FOOD SCIENCE AND TECHNOLOGY

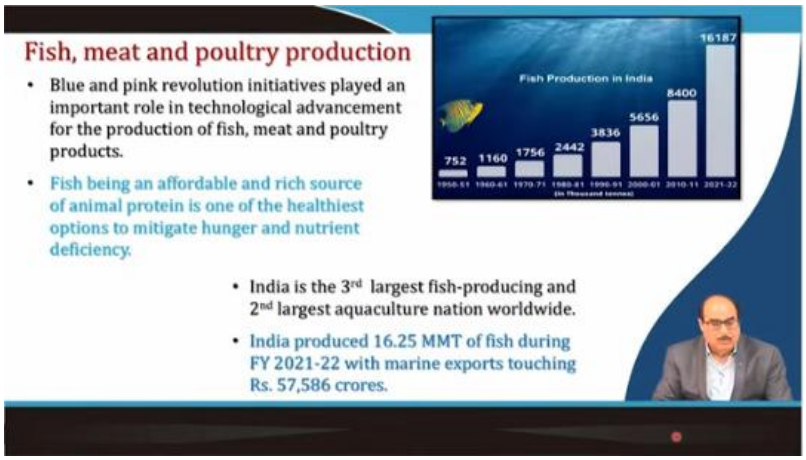
Lecture 59

Lecture 59: Fish, Meat and Poultry Processing Waste Utilization

Hello everybody, Namaskar.

Now we are in the 59th lecture of this course today. In this class, in the next half an hour or so, I will talk about fish, meat, and poultry processing waste utilization.

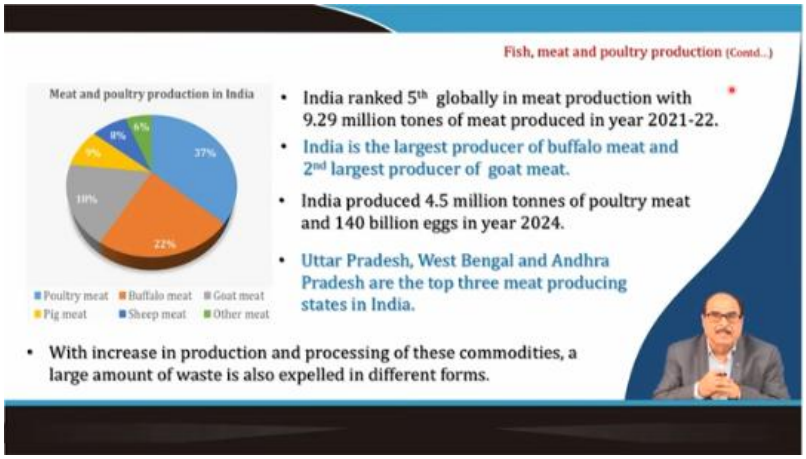
We will discuss the scenario of fish, meat, and poultry production in India. Industry by-products and waste utilization, particularly chitin production. We will also talk about the various by-products generated during the slaughtering of animals, particularly hides, skins, and bones, and how they can be effectively utilized. Then, towards the end, we will talk about poultry product processing waste recycling.



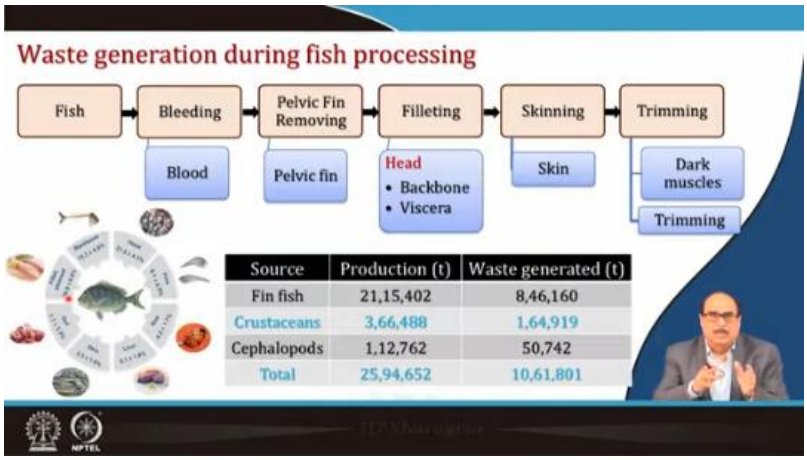
So, this blue and pink revolution initiative played an important role in technological advancement for the production of fish, meat, and poultry products. Fish, being an affordable and rich source of animal protein, is one of the healthiest options to mitigate hunger and nutrient deficiency. India is the third-largest fish-producing and second-largest aquaculture nation worldwide.

India produced around 16.25 million tons of fish during the financial year 2021-22, with exports reaching ₹57,586 crores. So, if you look at the scenario of food production in India, it is given in this graph. In 1950-51, it was around 752,000 tons, and in the year 2021-22,

the production reached 16,187,000 tons. So, every year, the production is increasing. As far as the production of meat and poultry is concerned,

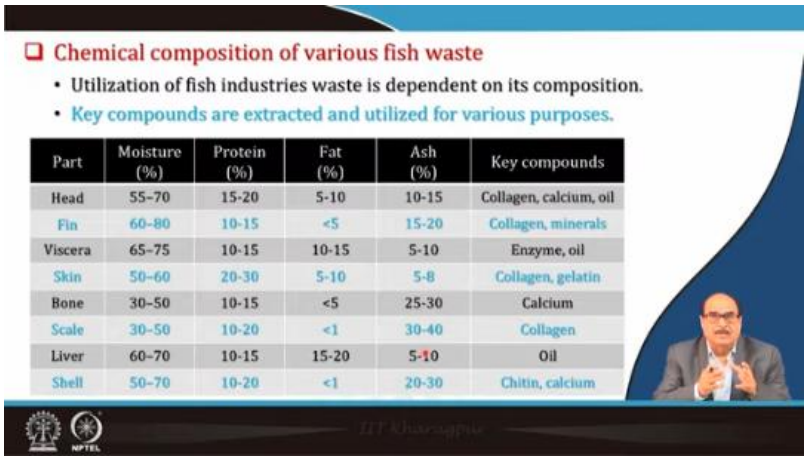


India ranked fifth globally in meat production, with 9.29 million tons of meat produced in the year 2021-22. India is the largest producer of buffalo meat and the second-largest producer of goat meat. India produced 4.5 million tons of poultry meat and 140 billion eggs in the year 2024. Among the different states of India, Uttar Pradesh, West Bengal, and Andhra Pradesh are the top three meat-producing states. If you look at the scenario, that is, the proportion of the total contribution of various animals in meat production. 37 percent of the total meat produced in the country comes from poultry, followed by 22 percent from buffalo meat, about 18 percent goat meat, 9 percent pig meat, 8 percent sheep meat, and 6 percent from the remaining types of animals. So, you can understand that with the increase in production and processing of these commodities, a large amount of waste is also generated, and this waste generated is in different forms.



So, we will discuss one by one all these three commodities, fish, meat, and poultry products, and also how they can be effectively utilized. So, first, let us talk about what are the different types of waste generated during fish processing. So, fish from the time it is caught until it reaches the processing factory. It is subjected to various treatments like bleeding treatment, pelvic fin removal, filleting, skinning, and trimming for preparing for processing or for cooking purposes. So, in the process, the major byproducts or waste generated include blood, pelvic fin, head, backbone, viscera, skin, even dark muscles, and trimming portions of the trimmings. So, if you look at the quantum, that is, the finfish production. It was about 2,115,402 tons total, and the waste generated from this finfish processing is to the tune of 846,160 tons. So, almost one-third of the total production, or even more than that, about 40 percent of the total production is wasted; it is turned into some sort of one or the other type of waste.

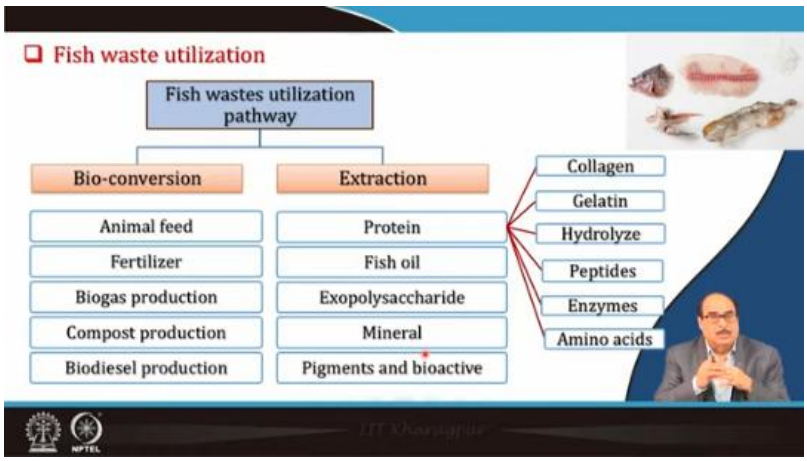
Similarly, crustaceans, if you see that out of the total production of 366,488 tons, about 164,919 tons is the waste generated. So, if you look at the total, that is, of all these three, fin fish, crustaceans, and cephalopods, the total production of these three commodities of fish includes around 2,594,652 tons. And the waste generated from these three commodities amounts to 1,061,801 tons. So, approximately 40 percent on an average basis is the waste generated during fish processing.



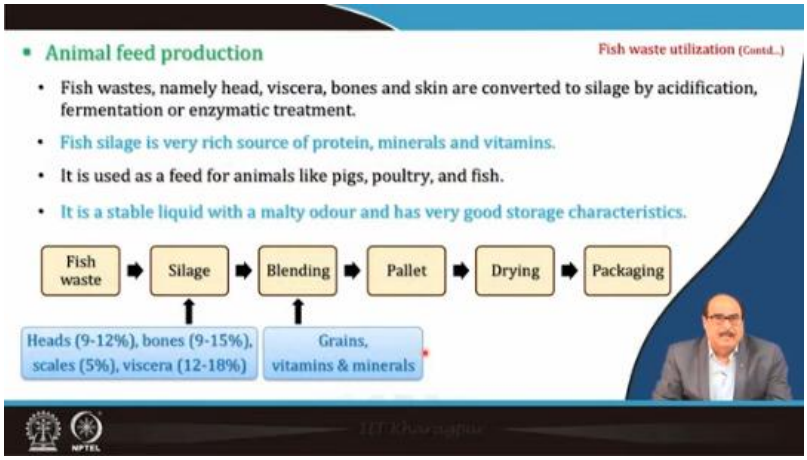
So, obviously, the utilization of this fish industry waste is dependent on its composition. And it contains major, that is, all these wastes contain various types of major, different valuable compounds. So, these key compounds are extracted and utilized for various purposes. For example, if you take the head, the head of the fish, which is removed during

processing, it may contain around 15 to 20 percent protein, 5 to 10 percent fat, and 10 to 15 percent ash. And the major component key compounds which are utilized, which are extracted from these materials from the head are collagen, calcium, and oil.

Similarly, in the fins, collagen and minerals are the key compounds that can be extracted; from the skin, also collagen and gelatin. From the bones, you can get calcium; they contain about 25 to 30 percent ash and even 10 to 15 percent protein. The liver contains around 15 to 20 percent fat and 5 to 10 percent ash. So, liver, even fish liver oil is a very popular material, particularly for use in pharmaceutical preparations and various other purposes. The shell of the fish contains around 10 to 20 percent protein and about 20 to 30 percent ash. So, it can again be used or even be used by the industry for chitin production or for calcium production, etcetera.

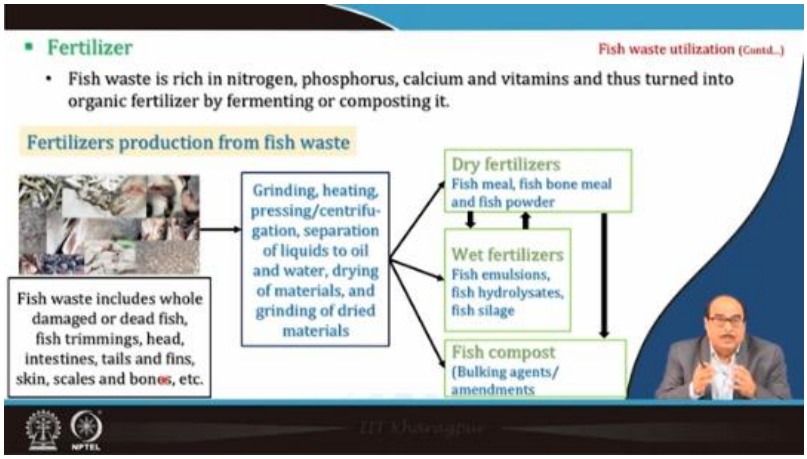


So, the various pathways for the utilization of fish waste may be: one major pathway is bio-conversion, and another may be extraction into various valuable compounds. So, after bio-conversion, they can be utilized as animal feed, they can be used as fertilizer, they can be used for biogas production, for compost production, or even for biodiesel production. If you go the extraction route, then these wastes can be used for the extraction of protein, particularly collagen, gelatin, hydrolysates, peptides, enzymes, amino acids, etcetera. Or they can be used for the production of fish oil, production of exopolysaccharides such as chitin. Production of minerals and various pigments and bioactives.



So, we will elaborate a little bit: fish wastes, particularly heads, viscera, bones, and skins, are converted to silage by acidification, fermentation, or enzyme treatments. And fish silage is a very rich source of proteins, minerals, and vitamins. It is used as feed for animals like pigs, poultry, and fish. It is a stable liquid with a malty odor and has very good storage characteristics.

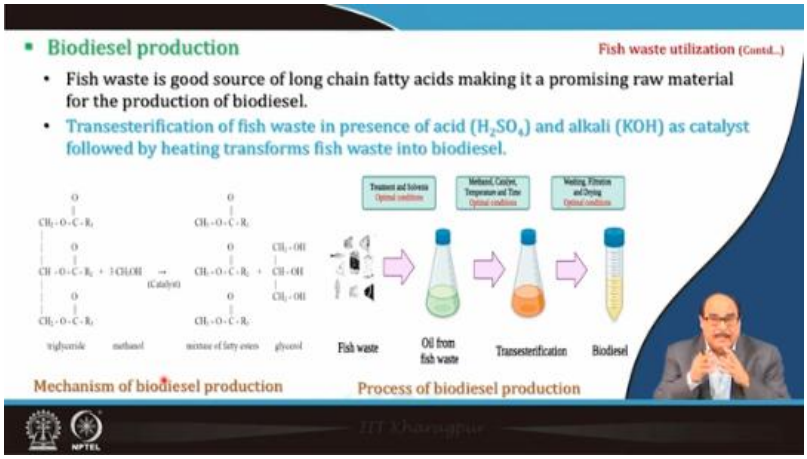
So, that silage, in fact, consists of heads about 9 to 12 percent, bones 9 to 15 percent, scales, viscera, etcetera, which are converted into silage. Even this silage can be blended, sometimes with grains, vitamins, minerals, etcetera, to make suitable feed for animals and cattle.



Fish waste is a very rich component; it contains high levels of nitrogen, phosphorus, calcium, and vitamins. And therefore, it can be turned into organic fertilizer by fermenting or composting it. So, the fertilizer production, if you look at fish waste, includes various waste fish, even damaged or dead fish. Fish trimmings, heads, intestines, tails, fins, skin,

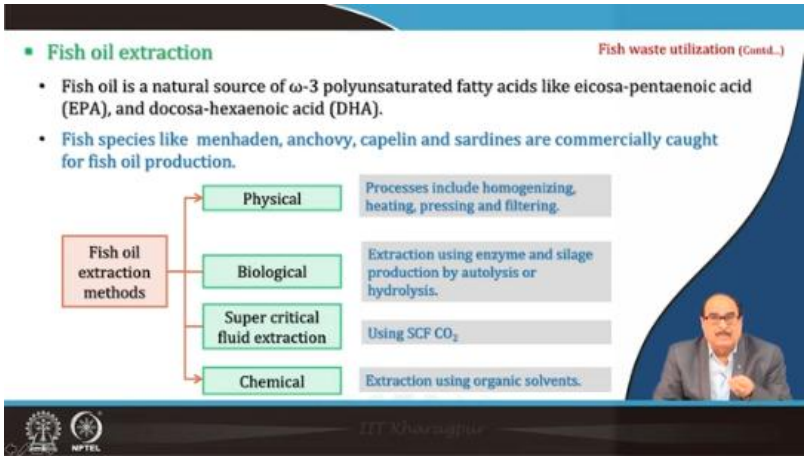
scales, bones, etcetera. So, various wastes, all these can be subjected to different treatments like grinding, heating, pressing, or centrifugation, then separation of liquids into oil and water, and even drying of the pressed material, and grinding of the dried material. In the process, one can generate dry fertilizers, which can be used in fish meal production, that is, it contains fish bones, fish meal, and fish powder.

Then, wet fertilizers like fish emulsion, fish hydrolysates, and fish silage and fish compost like bulking agents or amendments, etcetera. So, this can be used for making dry fertilizer, wet fertilizer, or even fish compost.



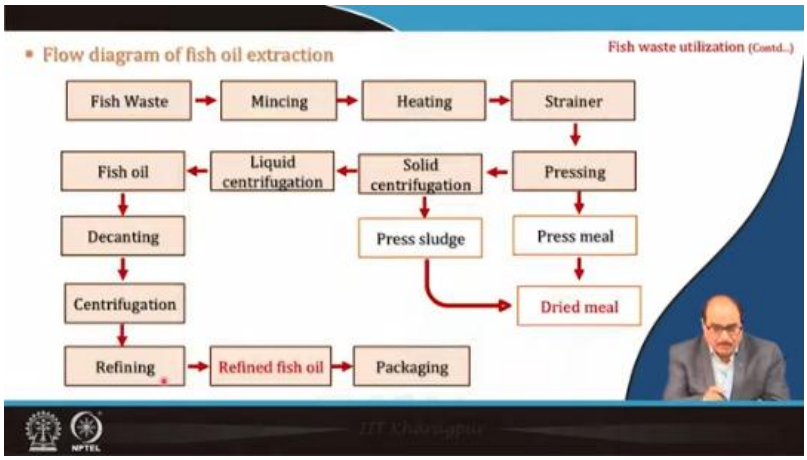
Then, this fish waste can also be used for biodiesel production. As you know, fish waste is a good source of long-chain fatty acids, making it a promising raw material for the production of biodiesel. So, what is done here is that these fatty acids, first, by a suitable process, maybe by treating them with methanol, etcetera, these fatty acids are broken down, triglycerides are hydrolyzed, and then the fatty acids obtained are subjected to transesterification.

So, transesterification of the fish waste in the presence of acids like sulfuric acid and alkalis like potassium hydroxide as catalysts is followed by heating this transforms heating and it transforms fish waste into biodiesel, which is a very good fuel or used as biodiesel fuel.



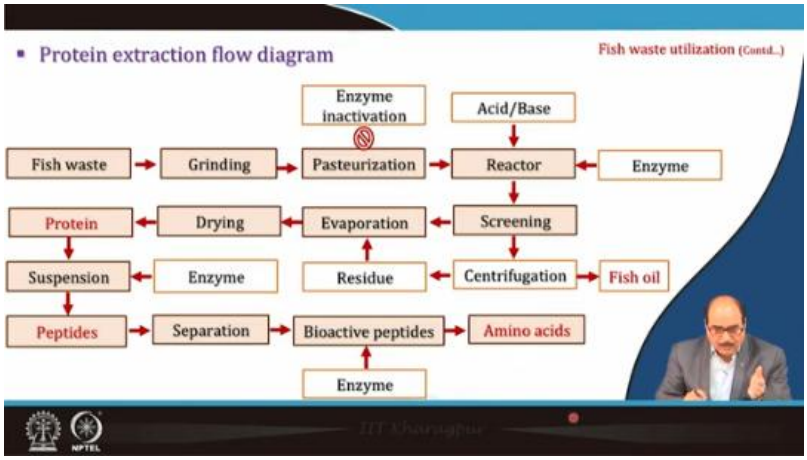
Then, for the extraction of oil from the fish, you know the fish is a very good natural source of omega-3 polyunsaturated fatty acids like eicosa-pentaenoic acid and docosa-hexaenoic acid. And fish species like menhaden, anchovy, capelin, and sardines are commercially caught for fish oil production. So, various methods like physical, biological, supercritical fluid extraction, or chemical methods can be used, or even these are now also being used by the industry for the production of fish oil for use in various food purposes, various pharmaceutical purposes, and so on, or even for developing health foods, etcetera.

So, the physical methods of fish oil extraction may include processes like homogenizing, heating, pressing, and filtering, whereas the biological method uses enzymes and silage production by autolysis or hydrolysis. In supercritical carbon dioxide extraction, that is, the supercritical fluid like carbon dioxide is used to extract the oils in SCFE extraction. Whereas the chemical processes use some organic solvents like benzene, ether, etcetera, to extract the oil, that is, the various solvents.



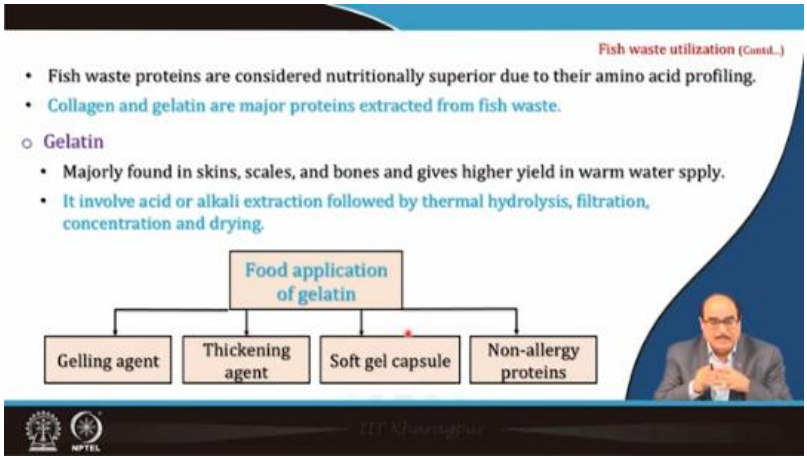
So, the process flowchart for the fish oil extraction means the fish waste is minced, heated, and strained, and after straining, it is subjected to pressing treatment. So, after the pressing, that is, you get the press meal or even solid centrifugation; the liquid is separated, and the pressed sludge is done. Both press meal and pressed sludge are dried, and you get the dried fish meal powder, which is again a very good source of protein and that can be used for the extraction of protein, etcetera. So, the liquid material which is obtained after the centrifugation is basically the fish oil. It is decanted, centrifuged, and refined to get the refined fish oil, and finally, it is packaged using suitable technology.

Then, the protein extraction from the fish waste, this, you know, is as I told you earlier also. This fish waste is a rich source of very high-quality protein, typically comprising around 15 to 25 percent of its composition, depending upon the type of fish and waste material. So, fish waste proteins are known for a well-balanced amino acid profile, including essential amino acids like lysine, methionine, threonine, and leucine. Fish waste proteins possess excellent emulsifying, foaming, and gel-forming properties, and thus they are used in the development of processed foods, such as ingredients in food texture enhancement, etcetera. These proteins are widely used in the production of hydrolyzed protein for nutritional supplements, for animal feed production, or animal feed formulations, for pet foods and aquaculture diets, which support sustainable protein sourcing. Fish waste proteins are also applied in enzymatic hydrolyzates for bioactive peptides, biodegradable films, and other industrial applications, offering both nutritional and environmental benefits.



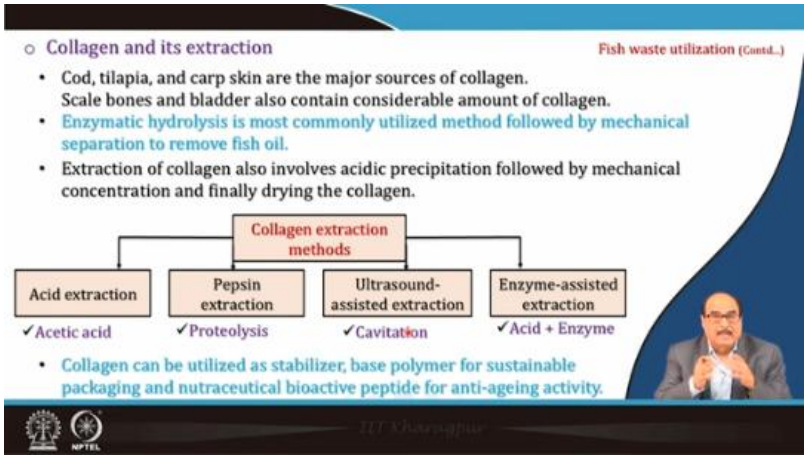
So, let's see the extraction flow diagram for the protein from the fish. As you see, the fish waste is taken, ground, and pasteurized to inactivate the enzymes, etcetera. Then it is put in a reactor where it is treated with an acid or base catalyst or enzyme-treated, and then it is screened and centrifuged to get the fish oil. After removal of the fish oil, whatever material you are getting, that is the residue and screened material, the solid material meal, which you call fish meal. It is evaporated, dried, and you get basically the protein.

It is almost a similar process to that used for fish oil extraction. So, after the extraction of the oil, you get the meal, the protein. And which again is suspended, prepared as a suspension in water, some amount of water, etcetera is added, and an enzyme solution is added. So, it hydrolyzes and breaks down the protein into peptides. So, again, it may be separated with the help of enzymes that are converted into bioactive peptides, and it can even be broken down into amino acids. So, proteins, peptides, bioactive peptides or amino acids, this can be this is a series. And of course, there is a specific process parameters and other conditions like pressure, temperature and other conditions also can be used. And optimum process parameters, optimum technologies are available in the literature and even many industries are using it commercially to produce this product.



Fish waste proteins are considered nutritionally superior. As I told you earlier also due to their amino acid profiling, even they are used for collagen and gelatin production, collagen and gelatin are major proteins which are extracted from fish paste.

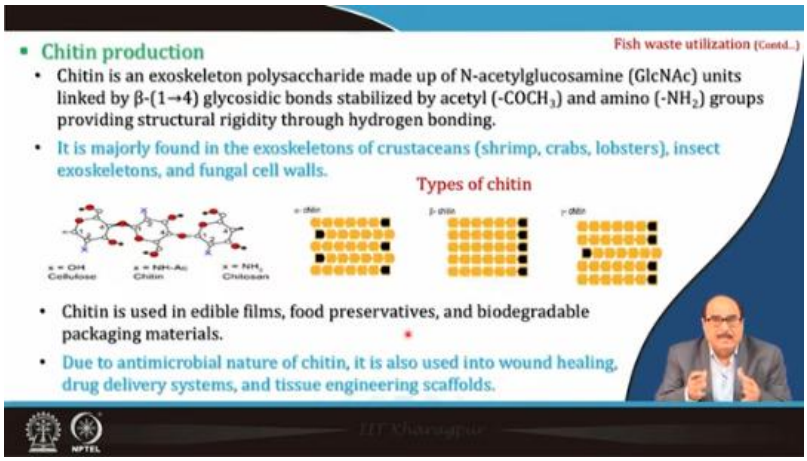
Gelatin it is majorly found in skin, scales and bones and gives higher yield in warm water supply. It involves acid or alkali extraction followed by thermal hydrolysis, filtration, centrifugation and drying. And this gelatin which is extracted or obtained from the fish waste, it can be used as a gelling agent, as a thickening agent, as a for preparation of soft gel capsules or even for the purpose of producing non-energy proteins. It has a wide application in functional food industry or other industry in the pharmaceutical industry and so on.



Then collagen and its extraction like cod, tilapia and crab skins are the major sources of collagen. Scale, bones and bladder of these fishes also contain considerable amount of collagen. So, enzymatic hydrolysis is the most commonly utilized method followed by

mechanical separation to remove the fish oil. And then from the meal the collagen is extracted by either acidic precipitation which is followed by mechanical concentration and finally, drying the collagen. So, the different methods may be acid precipitation whether using acetic acid or pepsin extraction that is the proteolysis.

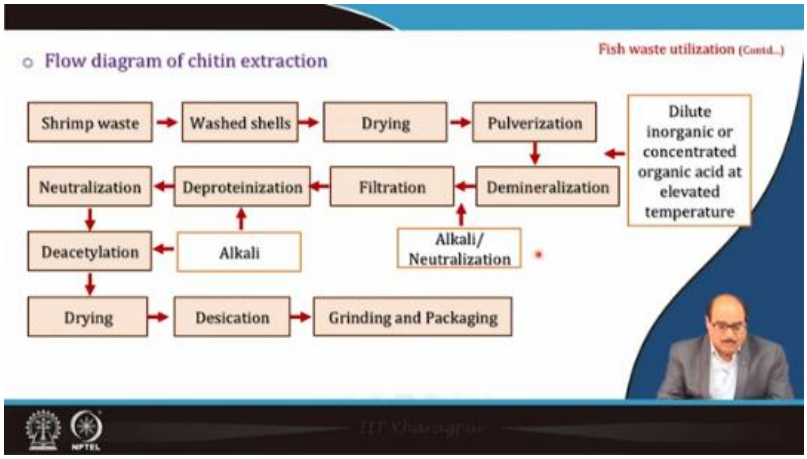
Even ultrasound assisted extraction there is cavitation it ultrasound creates cavitations and facilitate the extraction of protein and then it may be acid plus enzyme that is extraction enzyme assisted extraction. So, this collagen can be utilized as a stabilizer, base polymer for sustainable packaging and nutraceutical bioactive peptide for anti-aging activity. It has lot of use in again food and pharmaceutical.



Then let us talk about another major product byproduct or product of industrial significance which is produced from the fish industry waste material and that is the chitin, and which provides a structural rigidity through hydrogen bonding. So, this is a little complex structure and it is majorly found in exoskeletons of crustaceans, fishes like shrimps, crabs, lobsters' etcetera, also in the insect exoskeletons and fungal cell walls.

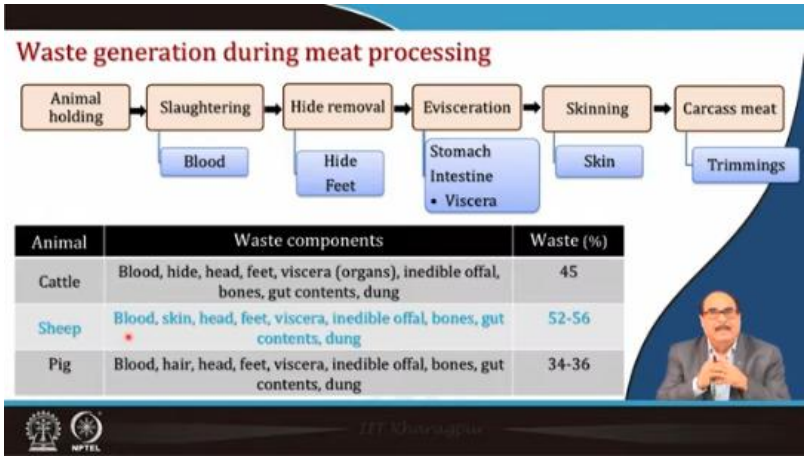
Look at the structure that is it has a complex structure and this you can see the in this X where this X is a OH group hydroxyl group in this structure then it becomes cellulose the same molecule, but when the X is replaced by amino group or acetyl group then it becomes chitin and when it is only amino group X is only amino group it becomes chitosan. There are depending upon the structure and other things there may be alpha chitin, beta chitin and gamma chitin as you can see here.

So, this chitin is used in edible film preparation, in food preservatives preparation as well as biodegradable packaging materials. It is used in preparation of biodegradable packaging materials. And due to antimicrobial nature of chitin, it is also used into wound healing, drug delivery systems and tissue engineering scaffolds. So, this chitin has very very wide commercial application in the packaging industry or even food preservation industry or many other such areas.

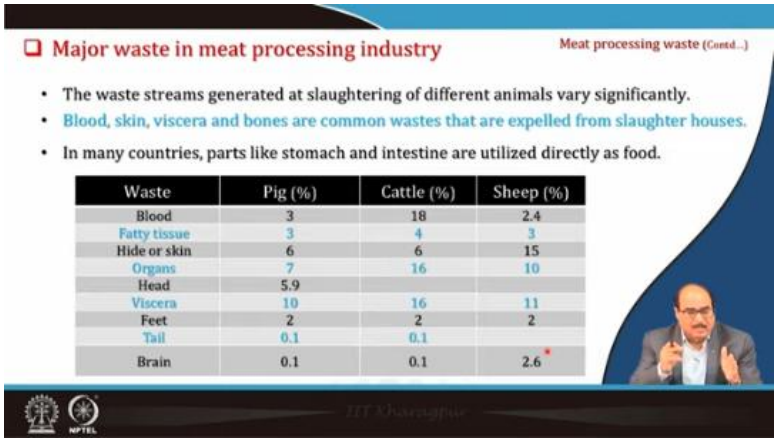


So, as far as the process of the chitin extraction. So, it is given here in this flow diagram. So, you can see the fish waste particularly if you say is to be very specific shrimp waste or such other fish waste. It has shells are washed, dried, and pulverized, ground into fine aerial and then it is treated with dilute inorganic or concentrated organic acids at elevated temperature. So, it causes demineralization. Then further it is treated with alkali or subjected to neutralization steps filtration and then deproteinization where proteins are removed with the help of alkali treatment.

Then again subjected to neutralization, deacetylation and the alkali also after deacetylation directly it is used. So, in this loop you get the chitin it is extracted chitin is extracted after deacetylation and then dried, ground and packaged. So, this is a process flow type of course, again I will emphasize that this is just I have given you the steps and this process has to be there are commercially available that technology is available and industries are using. So, one has to use the optimum conditions parameters as in every step to get the quality in the product.

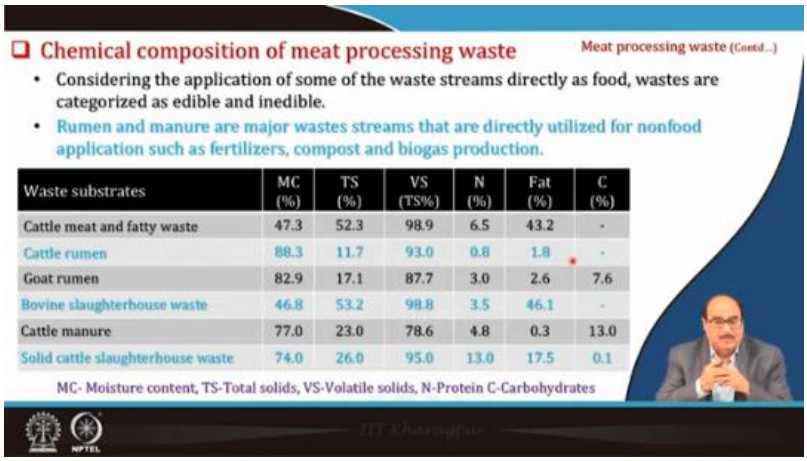


Then we will discuss now briefly the waste generation during meat processing. Again, the animal and animal are slaughtered till it is slaughtered for the different pieces of the meat which is used for cooking purposes or for conversion into various products. So, it is subjected to like slaughtering then after the as a step of slaughtering that is it is cut and then you get the blood and well as carcass and finally, carcass. So, in the process there is a removal of a hide and feet, then viscera are removed which includes stomach, intestine or other parts, then de-skinning is done, the skin is removed, feather is removed etcetera as the even after cutting the carcass various trimmings etcetera are removed. So, this various waste generation again in the process you can see that the cattle contain around 45 percent of the waste in the form of blood, hide, head, feet, viscera, inedible offal, bones, gut contents, dung, etcetera. Sheep contain around 52 to 55 percent waste, and pigs contain around 34 to 36 percent waste.



So, again, this can be used to show that the major waste stream generated during the slaughtering of different animals may vary in types, components, quantity, etcetera,

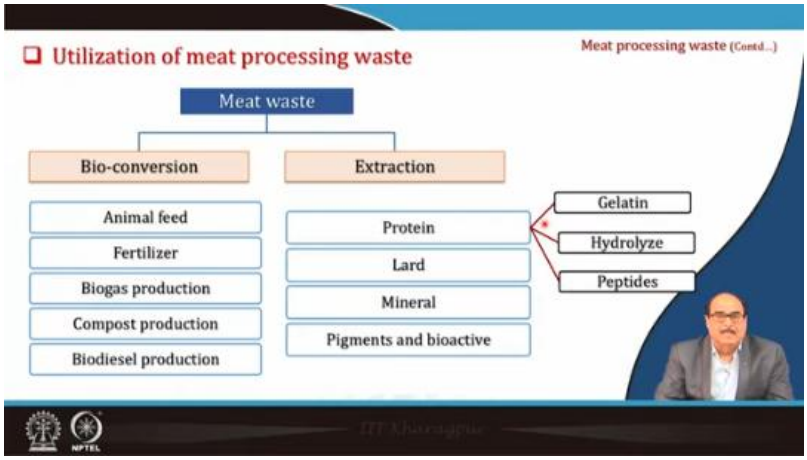
depending on the type of animal. Blood, skin, viscera, and bones, however, are the common wastes expelled from slaughterhouses. So, in many countries, parts like the stomach and intestine are utilized directly for food purposes. For example, you can see that pig blood contains 3 percent, cattle 18 percent, and sheep 2.4 percent. Fatty tissues account for almost 3 to 4 percent in pigs, cattle, sheep, etcetera—these three animals serve as examples. Here, hides and skins in sheep account for about 15 percent of the waste generated. In viscera, cattle produce around 15 to 16 percent waste, while pigs and sheep produce 10 to 11 percent. Similarly, the tail accounts for around 0.1 percent, and other components like the brain may account for 2.5 to 3 percent in sheep, and so on.



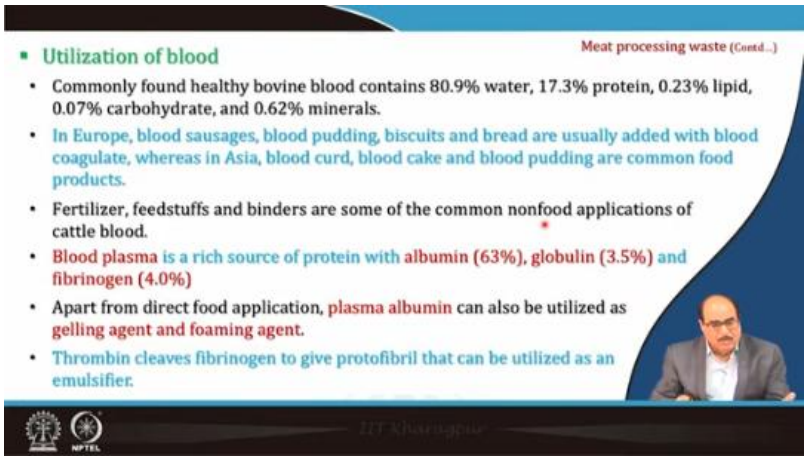
Waste substrates	MC (%)	TS (%)	VS (TS%)	N (%)	Fat (%)	C (%)
Cattle meat and fatty waste	47.3	52.3	98.9	6.5	43.2	-
Cattle rumen	88.3	11.7	93.0	0.8	1.8	-
Goat rumen	82.9	17.1	87.7	3.0	2.6	7.6
Bovine slaughterhouse waste	46.8	53.2	98.8	3.5	46.1	-
Cattle manure	77.0	23.0	78.6	4.8	0.3	13.0
Solid cattle slaughterhouse waste	74.0	26.0	95.0	13.0	17.5	0.1

So, if you look at the chemical composition of meat processing waste, it varies—for example, in cattle meat. Fatty waste may contain around 52 percent total solids, about 98 percent volatile solids, 6.5 percent nitrogen, and approximately 43 percent fat. Even goat rumen contains around 17 percent solids, 87 to 88 percent volatile solids, and about 7.6 percent carbohydrates. Similarly, solid cattle slaughterhouse waste, on average, contains 26 percent total solids, with about 95 percent volatile solids, 13 percent protein, 17.5 percent fat, and 0.1 percent carbohydrates, etcetera.

So, obviously, that is considering the application of some of the waste streams directly as food wastes are categorized as edible and inedible materials. And rumens and manures are major waste streams that are directly utilized for non-food applications such as fertilizer, compost, and biogas production.

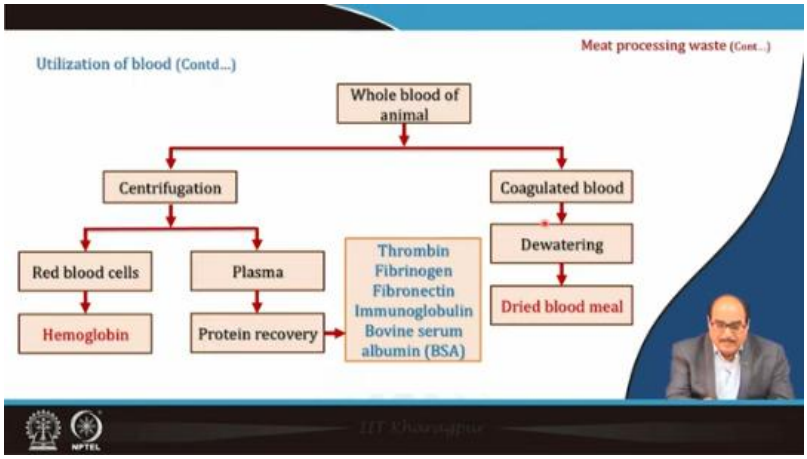


So, again, the utilization pathway for the meat processing waste may be bio-conversion or extraction. Bio-conversion, just like the case of fish, here also meat can be used for animal feed, fertilizer, biogas production, compost, and biodiesel production. And it can be used for extraction of protein like gelatin, hydrolyzed peptides, or even for lard production, minerals, pigments, and bioactives.



So, the blood mainly can be utilized; the commonly found healthy bovine blood contains around 81 percent water, about 17 percent protein, 0.23 percent lipid, and some amounts of carbohydrate and mineral. So, in Europe, blood sausages, blood puddings, biscuits, and breads are usually added with blood coagulates, whereas in Asia, blood curd, blood cake, and blood puddings are common food products. Fertilizers, feedstuffs, and binders are some of the common non-food applications of cattle blood. Even blood plasma, which is a rich source of protein with albumin about 63 percent, globulin 3.5 percent, and fibrinogen 4.0 percent, can be used for various purposes. Apart from direct food application, even the

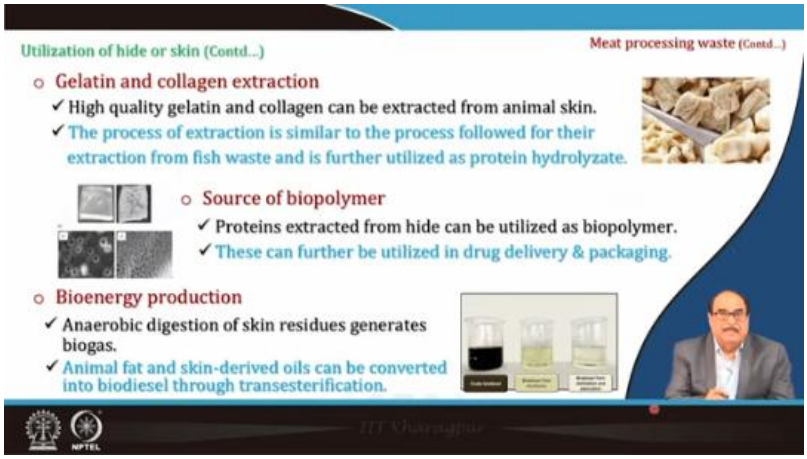
plasma albumin can also be utilized as a gelling agent as well as a foaming agent in various processes. Thrombin cleaves fibrinogen to give profit, that is the protofibril, that can be utilized as an emulsifier.



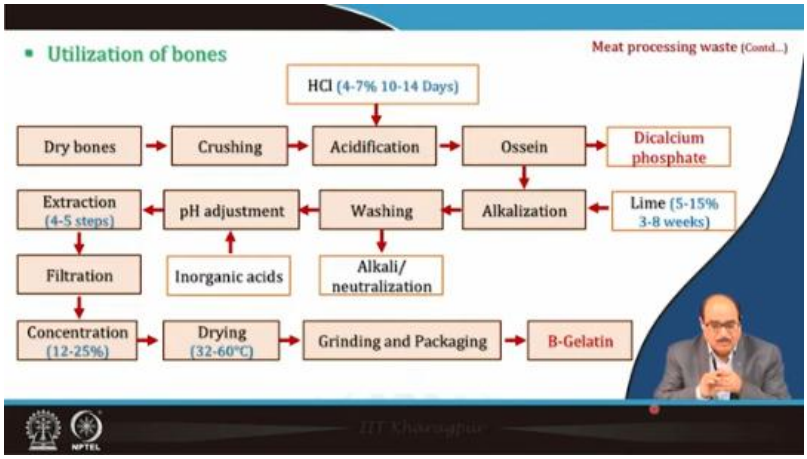
So, this blood has various food as well as non-food uses. There is whole blood of the animal; again, it is centrifuged, you get red blood cells, hemoglobin, or the plasma, which is obtained and used for protein recovery like thrombin, fibrinogen, immunoglobulin, bovine serum albumin, and so on. And the coagulated blood is dewatered and dried into blood meal, which can be further used in various food preparations, etcetera.

Similarly, the utilization of hides or skins, if you look at India, shows that 2 million tons of raw hides and skins are produced annually, with buffalo and cattle accounting for a significant portion of this. So, it is often regarded as waste but has significant economic potential, when processed into value-added products like leather, gelatin, and collagen. The animal skin waste supports a robust leather industry in India, contributing to about 5 billion

US dollars in annual exports. Apart from leather, animal skin is utilized for the extraction of several compounds and used in pharmaceutical, cosmetic, and functional food industries.

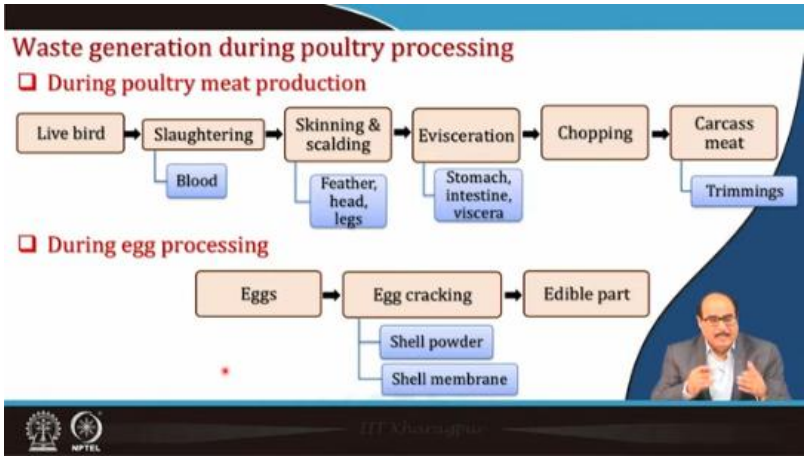


It can be majorly utilized for gelatin and collagen extraction using the same process that we discussed in the case of fish, etcetera. It can be used as a source of biopolymers like proteins, which can be utilized as biopolymers. These can further be utilized in drug delivery and packaging these biopolymers. These can be utilized for bioenergy production because anaerobic digestion of skin residues generates biogas or even. Animal fat and skin-derived oils can be converted into biodiesel through transesterification, etcetera, of the process which we discussed earlier.

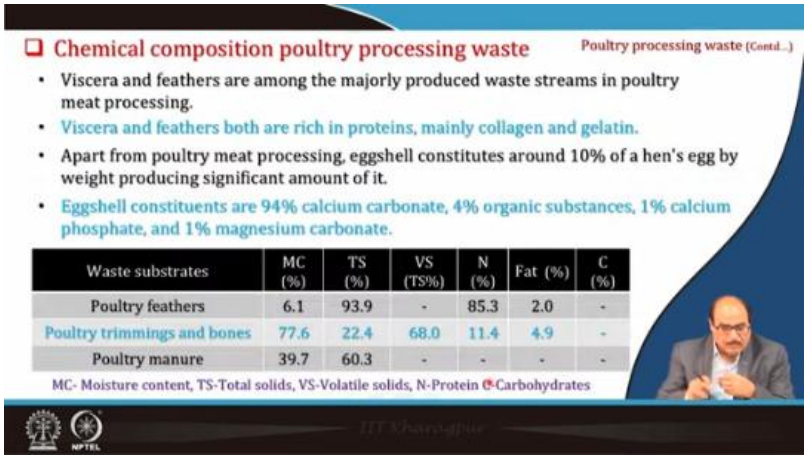


So, even the bones can also be utilized for the preparation of dicalcium phosphate or for beta gelatin, etcetera. And the process is shown here: dry bones, crushing, acidification with the help of hydrochloric acid (4 to 7 percent) for 10 to 14 days, then alkalization

washing, pH is adjusted, and finally, there are 4-5 steps of extraction used, and you get the material. It is filtered, concentrated, and dried so that you can get the bones, dried bone powder, etcetera. Even if it is drying, it may be done at 32 to 60 degrees Celsius, and then it is ground and packaged to get the gelatin.

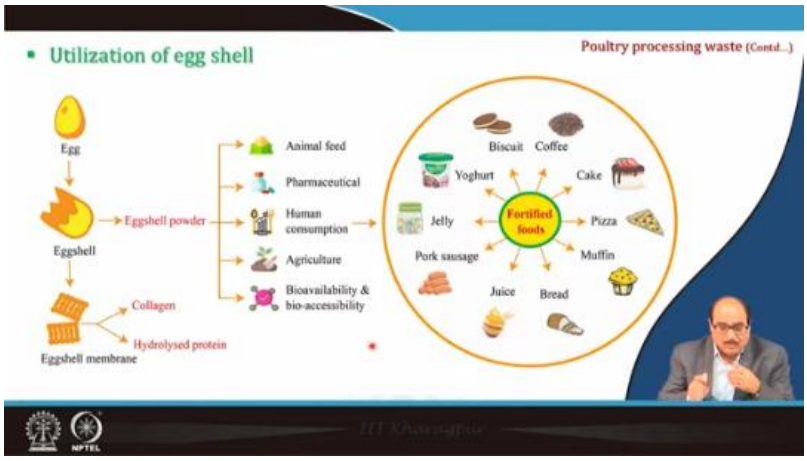


Then finally, let's briefly talk about waste generation during poultry processing, whether it may be poultry meat processing or egg processing. In poultry meat processing, major waste includes blood, feathers, heads, legs, stomachs, intestines, viscera, and trimmings. Whereas, in egg processing, such as egg cracking, it generates shell powder or shell membrane, etcetera.



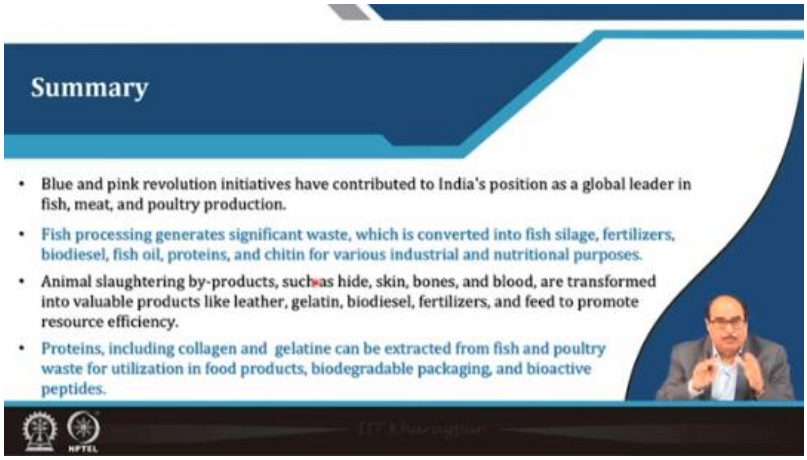
So, the chemical composition again, viscera and feathers are among the majorly produced waste streams in poultry meat processing. Viscera and feathers, like others here, are rich in protein, mainly collagen and gelatin. Apart from poultry meat processing, eggshells constitute around 10 percent of a hen's eggs by weight, producing a significant amount of

it. Eggshells consist of around 94 percent calcium carbonate, 4 percent organic substances, 1 percent calcium phosphate, and 1 percent magnesium carbonate. And these can be used for various purposes. You can see here that poultry feathers contain around 93 percent total solids, 85 percent proteins, and 2 percent fats. Poultry trimmings and bones contain around 22 percent total solids, 68 percent volatile solids, and 11 percent protein. Even poultry manure can be used, which contains 60 percent total solids.



So, overall utilization of eggshells, that is, the eggshell can be converted into eggshell powder or used for the eggshell membrane for collagen extraction as well as hydrolyzed protein preparation.

This eggshell powder, once made, can be used as animal feed or in pharmaceutical industries. It can also be used for human consumption, particularly for the fortification of various foods, because eggshell powder contains good-quality minerals and even some vitamins, etcetera. These minerals can be used to fortify cakes, pizzas, muffins, bread, jam, jelly, pork, sausage, yogurt, biscuits, etcetera, or even coffee fortification. Also, this can be used in agriculture, or it is very good. Its bioavailability and bioaccessibility of this powder are very good.



So finally, I would like to summarize this lecture by saying that the Blue and Pink Revolution initiatives contributed to India's position as a global leader in fish, meat, and poultry production. Fish processing generates significant waste, which is converted into fish silage, fertilizers, biodiesel, fish oil, protein, and chitin for various industrial and nutritional purposes. Animal slaughtering byproducts like hide, skin, bone, blood, etc., are transformed into valuable products like leather, gelatin, biodiesel, fertilizers, etc., to promote resource efficiency.

Proteins, including collagen and gelatin, are extracted from fish and poultry for utilization in food products, biodegradable packaging, and bioactive peptides, etc. So, in this way, they not only prevent, that is, they prevent or eliminate environmental pollution, because otherwise, if these materials are left as such, they will degrade and cause greenhouse gas emissions, carbon emissions, etc., thereby polluting the environment. So, by having an effective mechanism in place for proper collection and utilization of fish, meat, and poultry processing industry waste into value-added products, we achieve better environmental control as well as resource economy. There is a better output, and it adds more value to both producers and consumers.

So, these were the references used in the preparation of this lecture.

With this, Thank you very much for your patient hearing. Thank you.