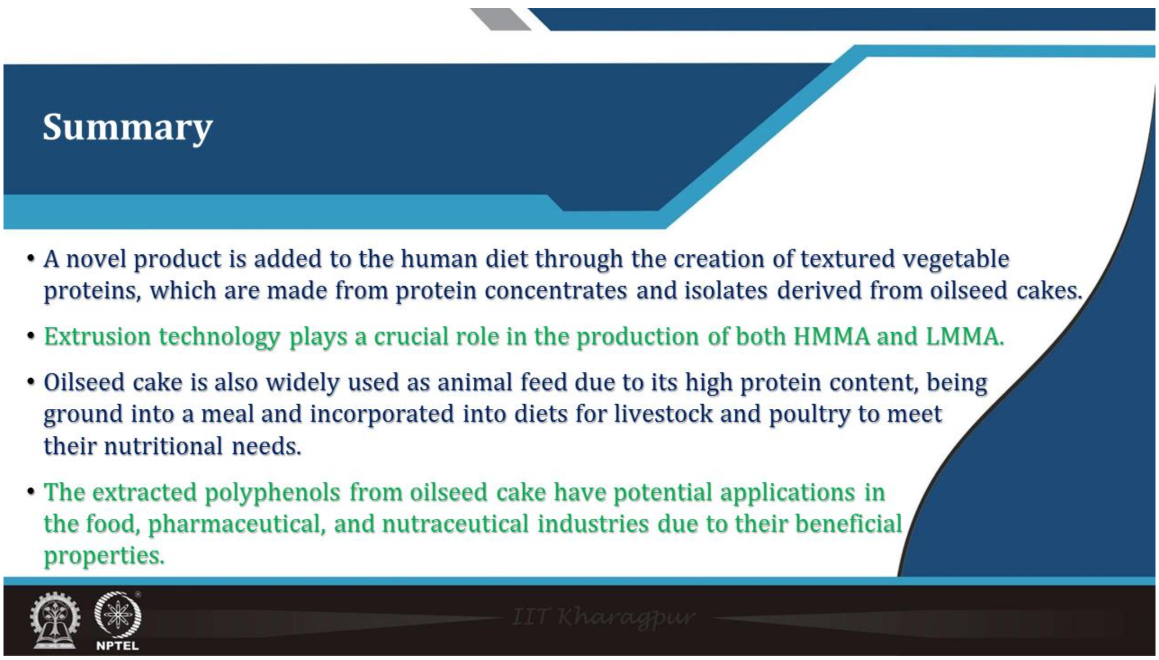
So, the extract effect of ultrasonic treatment on the polyphenolic that was reported by Teh and Birch in 2014. The raw material used as hemp, flax and canola cake meals. Solvent were methanol, acetone and water, ok, in 7 7 6 volume by volume by volume. Instrument used are ultrasonic bath, ok, fixed power level 200 Watt was used. And the process, where solvent volume was 25, 50, 75 and 100 mL, extraction time, 20, 30, 35 minutes; temperature were 40, 50, 60, 70 degree Celsius, and design was orthogonal design test, and you can see the results are given here in the figure, ok. So, you can see that, in all these experiment, what was the summary, it was the found that the best solvent volume that yielded the highest phenolic content was 50 mL followed by 75 and 100 mL.



So, 50 mL was the best volume in the, of course, depending upon the sample size of the extract and other cake. In the present study, which, they were reported by that Teh and Birch 2014, it was found that flavonoid content of the extracts increased proportionately to the solvent volume and resulted in the highest flavonoid recovery from the extract in 100 mL of solvent. Antioxidant capacity, that is, DPPH and FRAP values of the extract was highest in 50 mL of solvent which was in accordance with the phenolic content of the extract. Ultrasonication time of 20 minutes yielded the highest total phenolic and flavonoid content from the seed cake and the polyphenol content of the seed cake extract started reducing when the ultrasonic time was 30 minutes and beyond. This is because the ultrasonic wave decomposes the polyphenols of the extract in longer exposure periods. Phenolic content increased with the temperature, when it was increased from 40 to 70 degree Celsius while percent inhibition of DPPH and FRAP were correlated well with the phenolic content. Total flavonoids of all seed cakes increased significantly from 40 to 50 degree Celsius. After 60 degree Celsius, total flavonoids in flax and canola seed cake extract decreased, while total flavonoids in hemp seed cake extract decreased at 70 degree Celsius. From an orthogonal design test, the best combination of parameters was 50 mL of solvent volume, 20 minute extraction time, and 70 degree Celsius ultrasonic temperature.



Finally, summary of this lecture is that novel product is added to the human diet through the creation of textured vegetable protein, which are made from protein concentrate and isolate or protein flour, protein powder derived from oilseed cakes. Extrusion technology plays a crucial role in the production of both high moisture meat analogue as well as low moisture meat analogue. Oilseed cake is also widely used as animal feed due to its high protein content, being ground into a meal and incorporated into diets of livestock and poultry to meet their nutritional needs. The extracted polyphenols from oilseed cakes have potential applications in food, pharmaceutical, and nutraceutical industries due to their beneficial property, and they can be used to extract.

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These were the references in this lecture, ok.

And finally, thank you very much for your patience here. Thank you.