FOOD SCIENCE AND TECHNOLOGY

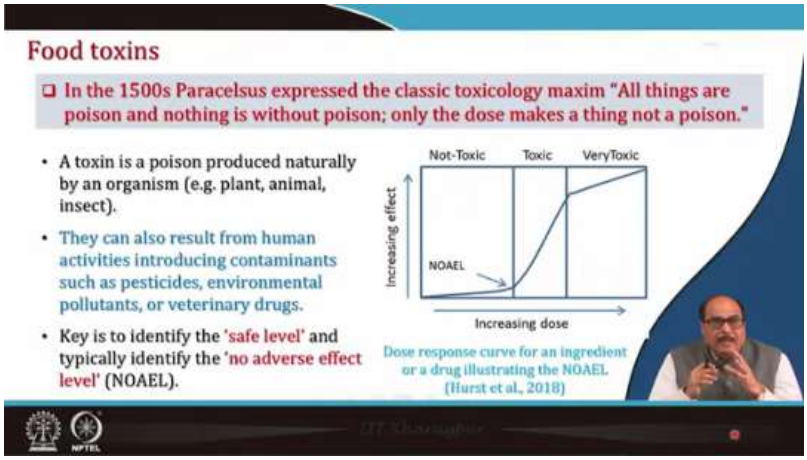
Lecture39

Lecture 39: Toxins and Allergens

Hello everyone. Namaste.

In today's lecture, we will talk about food toxins and allergens.

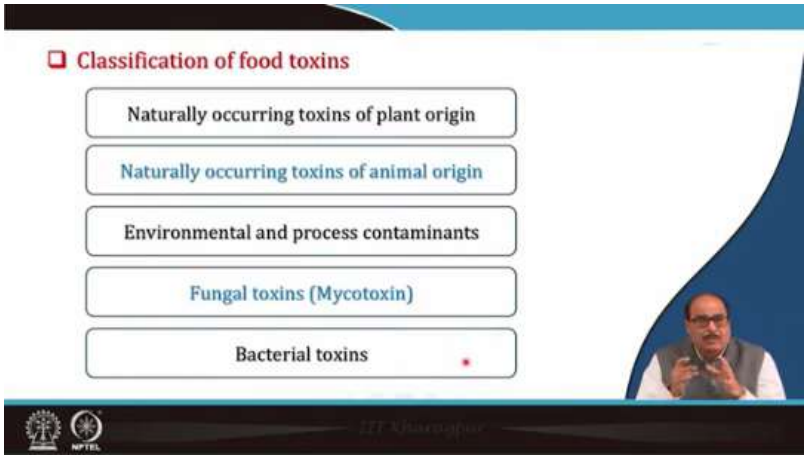
We will discuss various naturally occurring food toxins, microbial toxins, and contaminants, food allergens and anti-nutrients, and towards the end of the lecture. We will also talk about the detection of allergens and toxins in foods.



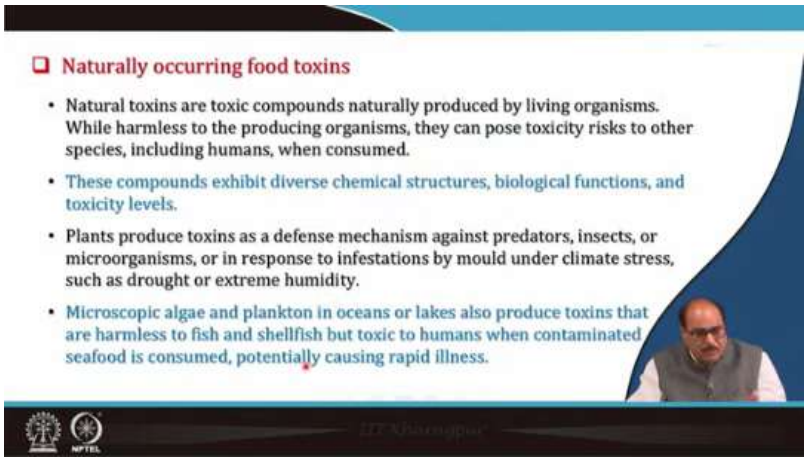
In the 1500s, Paracelsus expressed the classic toxicology maxim, and what did he say? All things are poison, and nothing is without poison. Only the dose makes a thing, not a poison. So, a toxin is a poison produced naturally by an organism, such as a plant, animal, insect, microorganism, or so on. They can also result from human activities introducing contaminants such as pesticides, environmental pollutants, or veterinary drugs. So, the key is to identify the safe level and typically identify the no adverse level, that is nodal, okay. So, you can see here in this figure that it has been shown for any product, such as toxin, etcetera, increasing the dose and then increasing the effect. So, there may be a dose range where there is no effect. It has no toxic effect. So, then there will be a toxic effect, and finally, it may be that when you further increase the dose, it may become very toxic. So, this point can be a nodal, that is, there may be no adverse effect level. So, that has to be found out, and accordingly, one should proceed.

Then, scheme of the toxic compounds that could be found in milk food material, there may be bacterial toxins, there may be mycotoxins that is fungal toxins or even heavy metals like lead, mercury, arsenic, cadmium, chromium, etcetera or even pesticide residues,

chlorpyrifos or diazinon etcetera. There may even be many anti-nutrients present in the food, like phytates, oxalates, and so on.

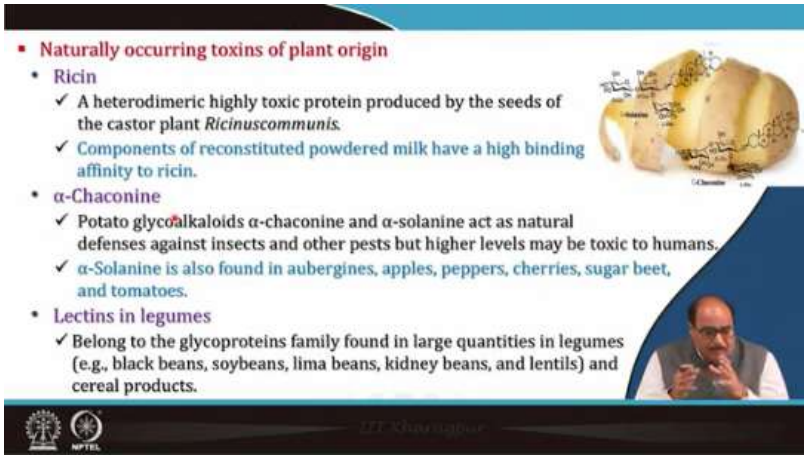


So, these food toxins that might be present in the food can be classified into various groups. There may be a class called naturally occurring toxins of plant origin or naturally occurring toxins of animal origin. They may be environmental and process contaminants, even fungal toxins like mycotoxins, etcetera. And more importantly, there will also be a class of toxins that are produced by bacteria, which are bacterial toxins.

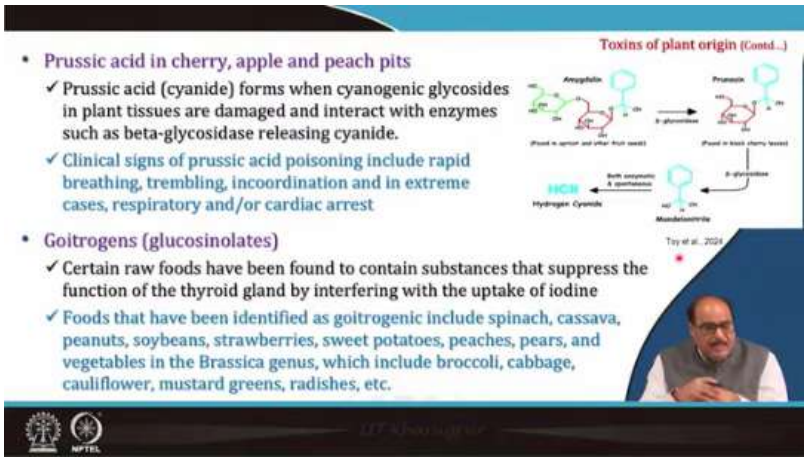


So, let us briefly take one by one, like naturally occurring toxins in food. They are toxic compounds. Naturally produced by living organisms, while they are harmless to the producing organism that produces these toxins, they might not be harmless to other organisms, but they can pose a toxicity risk to other species, including humans, when consumed. These compounds exhibit diverse chemical structures, biological functions, and toxicity levels. Plants produce toxins as a defence mechanism against predators, insects, or microorganisms or in response to infections by mould under climate stress, such as drought

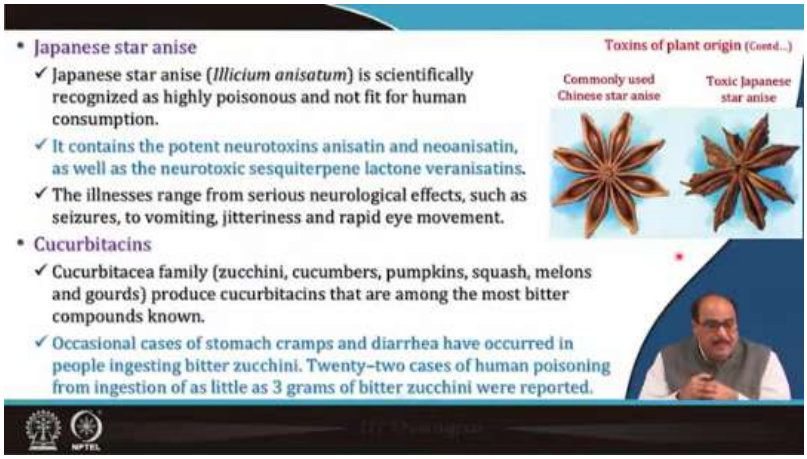
or extreme humidity. Microscopic algae and plankton in oceans or lakes also produce toxins that are harmless to fish and shellfish but are toxic to humans when contaminated seafood is consumed and they potentially cause rapid illness, etcetera.



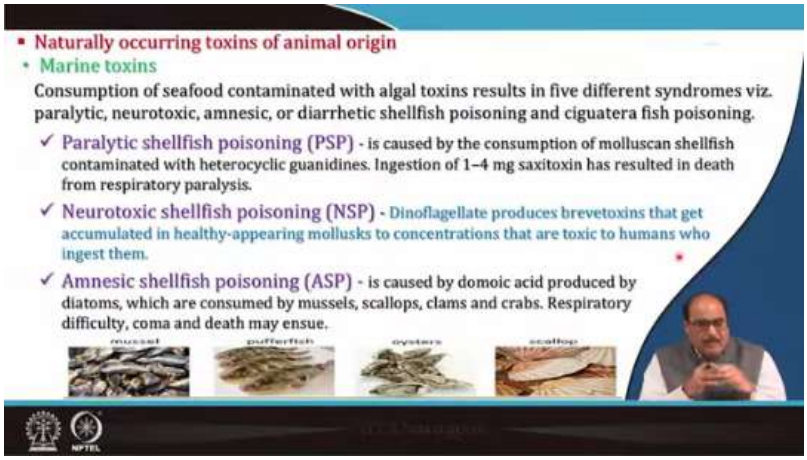
So, sometimes it even happens that these plant or animal materials produce certain compounds in their self-defense mechanism, but those compounds might be toxic to other biological agents or humans when consumed. You can take a few examples like ricin, a heterodimeric highly toxic protein produced by the seeds of the castor plant. The components of reconstituted powdered milk have a high binding affinity to ricin. Then alpha-chaconine is a potato glycoalkaloid. Alpha-chaconine and alpha-solanine. They act as a natural defence against insects and other pests, but higher levels may be toxic to humans. Alpha-solanine is also found in aubergines, apples, peppers, cherries, sugar beet, tomatoes, etcetera. But if you consume high levels of these, it may be toxic. Then lectins in legumes belong to the glycoprotein family and are found in large quantities in legumes like black beans, soybeans, lima beans, kidney beans, and other lentils, and even many other cereal products.



Then prussic acid in cherry, apple, and peach pits, that is prussic acid or cyanide, it forms when cyanogenic glycosides in plant tissues are damaged and they interact with enzymes such as beta-glycosidases, releasing cyanide. Then, clinical signs of prussic acid poisoning include rapid breathing, trembling, incoordination, and in extreme cases, respiratory and even cardiac arrest. Goitrogens or glucosinolates might be present naturally in various materials. So, certain raw foods have been found to contain substances that suppress the function of the thyroid gland by interfering with the uptake of iodine. Foods that have been identified as goitrogenic include spinach, cassava, peanuts, soybeans, even sweet potatoes, pears, and vegetables in the Brassica genus which include broccoli, cabbage, cauliflower, mustard greens, radishes, etcetera.



Then, even Japanese star anise is scientifically recognized as highly poisonous and is not fit for human consumption. It contains the potent neurotoxins anisatin and neoanisatin, as well as the neurotoxic sesquiterpene lactone veranisatins. The illness ranges from serious neurological effects, such as seizures, to vomiting, jitteriness, and rapid eye movement. Then, cucurbitacins: The Cucurbitaceae family, like cucumbers, pumpkins, squash, melons, and gourds, etc. They produce cucurbitacins, which are among the most bitter compounds known. Occasional cases of stomach cramps and diarrhea have occurred in people ingesting bitter zucchini. Even 22 cases of human poisoning from ingesting as little as 3 grams of bitter zucchini have been reported in the literature.

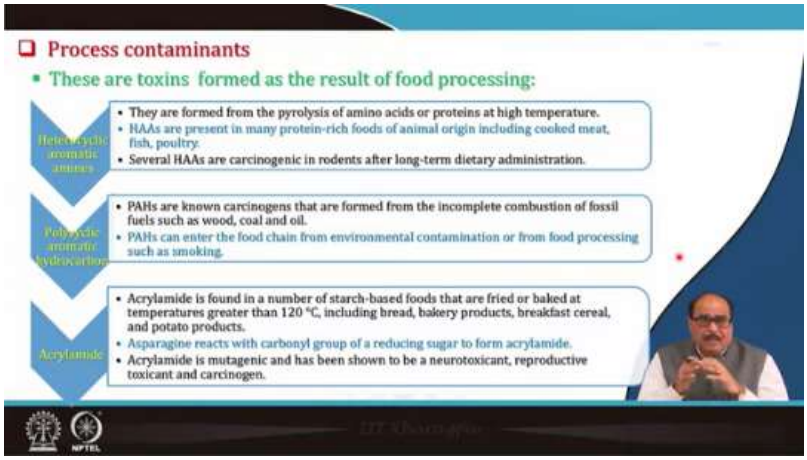


Then, let us talk about naturally occurring toxins of animal origin, like marine toxins. Consumption of seafood contaminated with algal toxins results in five different syndromes, such as paralytic, neurotoxic, amnesic, diarrhetic shellfish poisoning, and ciguatera fish poisoning. Paralytic shellfish poisoning, or PSP, is caused by the consumption of molluscan shellfish contaminated with heterocyclic guanidines. Ingestion of 1 to 4 milligrams of saxitoxin has resulted in death from respiratory paralysis. Then, neurotoxic shellfish poisoning, or NSP, is caused by dinoflagellates that produce brevetoxins that accumulate in healthy-appearing mollusks to concentrations toxic to humans who ingest them. Amnesic shellfish poisoning is caused by domoic acid, produced by diatoms, which are consumed by mussels, scallops, clams, and crabs. It may result in respiratory difficulty, coma, and even death of the person who consumes this.

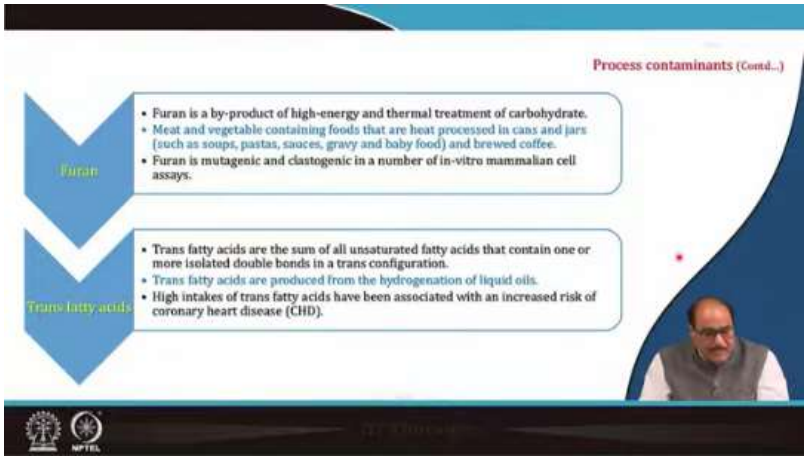
Then, diarrhetic shellfish poisoning, or DSP, is caused by the production of okadaic acid and dinophysistoxins in the dinoflagellates consumed by mollusks. Symptoms of DSP are relatively mild, but long-term, low-level exposure to DSP toxins has been shown to be tumor-promoting. The other type is the Ciguatera fish poisoning CFP, and it is caused by

the Dinoflagellate that is Dinoflagellate Gambierdiscus toxicus, which grows in the filamentous microalgae associated with coral reefs. High Ciguatoxin concentrations may be found in Barracuda, Snapper, Grouper and Jacks etcetera. So, naturally occurring toxins do not involve marine algae that is a gempylotoxin found in oilfish or cocco result in diarrhea. tetrodotoxin found primarily in puffer fish, extremely fatal with no known antidote, antidote etcetera.

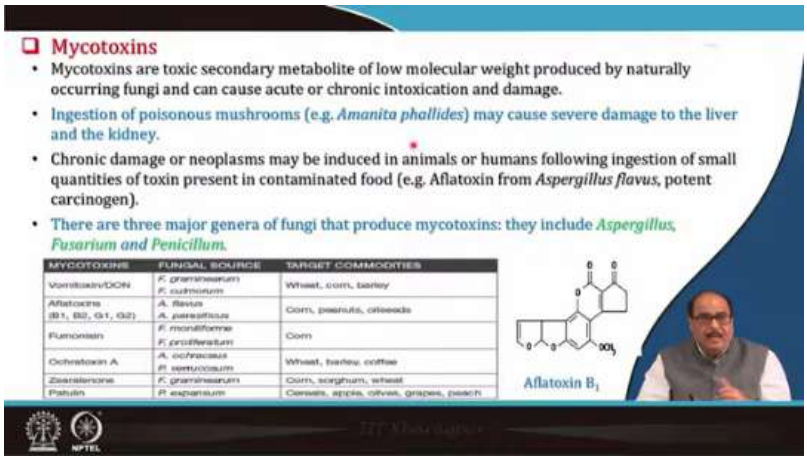
The environmental food toxins like selenium are found some time in grains. This selenium enters the food chain via the plant and microorganism conversion of inorganic conversion of inorganic selenium to organically bound forms. The most common symptoms are loss of hair deformity and loss of nails. 3 to 5 milligrams per day of selenium consumption would cause selenosis. Methyl mercury in seafood is another very common type of environmental food toxin. Exposure to elementary mercury is relatively rare. That is elemental mercury exposure to elemental mercury is relatively rare, but it may cause neurological paresthesias, ataxia, dysarthria, hearing defects and death even. Fish consumption causes human exposure. Mercury in a specific occupational area. So, particularly in lakes or ponds where heavy industrial pollutants, etcetera, are present. So, fish consumption may be contaminated with methylmercury. And if fish contaminated with methylmercury is consumed, it may be fatal. There are quite a few cases reported in the literature regarding this toxin.



Then, again, a very important group is the process contaminants, that is, contamination or toxic compounds, which might form during faulty processing or during the processing of food materials, that is, you can say, heterocyclic aromatic amines. They are formed from the pyrolysis of amino acids or proteins, particularly at high temperatures. So, when food is processed at high temperatures, it may lead to the formation of heterocyclic aromatic amines. These HAAs are present in many protein-rich foods of animal origin, including cooked meat, fish, poultry, etcetera. Several HAAs are carcinogenic in rodents after long-term dietary administration. So, there are other types of compounds that can be formed during processing but are toxic; they may include polycyclic aromatic hydrocarbons (PAHs). So, these polycyclic aromatic hydrocarbons are known carcinogens that are found in formed from the incomplete combustion of fossil fuels such as wood, coal, and oil. These polycyclic aromatic hydrocarbons can enter the food chain through environmental contamination or from food processing such as smoking, etcetera. Then, acrylamide, another very important type of chemical, is generated during food processing. Acrylamide is found in a number of starch-based foods that are fried or baked at high temperatures, particularly at temperatures greater than 120 degrees Celsius. This may be present in bread, bakery products, breakfast cereals, potato products, fries, etcetera. Asparagine, which is an amino acid, reacts with the carbonyl group of the reducing sugar present in these compounds when such foods are exposed to temperatures above 120 degrees Celsius, and it forms the chemical acrylamide. Acrylamide is mutagenic and has been shown to be a neurotoxicant, reproductive toxicant, and carcinogen.

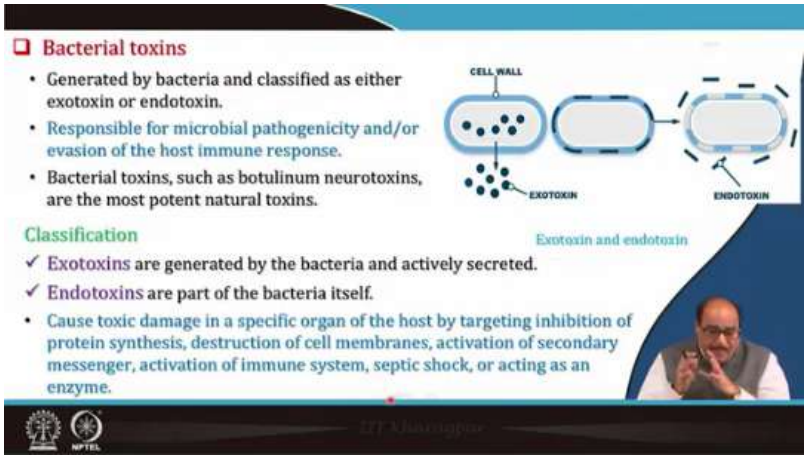


Then, furan or furan derivatives. Furan is a byproduct of high-energy and thermal treatment of carbohydrates. Meat and vegetable-containing foods that are heat-processed in cans and jars, such as soups, pasta, sausage, gravy, baby foods, etc., as well as brewed coffee, might contain significant amounts of furan. So, this furan is mutagenic and clastogenic in a number of in vitro mammalian cell assays. Then trans fatty acids are very important chemicals which are formed during processing. Trans fatty acids are unsaturated fatty acids that contain one or more isolated double bonds in a trans configuration. In fact, natural fatty acid fats and oils consist of polyunsaturated fatty acids in cis configuration. So, in such oils, either during the process of hydrogenation or during the refining process, when these oils are given heat treatment, then this cis configuration is converted into trans configuration. These trans fats are even more dangerous than saturated fats because they result in a high intake of trans fat. Trans fatty acids have been associated with an increased risk of coronary heart disease etcetera CSDR CVD.



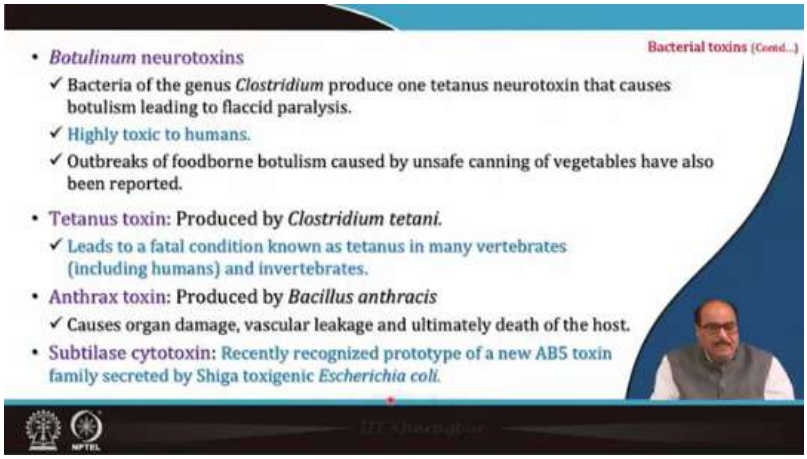
Then, let us talk about fungal toxins or micor mycotoxins. These mycotoxins are secondary metabolites of low molecular weight produced by naturally occurring fungi that can cause

acute or chronic intoxication and damage. Ingestion of poisonous mushrooms such as Amanita phalloides may cause severe damage to the liver and kidneys. Chronic damage or neoplasms may be induced in animals or humans following ingestion of small quantities of toxins. Present in contaminated food, such as aflatoxin, which is produced by the fungi *Aspergillus flavus*. It is a potent carcinogenic material. There are three major genera of fungi that produce mycotoxins: *Aspergillus*, *Fusarium*, and *Penicillium*. There are various mycotoxins, such as vomitoxin (DON), which is produced by *Fusarium graminearum* or *Fusarium culmorum*, and may be present in wheat, corn, and barley. Then there are aflatoxins B1, B2, G1, G2, etc. The fungi Aspergillus flavus or Aspergillus parasiticus may be problematic in corn, peanuts, oilseeds, etc. Ochratoxin A is produced by *Aspergillus ochraceus* and *Penicillium verrucosum*, and may be present in wheat, barley, and coffee. Patulin is produced by *Penicillium expansum* and may be present in cereals, apples, olives, grapes, peaches, etc. There are several toxin-producing fungi, yeasts, or molds that should be taken care of.

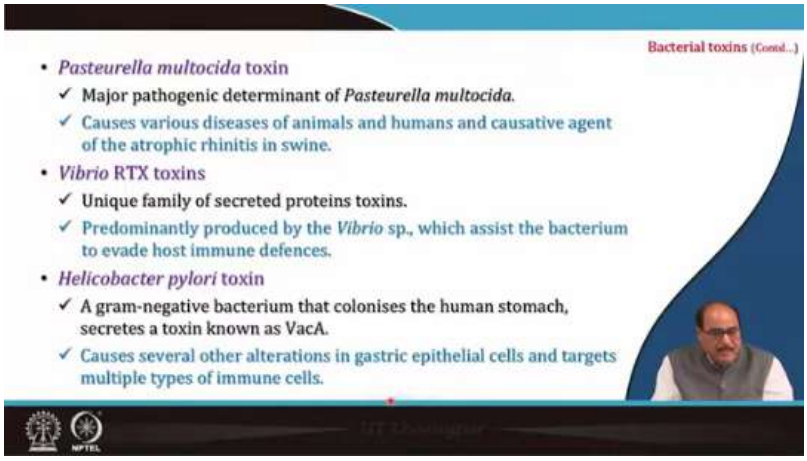


Then, bacterial toxins in the earlier class, when we were talking about microbiology or microorganisms associated with foods, we also talked about bacterial toxins. So, these are basically toxins generated by bacteria and classified as either exotoxins or endotoxins. That is, the bacteria produce toxins that remain inside the bacterial cell. Then, it does not release the toxin outside. So, it is an endotoxin. So, when you consume bacteria containing toxins, it causes problems. But there may be another group of bacteria that, when they grow on food, produce toxins and release them into the food. So, the food becomes toxic. So, accordingly, that is the exotoxin. So, bacterial toxins are responsible for microbial pathogenicity and or evasion of the host immune response. Bacterial toxins such as *botulinum* neurotoxins are the most potent natural toxins. Then, the exotoxins are generated by bacteria and actively secreted, while endotoxins are part of the bacteria itself. Then,

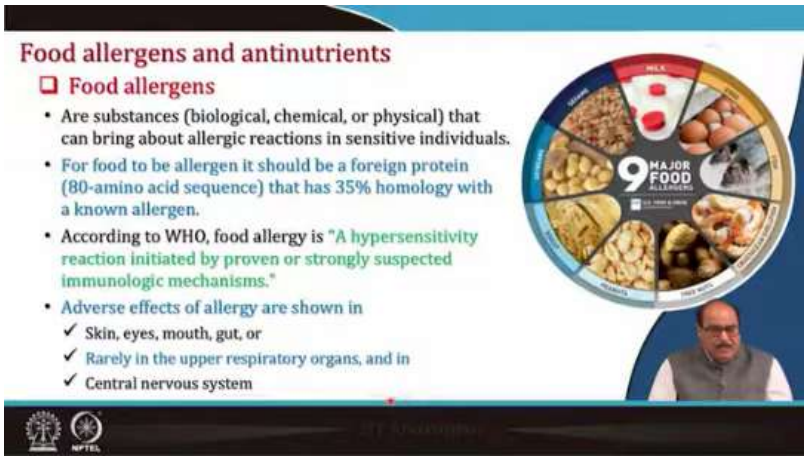
both cause toxic damage in a specific organ of the host by targeting and inhibiting protein synthesis. Destruction of the cell membrane, activation of secondary messenger, activation of the immune response or septic shock, or acting as an enzyme.



Then, *botulinum* neurotoxins—we have earlier also discussed with the bacteria of the genus *Clostridium* produce one tetanus neurotoxin that causes botulism, leading to flaccid paralysis; it is highly toxic. to humans. Even a microgram of this botulinum toxin is fatal to human beings and may cause the death of a healthy person. Outbreaks of foodborne botulism caused by unsafe canning of vegetables have also been reported in the literature. Then, tetanus toxin is produced by *Clostridium tetani*; it leads to a fatal condition known as tetanus in many vertebrates, including humans, as well as in invertebrates. Then, anthrax toxin is produced by Bacillus anthracis, which causes organ damage, vascular leakage, and ultimately the death of the host. Then, subtilase cytotoxin is a recently recognized prototype of a new AB5 toxin family secreted by Shiga toxigenic *E. coli*.



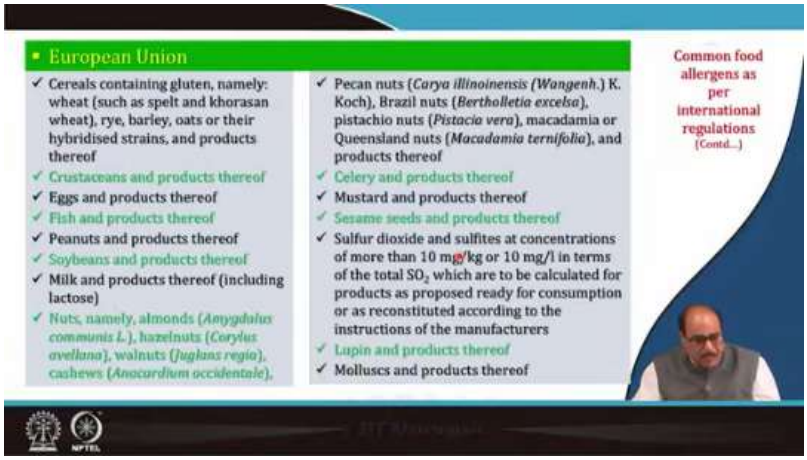
Then, even *Pasteurella multocida* toxin. It is a major pathogenic determinant of *Pasteurella multocida*. It causes various diseases in animals and humans and is the causative agent of atrophic rhinitis in swine. Then, Vibrio-RTX toxins are a unique family of secreted protein toxins. It is predominantly produced by Vibrio species, which assist the bacterium in evading host immune defence. Helicobacter polytoxin is a gram-negative bacterium that colonizes the human stomach. It secretes a toxin known as VacA, which causes several other adulterations in gastric epithelial cells, and targets multiple types of immune cells.



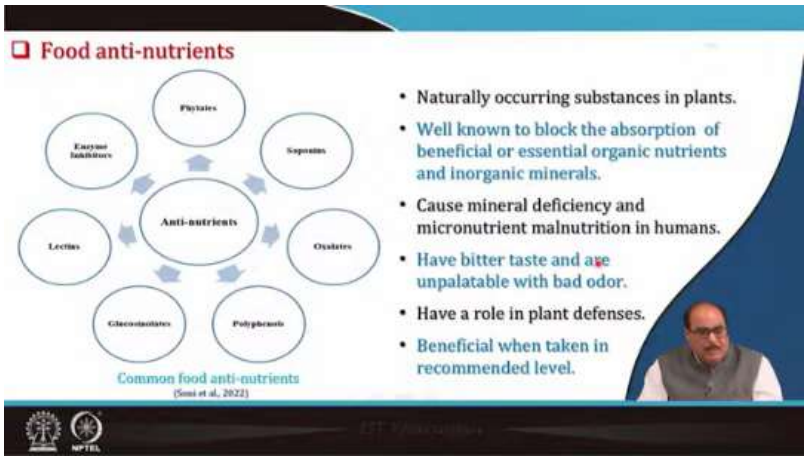
Then, let us discuss food allergens and anti-nutrients. We have discussed the naturally occurring toxins, the environmental effects of toxins, processing and even mycotoxins. Now, let us talk about food allergens and anti-nutrients. So, food allergens again they are biological, chemical or physical substances, physically present or biologically or chemical substances that can bring about allergic reactions in sensitive individuals. For food to be an allergen, it should be a foreign protein, which may be 80 amino acids in chickens, that have 35 percent homology with a known allergen. According to the World Health Organization, food allergy is a hypersensitivity reaction initiated by a proven or strongly suspected immunologic mechanism. So, adverse effects of allergy are shown in the skin, eye, mouth, gut or rarely even upper respiratory organs, as well as in the central nervous system.

Then, symptoms of the food allergy may include wheezing, skin reactions like swelling and itching, watery and itchy eyes, runny nose, or even anaphylaxis, including trouble breathing and dizziness or a burning sensation in the lips and mouth, etcetera. So, there might be various symptoms if one is allergic to any food or food material.

So, common food allergens, as per international regulations, include cereals containing gluten—wheat, rice, barley, oats, spelt (hybridized strains), and products of these. Then, crustaceans and their products; eggs and egg products; fish and fish products; peanuts; soybeans and their products; milk and milk products, including lactose; tree nuts and nut products; sulphites in concentrations of 10 milligrams per kg or more. So, these are the food allergens as per the Codex Alimentarius.

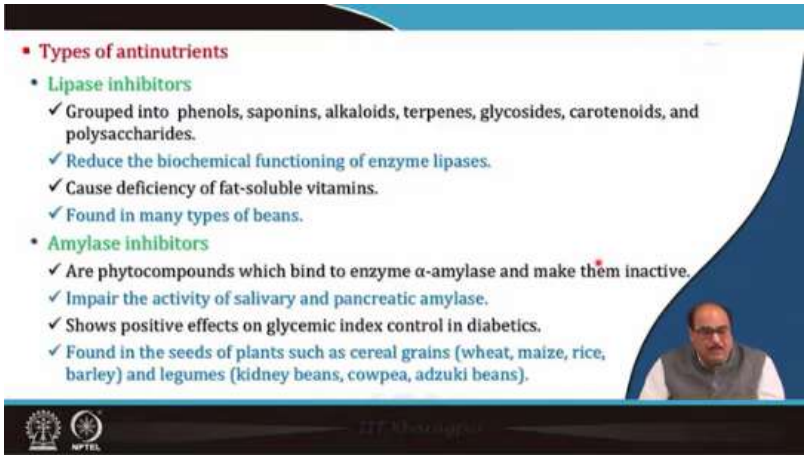


In the European Union, the rules are even stricter, defining food allergens as cereals containing gluten, like wheat, rye, barley, oats, or hybridized strains, and their products. Crustaceans and products thereof; eggs and products thereof; fish and products thereof; Peanuts, soya bean, milk and milk products, nuts namely almonds, hazelnuts, walnuts, even pecan nuts, Brazil nuts, macadamia nuts. Macadamia or queen's leg nuts, celery and products thereof, mustard and products thereof, sesame seed and products thereof, sulphur dioxide and sulphide concentration more than 10 milligrams per kg or 10 milligrams per litre in terms of the total sulphur dioxide or lupin and products thereof, molluscs and products thereof. So, all these contain one or the other allergens according to the European Union regulations.

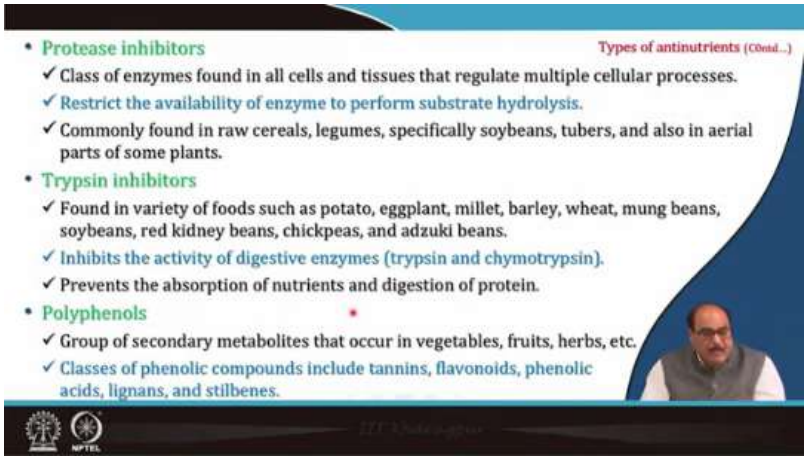


Then food anti-nutrients: The anti-nutrients are a class of naturally occurring substances in plants or other foods. They are well known to block the absorption of beneficial or essential organic nutrients and inorganic material, particularly minerals. They cause mineral deficiency and micronutrient malnutrition in humans. They have a bitter taste and are

unpalatable with a bad odour. They have a role in plant defence. However, they are sometimes beneficial when taken at the recommended level.

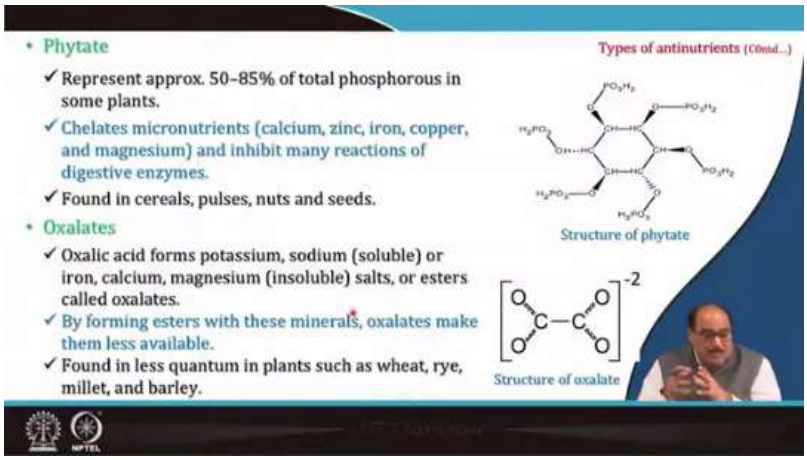


So, the different types of inhibitors, if you look at the lipase inhibitors, they are grouped into phenols, saponin, alkaloids, terpenes, glycosides, carotenoids and polysaccharides. Reduce the biochemical functioning of the enzyme lipase, causing defence. A deficiency of fat-soluble vitamins is found in many types of beans. Amylase inhibitors are phyto-compounds that bind to the enzyme alpha-amylase and make them inactive. They impair the activity of salivary and pancreatic amylases. They show a positive effect on glycemic index control in diabetics. These amylase inhibitors are found in the seeds of plants, such as cereal grains like wheat, maize, rice, barley, as well as in legumes like kidney beans, cowpea, and other beans.

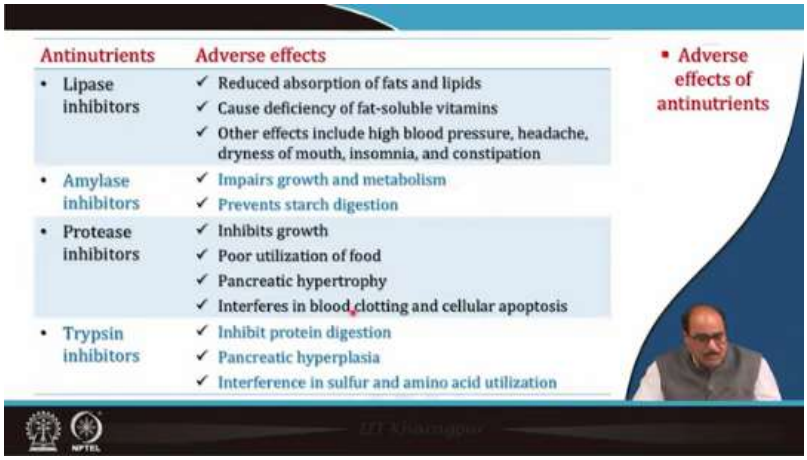


Then, protease inhibitors are a class of enzymes found in all cells and tissues that regulate multiple cellular processes. They restrict the availability of enzymes to perform substrate hydrolysis. Commonly found protease inhibitors are in cereals, legumes, especially

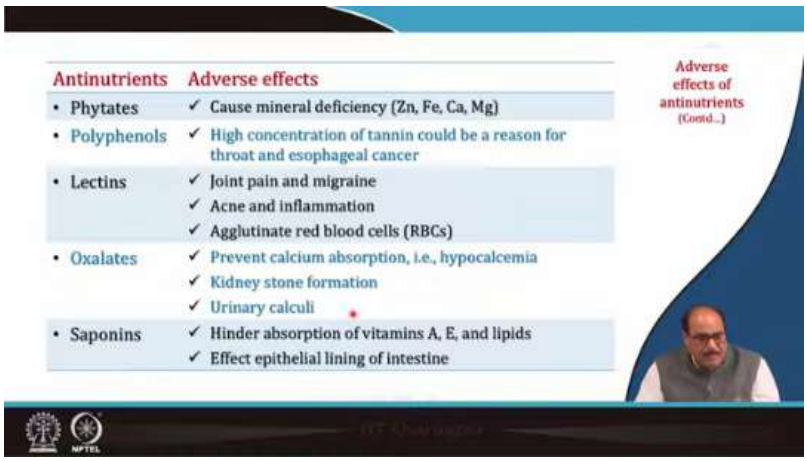
soybeans, tubers, and aerial parts of some plants. Then, trypsin inhibitor, one of the most widely known inhibitors, is found in a variety of foods such as potato, eggplant, millet, barley, wheat, and mung beans, and mainly in comparatively higher amounts. Soybeans, even red kidney beans, chickpeas, and adzuki beans. These trypsin inhibitors inhibit the activity of digestive enzymes, particularly trypsin and chymotrypsin. Obviously, it prevents the absorption of nutrients and the digestion of proteins. Then polyphenols—some of the polyphenols—are also anti-inhibitory; anti-nutrients come in this category. So, a group of secondary metabolites that occur in vegetables, fruits, herbs, they are a class of phenolic compounds, including tannins, flavonoids, phenolic acids, lignans, and stilbenes, etcetera. So, many, of course, are anti-nutrients, but many of these compounds have good beneficial—we have discussed earlier also—have beneficial properties, but they may, in some individuals, certain individuals, cause allergenicity may cause other adverse effects.



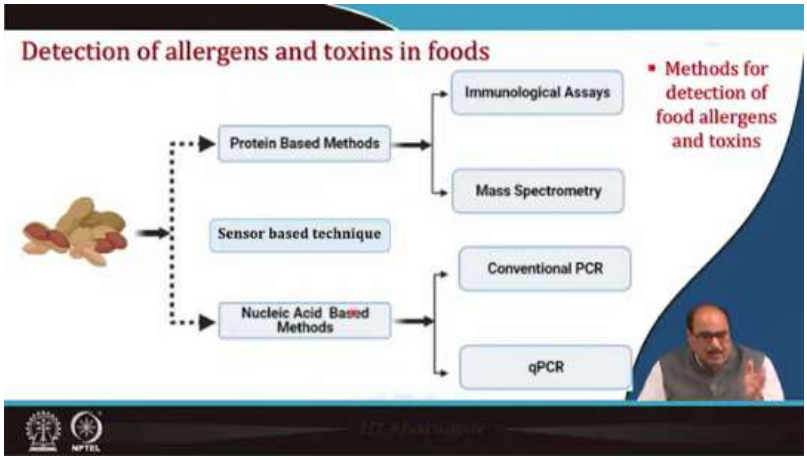
Then, even phytate—the phytate—represents approximately 50 to 85 percent of the total phosphorus in some plants. The chelates—the phytate chelates—are micronutrients like calcium, zinc, iron, copper, and magnesium and inhibit many reactions of the digestive enzymes, where these minerals act as cofactors in particular. They are found in cereals, pulses, nuts, and seeds. Then, oxalates. Oxalic acid forms potassium, sodium, iron, calcium, or magnesium salts or esters, which are called oxalates, etcetera. So, by forming esters with these minerals, oxalates make them less available. They are found in smaller quantities in plants such as wheat, rye, millet, and barley. So, these are the various different ones.



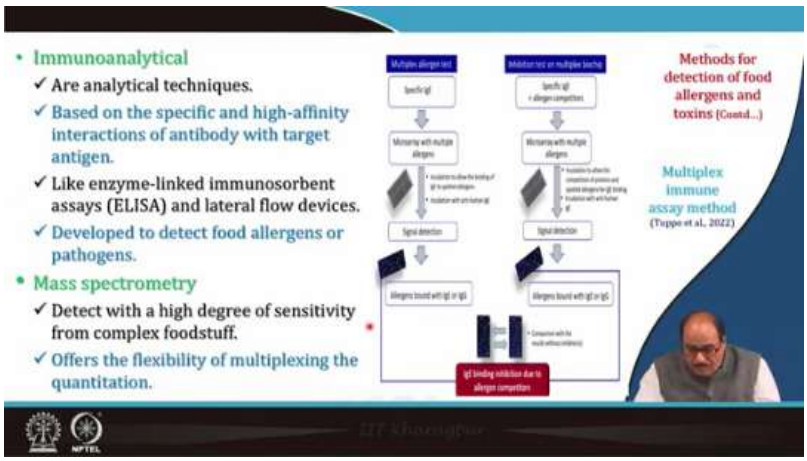
Again, I will give you a summary of some of the important anti-nutrients and their adverse effects, like lipase inhibitors. The adverse effects include reduced absorption of fats and lipids, causing a deficiency of fat-soluble vitamins. Other effects include high blood pressure, headaches, dryness of the mouth, insomnia, and constipation. Amylase inhibitors impair growth and metabolism. They prevent starch digestion. Protease inhibitors inhibit growth. They cause poor utilization of food proteins, particularly. Pancreatic hypertrophy interferes with blood clotting and cellular apoptosis. Then, trypsin inhibitors inhibit protein digestion. It causes pancreatic hyperplasia or interferes with sulfur and other amino acid utilization.



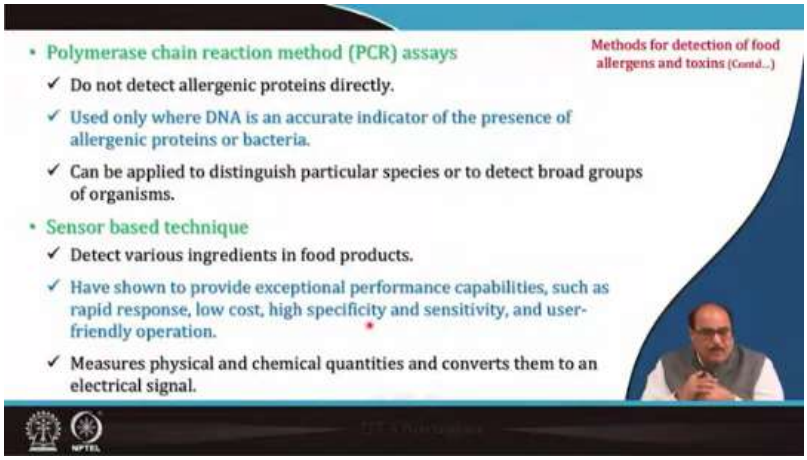
Then, phytates cause mineral deficiency, and polyphenols' high concentration of tannin could be a reason for throat and esophageal cancer. Lectins adversely affect joint pain, causing joint pain, migraines, acne, inflammation, and the agglutination of red blood cells. Oxalates prevent calcium absorption, causing hypocalcemia, kidney stone formation, and resulting in urinary calculi. Then, saponins hinder the absorption of vitamins A, E, and lipids, affecting the epithelial lining of the intestine, and so on. So, these are the effects.



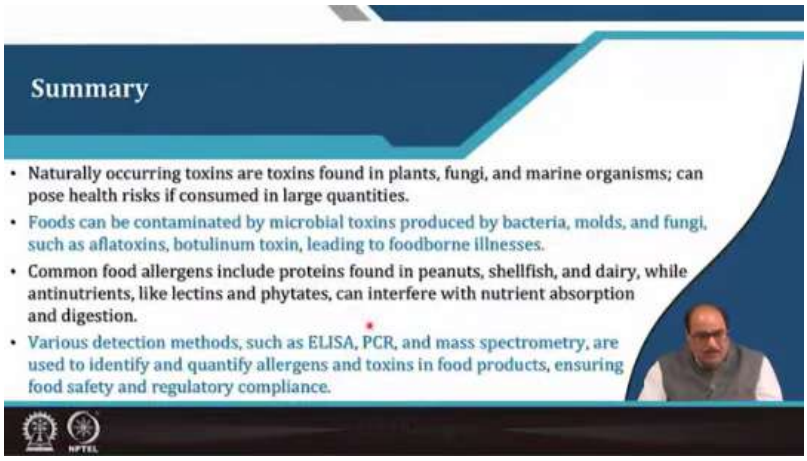
Next, we discuss the detection of allergens and toxins in foods. Methods include protein-based techniques like immunological assays or mass spectroscopy. There are also sensor-based methods or nucleic acid-based techniques, such as conventional PCR or qPCR. These are some common methods used to detect allergens and toxins present in food. Immunological or immunoanalytical methods are analytical techniques based on the specific and high-affinity interactions of antibodies with target antigens. Like enzyme-linked immunosorbent assays and lateral flow devices, they are developed to detect food allergens or pathogens. Then, mass spectroscopy detects with a high degree of sensitivity from complex food samples, offering the flexibility of multiplexing and quantitation.



So, here IGF binding, as shown in the figure, demonstrates how the multiplex immune SMA method is illustrated.

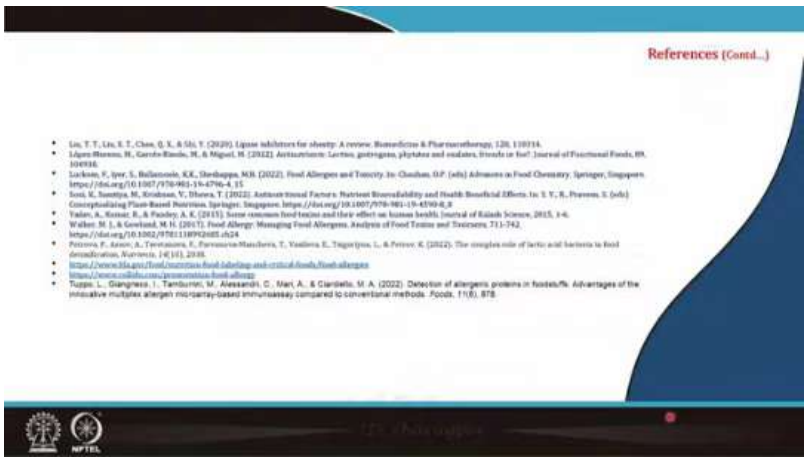


Even polymerase chain reaction methods and PCR assays do not detect allergenic proteins directly. They are used only when DNA is an accurate indicator of the presence of allergenic proteins or bacteria. This can be applied to distinguish particular species or to detect broad groups of organisms. Then sensor-based techniques, which detect various ingredients in food products, have shown exceptional performance capabilities Such as rapid response, low cost, high specificity, sensitivity, and user-friendly operations. These measure physical and chemical quantities and convert them into electrical signals.



Finally, I will summarize this lecture by saying that, so finally, now I will summarize this lecture by saying that naturally occurring toxins are found in plants, fungi, and marine organisms, and even they can pose health risks if consumed in large quantities. Foods can be contaminated by microbial toxins produced by bacteria, molds, and fungi such as aflatoxin, and botulinum toxins and they may lead to foodborne illnesses if we consume food that has bacterial toxin, common food allergens include proteins bound in peanuts, shellfish and dairy while anti-nutrients like lactin, phytates can interfere with the nutrient absorption and digestion. So, there are these means that, as you have seen the list now,

most of the food that we eat daily might contain either allergens, naturally present allergens, or allergens that might be produced in processing and environmental contamination. They can be contaminated with bacteria, so they may contain bacterial toxins. They might even have an anti-nutritional factor or allergens present naturally. So, the important thing is that, yes, one has to identify the particular chemicals or foods that one has allergens to or the safe levels of these allergens and toxins that can be consumed. Accordingly, there are various methods such as ELISA, PCR, and mass spectrometry. These methods are used to identify, detect, or quantify these allergens and toxins in food products. Therefore, they help ensure food safety and regulatory compliance, which is important to consider. It is not the presence of these allergens or anti-nutrient factors in the food, etc., but what matters is the safe level for consumption, which one can determine and proceed accordingly.



So, these are the references and literature used in this lecture to present this information.

Thank you very much for your patience while listening. Thank you.