FOOD SCIENCE AND TECHNOLOGY

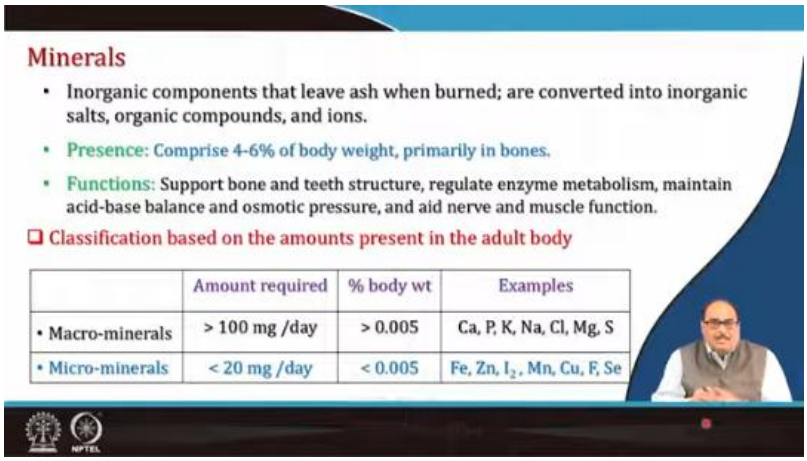
Lecture27

Lecture 27: Minerals

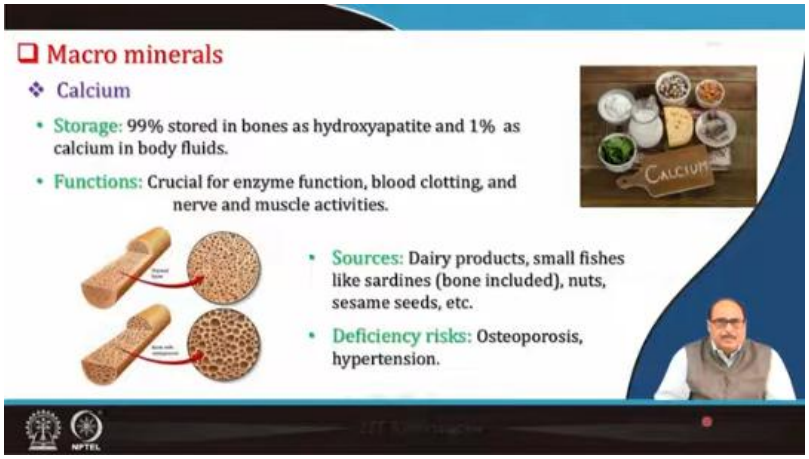
Hello everyone. Namaste. Now, in this second lecture of the sixth module, our lecture 27, we will talk about another very very important micronutrient present in food, which is minerals.

We will talk about macro and micro minerals, their functions, sources, and deficiency disorders.

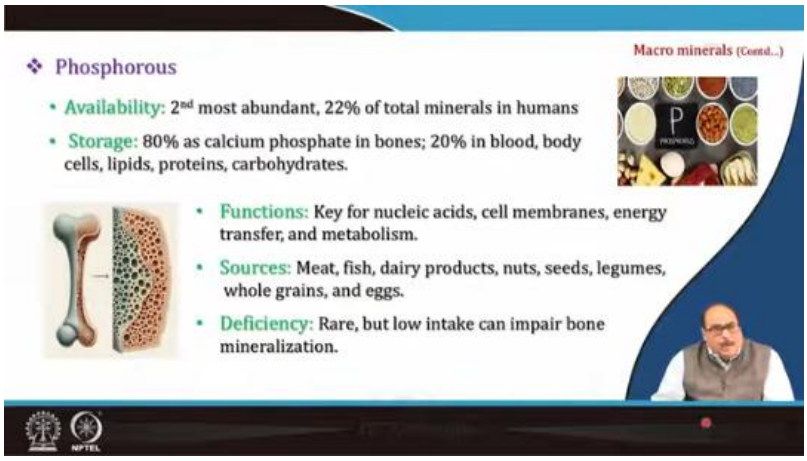
Also, we will talk about the forms of minerals in food, that is, in which form they are present actually in the food, either inorganic form, oxyanions, chelates, complexes, etcetera. Then, the uptake of minerals by foods. Stability of minerals during processing and storage, and the factors that influence the bioavailability of minerals, a very important component. So, we will talk about these aspects in the next half an hour or so.



Let us see what minerals are. You all know they are inorganic components present in the food and other biomaterials that leave ash when burnt. When the biological materials, like food, are burnt, then we get a residue, an ash residue, which is basically All organic components are burnt; only inorganic components are left as ash, meaning that they are converted into inorganic salts, organic compounds, and ions. These minerals comprise about 4 to 6 % of the total body weight and are present primarily as the major component of these minerals found in the bones. Minerals support bone and teeth structure, regulate enzyme metabolism, maintain acid-base balance and osmotic pressure, and aid nerve and muscle function. Now, minerals can be classified into two groups: macrominerals, depending upon their amount. That is present in an adult body. So, macrominerals are those minerals that are present or required more than 100 milligrams per day by an adult person and are present in an amount more than 0.005 % by body weight. Examples of macrominerals include calcium, phosphorus, sodium, potassium, chlorine, magnesium, and sulfur. The microminerals are required in a smaller amount, like less than 20 milligrams per day by the adult body, and they are present in a lesser quantity, less than 0.005 % of body weight, but they are very important otherwise. The examples of micro minerals include iron, zinc, iodine, manganese, copper, fluorine, and selenium. Now, let us discuss a little bit about their chemistry.



First, with the macro minerals, calcium is 99 % stored in bones as hydroxyapatite and 1 % as calcium in body fluids. It is crucial for enzyme function, blood clotting, and nerve and muscle activities. Calcium is found in dairy products. Small fishes like sardines, where you consume the fish with the bone itself. So, it is the bone that basically contains calcium, nuts, sesame seeds, etcetera. And obviously, the deficiency diseases of this include osteoporosis and hypertension.

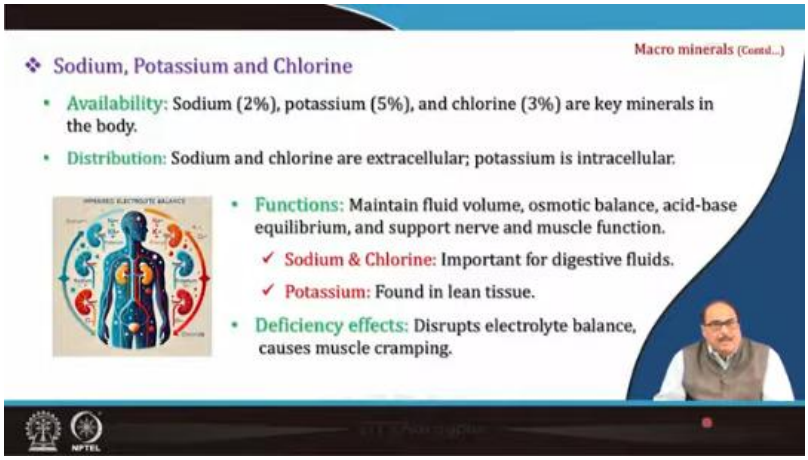


Phosphorus, it is the second most abundant mineral, about 22 % of the total minerals in humans is phosphorus. 80 % is stored as calcium phosphate in bones, 20 % in blood. and body cells, lipids, proteins, carbohydrates, etcetera. Its function, if you talk about phosphorus, is key for nucleic acids, cell membranes, energy transfer and metabolism. It is found in meat, fish, dairy products, nuts, seeds, legumes, whole grains, and eggs. Although deficiency of phosphorus is rare, if it occurs, one takes a comparatively lower amount. So, lower intake can impair bone mineralization.

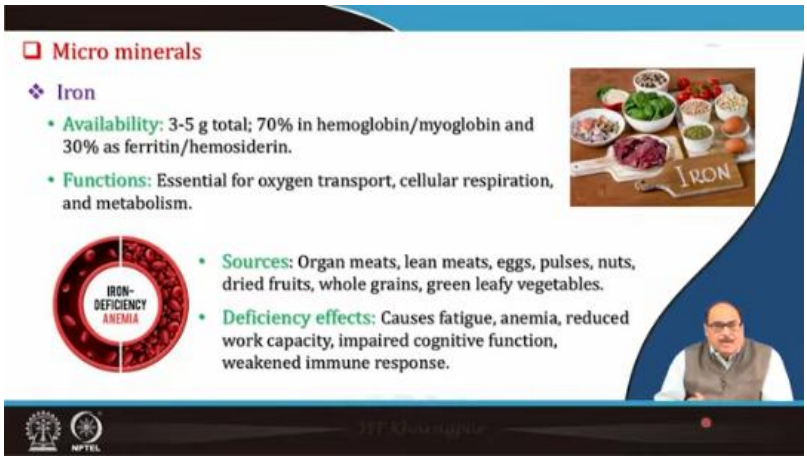
Sulfur is found in amino acids like cysteine, methionine, etcetera, which are sulfur containing amino acids. And is prevalent in keratin and glutathione, also present in vitamins like thiamine and biotin. It exists as sulfhydryl in reduced or disulfide in oxidized forms, which is essential for protein structure and enzyme activity. Dietary sources of sulfur include meat, eggs, cruciferous vegetables, garlic, legumes, etcetera. And the dietary deficiency effects of sulfur include impaired protein synthesis, affecting muscle growth and its repair.

Magnesium is involved in energy metabolism. Enzyme activity, nerve, and muscle functions. It exists as a free ion, that is, Mg^{2+}, a magnesium ion in the body fluids and tissues. Sources of magnesium include plant-based foods, as magnesium is a component of chlorophyll. Magnesium is a component of chlorophyll. So, all green plant foods have an abundant quantity of magnesium. However, it is low in animal products and processed

foods. Some algae, such as green algae, may contain it. Some algae, such as green algae, may contain it. Its deficiency is rare but can cause muscle cramping.

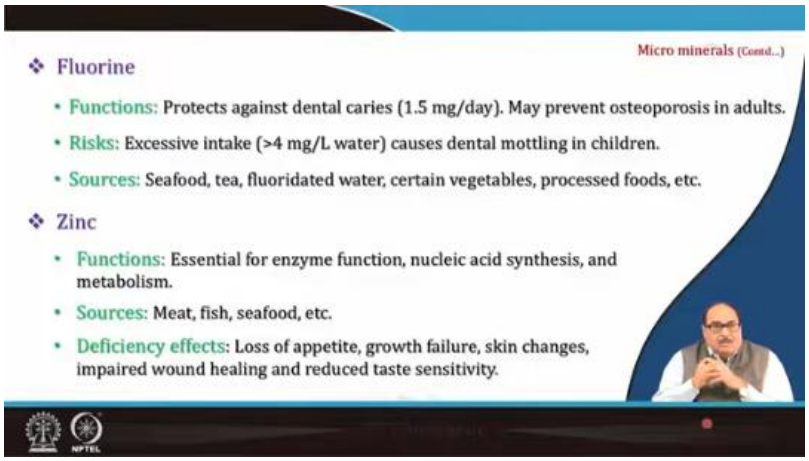


The other macrominerals, like sodium, potassium, and chlorine, are present in the body as follows: sodium approximately 2 %, potassium 5 %, and chlorine 3 %. They are key minerals in the body. Sodium and chlorine are extracellular, while potassium is intracellular. Their functions include maintaining fluid volume, osmotic balance, acid-base equilibrium, and supporting nerve and muscle functions. Sodium and chlorine are particularly important for digestive fluids, while potassium is found in lean tissues. Deficiency of sodium, potassium, and chloride may cause disruptions in electrolyte balance, which may ultimately lead to muscle cramping.



Now, let us talk about micro minerals like iron, which is a very important micro mineral. Its availability is around 3 to 5 grams total, with 70 % of which in hemoglobin or myoglobin, and 30 % is as ferritin or hemosiderin. It is very important, as it is essential

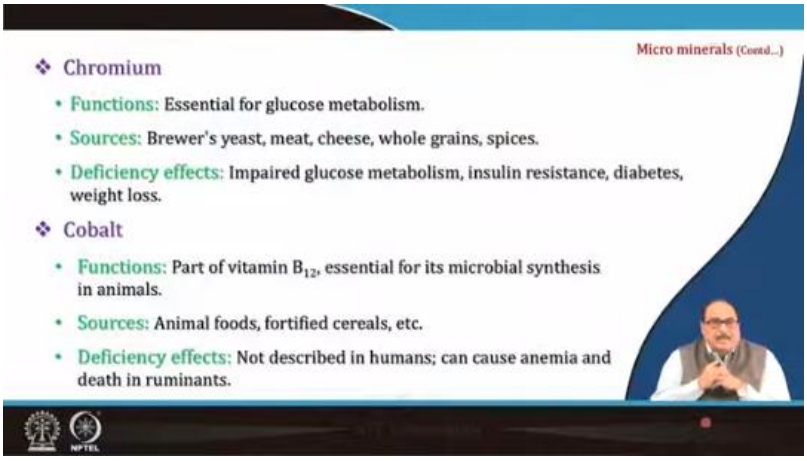
for oxygen transport, cellular respiration, and metabolism. Sources of iron include organ meats, lean meats, eggs, pulses, nuts, dried fruits, whole grains, green leafy vegetables, etcetera. Deficiency disorders of iron cause fatigue, iron deficiency anemia, reduced work capacity, impaired cognitive functions, and weakened immune response. Iron deficiency anemia is particularly a major burden and a major problem that developing countries of the world face.



The functions of fluorine include protecting against dental caries and may prevent osteoporosis in adults. Excessive intake of fluorine, that is, if you consume more than 4 milligrams per liter of water, causes dental mottling in children. Sources of fluorine include seafood, tea, fluoridated water, certain vegetables, processed foods, and so on. Then another micronutrient or micro mineral is zinc. It is essential for enzyme function, nucleic acid synthesis, and metabolism. It is found in meat, fish, and seafood. Its deficiency causes loss of appetite and growth failure. Skin changes, impaired wound healing, and reduced taste sensitivity.

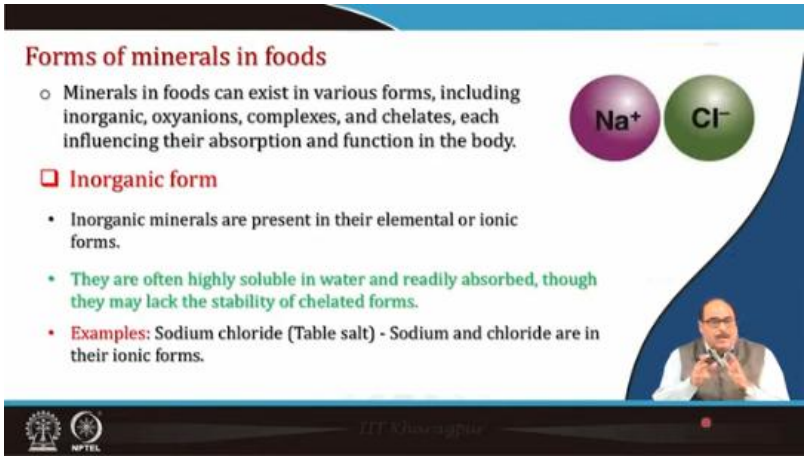
Copper is another very important micromineral, although it is required in very small quantities. But it is essential for RBC formation, iron absorption, connective tissue maintenance, and for the proper functioning of neurological tissues. It is found in liver, shellfish, nuts, whole grains, dark chocolate, and its deficiency causes anemia, skeletal defects, pigmentation issues, reproductive failure, and cardiovascular diseases. Iodine is essential for thyroid hormones, that is, thyroxine and triiodothyronine. Its sources are iodized salt, seafood, dairy products, eggs, seaweed, etc. And its deficiency causes goiter, that is, due to thyroid gland enlargement, etc. And that is why salt fortification with iodine is an important project that has been taken up by governments.

Then, chromium is essential for glucose metabolism. Its sources include brewer's yeast, meat, cheese, whole grains, and spices.

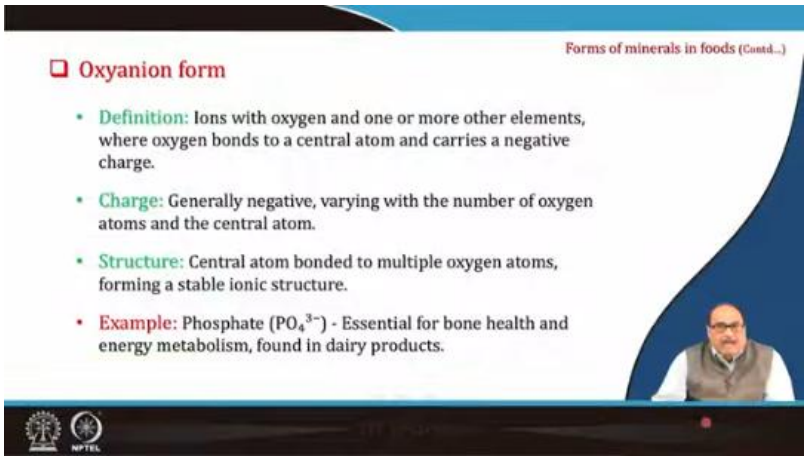


Deficiency affects impaired glucose metabolism, insulin resistance, diabetes, and weight loss. Cobalt takes part in or functions as vitamin B12. It is essential for its microbial biosynthesis in animals, that is, it is a component of cyanocobalamin, okay. It is found only in animal foods, fortified cereals, etcetera. And, deficiency, although not very described in humans, can cause anemia and death in ruminants, etcetera.

Now, having described these major types of macrominerals and microminerals, let us now talk about how they are present in the food system or biosystems, that is, they can exist in various forms including inorganic forms, oxyanion complexes, and chelates, and each of these, that is, the form in which they are present in the food, influences that is, its availability in the system, its absorption, its functions, and all those things.

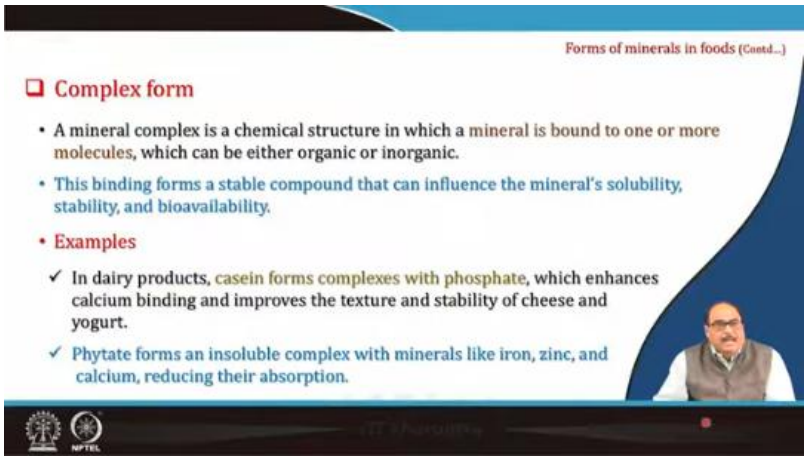


So, first is the inorganic form, that is, the inorganic minerals are present in their elemental or ionic form, like sodium chloride. which is stable salt here sodium and chlorine that is they are present in the they are ionic form sodium ion and chloride ion. And these inorganic forms are often highly soluble in water and they are readily absorbed though they may lack the stability of the chelated form that is chelated forms are more stable that is these inorganic forms are comparatively less stable. of their solubility.



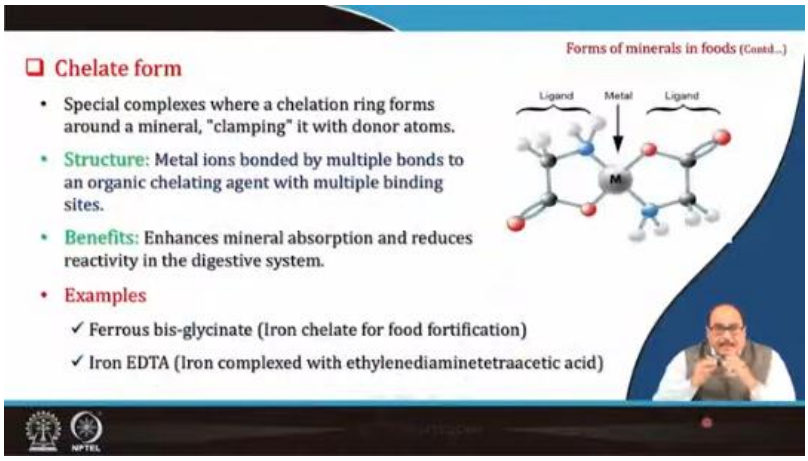
Then oxygen ion forms that is ions with oxygen and one or more other elements where oxygen bounds to a central atom and carries a negative charge that is generally their oxygen ion forms are negative bearing with the number of the oxygen atoms and the central atom. Structure may be that central atom bounded in multiple oxygen atoms forming a stable ionic structure. For example, you can say the phosphate group is present in various compounds that is which is essential for bone health and energy metabolism. It is mainly found in calcium phosphate or other compounds in the dairy products or many

and such products. So, here phosphate you can see PO_4^{3-} that is the phosphate and 3 negative charges are there in the PO_4, therefore, the oxygen molecule is joined with one phosphate molecule and there are three negative charges. So, similarly, this is the oxyanion form of phosphorus present in the dairy products or other products.

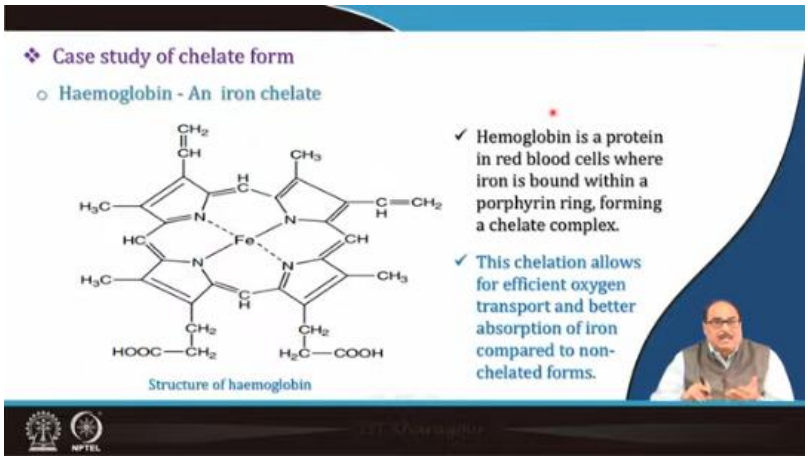


Then, the complex form. A mineral complex is a chemical structure in which a mineral is bound to one or more molecules, which can be either organic or inorganic, and this binding forms a stable compound that can influence the mineral's solubility, stability, and bioavailability. And the examples of these complex forms are in the dairy product casein. Casein forms a complex with phosphate, which enhances calcium binding and improves the texture and stability of cheese and yogurt, etcetera. That is, it is present in the form of calcium caseinate, etcetera. Present in the plant sources, phytates form an insoluble complex with minerals like iron, zinc, or calcium, calcium phytate, iron phytate, etcetera, which reduce their absorption. The same phytates, when they are present in the salt form with the complex form with the irons, etcetera, present in the phytates. That it makes the insoluble complex, which reduces its absorption as well as its availability in the system.

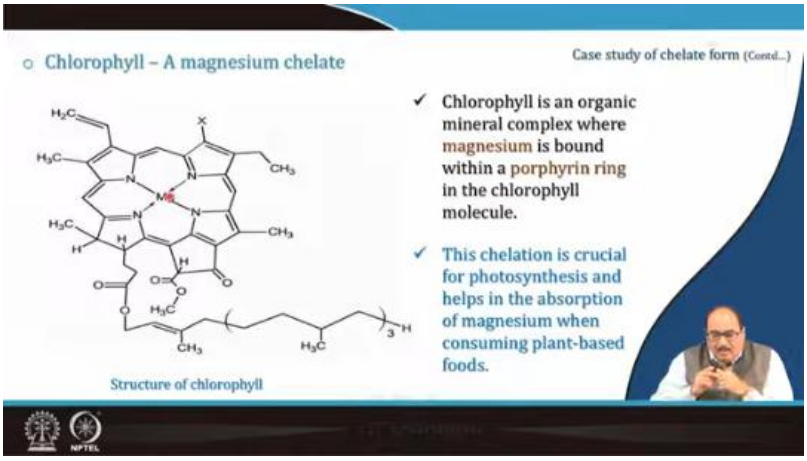
Then another very important form of some of the minerals is the chelate form. That is the chelate, the special complex where a chelation ring forms around a mineral clamping it with the donor atoms. You can see here there is a metal; it links with the ligands by coordinate covalent bonds, ok. There is a metal, and then a donor group and acceptor group, the ligand, and chelate metal complex. So, metal ions are bounded by multiple bonds to an organic chelating agent with multiple binding sites. So, it enhances mineral absorption and reduces reactivity in the digestive system.



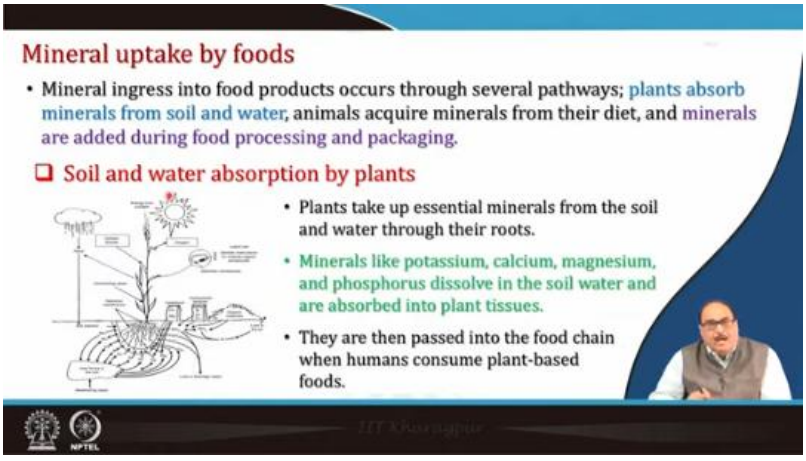
Examples of some of the minerals which are formed in the chelate form found in the chelate form, like ferrous bisglycinate, that is iron chelate for food fortification, ferrous pyrophosphate, etcetera, or even iron EDTA, iron complex with the ethylene di, I mean, tetra acetic acid. So, these are some of the forms.



So, we will also talk about some important elements which are found in the chelate form in the food. materials, and one among them is hemoglobin. It is, as you can see here, the structure in the center is the iron, and then this iron is present in it, chelated with different organic compounds linked in the quadrant. And it is hemoglobin, which you all know is a protein in the red blood cells, where iron is bound with a porphyrin ring, forming a chelate complex. And this chelation allows for efficient oxygen transport and better absorption of iron compared to non-chelated forms. Because these chelated forms are more stable, and their transportation is better, and they can be absorbed better in this chelate form.

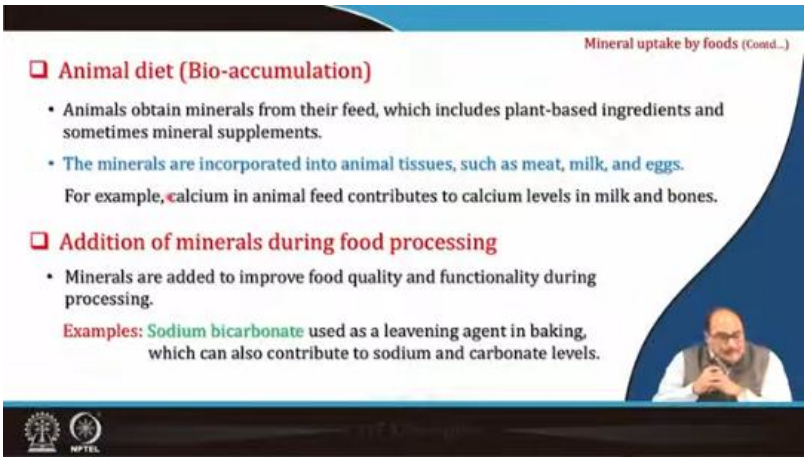


Similarly, there is chlorophyll, which is an important chelate found in the food system, and it is a magnesium chelate, okay. Similarly, you have seen the magnesium organic mineral complex, where magnesium is bound with okay, in the chlorophyll molecule in the plant system, all the green color in the plant is due to chlorophyll. And this chelation is crucial for photosynthesis and helps in the absorption of magnesium. When consuming plant-based foods. So, that is the magnesium you get from the chlorophyll. Similarly, that is the vitamin B12, cyanocobalamin; there also, it is a cobalt that forms the complex with propylene ruby and the chelate, etcetera. So, these are some of the naturally occurring elements, that is, magnesium, cobalt, iron, etcetera, present in the form of chelates, which influences both their stability as well as their absorption and others.



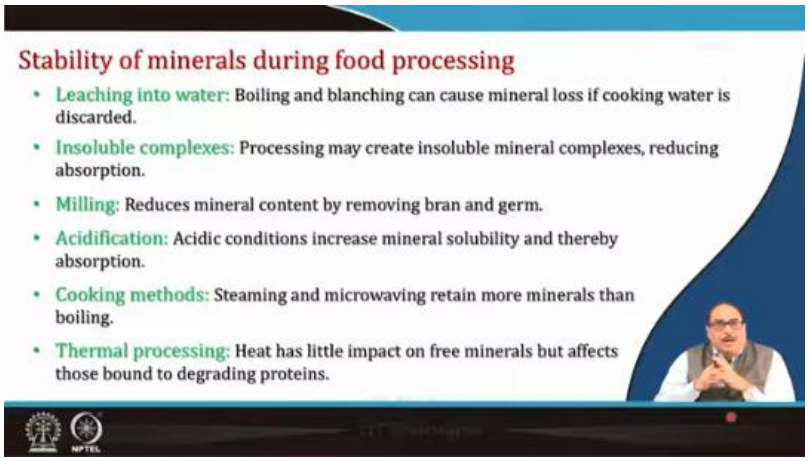
Now, let us talk about from where, that is, the very important aspect of mineral uptake by foods. There are minerals that come into the food products; their ingress into the food product occurs through several pathways, like the plants absorbing minerals from soil and

water. Even animals acquire minerals from their diet, and minerals are even added during food processing and packaging, as many times foods are fortified with minerals, etcetera. So, first, let us take the example of that is the absorption by plants from soil and water, during when the plants grow. Aquatic plants or even those in the soil uptake essential minerals from the soil and water. Through their roots, minerals like potassium, calcium, magnesium, phosphorus, etcetera dissolve in the soil water and are absorbed into the plant tissues. And they are then passed into the food chain where humans consume plant-based food that is when these plant foods we consume in different forms, then these minerals come into that.



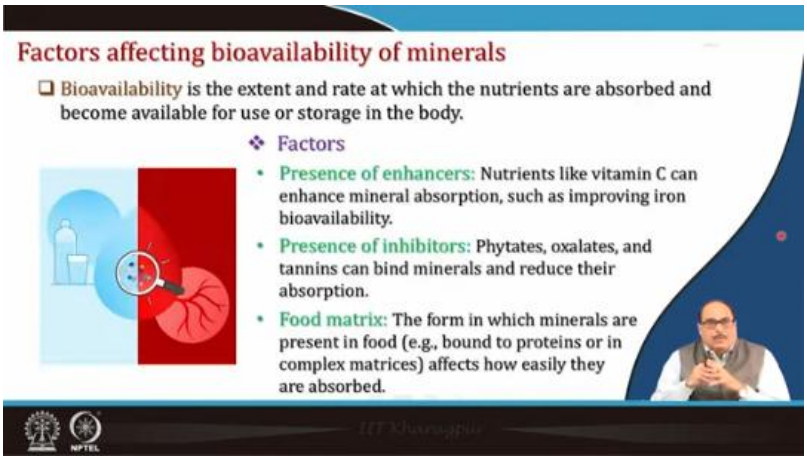
So, in the animal diet, that is the bioaccumulation, you can say animals obtain minerals from their feed, which includes plant-based ingredients and sometimes mineral supplementations, then minerals are also incorporated into animal tissues like meat, milk, eggs, etcetera. For example, calcium in the animal feed contributes to the calcium level in the milk and bones, that is, even the feed system, what you give to the animals, that is its feed, will influence the nature of the feed, the type of the feed will influence that mineral component and other nutrients present in there, meat, muscle, milk, and so on. Then also, the addition of micronutrients or minerals, particularly during food processing, they are added, many there are several examples in the literature which you can say that these minerals. are added to improve the quality of the food, the functionality of the food, to make them more available.

Now, even to tackle the country's iron deficiency, there is food fortification for the rice fortification. Fortification of other staple foods, wheat flour, milk, oil, salt, all these things are taken where various minerals, as well as some vitamins, etcetera, these macronutrients are added into the food by one or the other method to increase their availability and their amount. So, as to tackle their deficiency, okay. Then there is another important aspect, that is the minerals that are added when the food is processed during storage. So, from the processing machinery, from the packaging materials, etcetera, also the minerals are taken up by the foods. Like we discussed about fortification, that is, they are intentionally added to foods to enhance their value. Calcium is added to orange juice, or iron is added to cereals etcetera, then processing equipment. In fact, now there is one concern among nutritionists, like the replacement of iron utensils from cooking. Vegetables etcetera are cooked in iron utensils. So, there is some uptake of the iron from the utensils to the food, increasing their iron content. Similarly, when this milk is processed in the still. So, there is some uptake of the metals from this machinery containing etcetera. That is, these steels are other pipelines. So, there are several issues; even the mechanical wear causes metal particles to detach and mix with the food, and even corrosion of metal equipment leads to the unwanted mineral contamination, which is another negative side of this uptake during processing. Minerals can migrate from the metal packaging materials, such as tin cans or metal-lined containers, to the food products. Even migration of tin or aluminum from the cans into the food etcetera; there are several examples of this in the literature. So, that is another important aspect, okay.



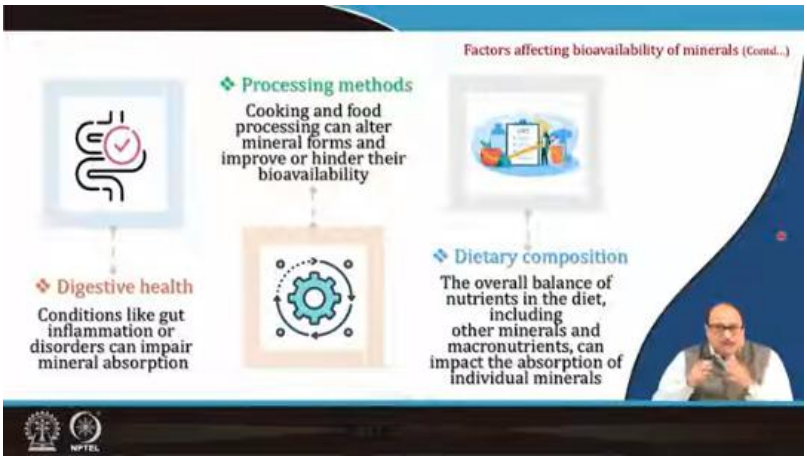
Now, let's talk about the stability of minerals during food processing, okay. So, there is number one: leaching into water. That is, because many of the minerals and the form in which they are present may be water-soluble, okay, like sodium chloride; sodium chloride is water-soluble. So, such water-soluble minerals can be leached. through water, etcetera. Particularly, boiling and blanching can cause mineral loss and particularly if the cooking water is discarded or washing water is discarded, etcetera. Then the insoluble complexes like processing may create insoluble mineral complexes during reducing their absorption, that is their form. Then during the processing method, etcetera, the forms in which the minerals There is a good example of milk, calcium, caseinate form. And therefore, their availability, their absorption, all these things can be affected. Even milling reduces the content by removing the bran and germs in most of them. Rice, you can say, or wheat, etcetera, that is the cereal grains, etcetera, they contain a layer brown, and the brown is a very important source of minerals, okay. So, when you polish during polishing in the rice, brown is removed, and so the mineral contents from this wheat germ or wheat bran is when it is removed, the majority of them. So, milling may be another regional factor which may contribute to the reduction of the mineral content in the food. Then acidification, that is acidic conditions, increases mineral solubility and thereby absorption process also is affected. Then, cooking methods like steaming and microwaving retain more minerals than boiling. Thermal processing methods, of course, heat has little impact on free minerals, but it affects those minerals which are bound to degrading proteins. Sometimes, the minerals are present in the degrading proteins, and therefore, they affect the stability of minerals during storage. Earlier, we talked about the stability of minerals during processing. So, in storage, there is a high moisture environment. So, high moisture levels can lead to mineral leaching, particularly if the food is stored in liquid environments or it has high water content. Elevated storage temperatures can increase the

rate of mineral leaching and the formation of insoluble complexes, resulting in nutrient losses. Using airtight packaging helps minimize exposure to air and moisture, which can degrade mineral content over time. So, storing food in cool, dry places helps maintain mineral stability and prevent accelerated nutrient losses. Storing in reduced moisture and temperature fluctuation conditions along with vacuum sealing or airtight packaging helps in preserving the minerals in food.



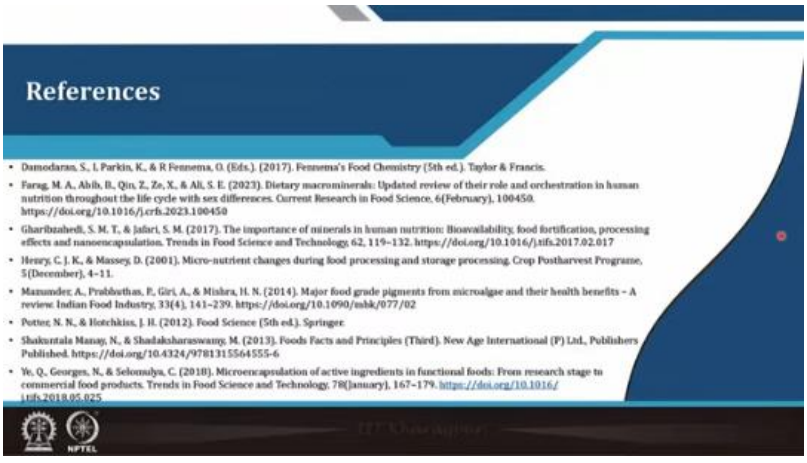
So, let us briefly talk about the factors that affect the bioavailability of the minerals in food. Bioavailability is the extent and rate at which the nutrients are absorbed and become available for use or storage in the body. So, various factors contribute to the bioavailability of the minerals. in the body include the presence of enhancers like nutrients such as vitamin C, which can enhance mineral absorption, such as improving iron bioavailability. It is said that if there is now in the fortified that iron when you are adding from outside, all right, if that along with this material, say vitamin C, is added. So, it improves the bioavailability or absorption of iron. Similarly, if there is a presence of inhibitors like phytates, oxalates, and tannins, etcetera, they can bind minerals and reduce their absorption. The food matrix, that is, the form in which minerals are present in the food, like whether they are bound to protein or in complex matrices, all these will affect how easily they are absorbed. Even their chemical forms, like you see that ferrous pyrophosphate, which is a form that is used, are ferrous sulphate, ferrous pyrophosphate, or sodium EDTA ferrous compounds. These different forms of ferrous compounds are there, and each form in which they are present has some positive points, some negative points, etcetera, like one form which has very good bioavailability, readily absorbed, but it is water-soluble, and its leaching is there; it can affect the sensory characteristics, etcetera, colours, and all those things of the food. So, there is another form which is most

accepted, that is, ferric pyrophosphate, which is water-insoluble, but its losses, etcetera, are not there since it is water-insoluble. So, it is the form which is used. With the fortification of rice or other cereals, but it has a problem that its bioavailability is comparatively less. So, it is recommended that if these fortified food products, which are fortified with iron ferric pyrophosphate or iron pyrophosphate as a source of iron. So, its bioavailability and absorption can be increased if lemon or such other vitamin C etcetera, can be used during the cooking process or food is used with this number 1. Number 2, more importantly, it is also recommended that if the ferric pyrophosphate, the chemical if it is micronized, that is reduced to a very vulnerable D90 level, that is, the particle size is reduced to about 3 to 4 microns or 5 microns or even less. So, its bioavailability is increased significantly. So, there are various factors by which you can increase or manage the bioavailability. So, yes, that is your digestive health, like conditions such as gut inflammation or disorders, can impair mineral absorption in the body.



Processing methods like cooking and food processing can alter mineral forms and improve or hinder their bioavailability. I gave you the example of iron; that is why, by processing, by milling, you can increase or even by cooking, if you add vitamin C or other vitamin C-containing compounds, it will increase. And then also, dietary composition, like the overall balance of nutrients in the diet, including other minerals and macronutrients, can impact the absorption of individual minerals.

So, now finally, I would like to summarize this lecture by saying that essential minerals are very important components for our life, for our body's sustainability and growth. Development supports critical body functions and helps prevent diseases. Minerals are found in food in various forms. Food can uptake minerals through absorption by plants, mineral fortification, additives, and migration from packaging or other machinery used for processing. The stability of minerals can be affected by processing and storage conditions. Even the bioavailability of minerals is influenced by nutrient interactions as well as the chemical forms of the mineral in which it is present, its particle size, and so many other factors. So, one should be very careful because although these minerals are required in smaller quantities, they are very important. for our proper functioning, and therefore, we should properly manage the intake of minerals in our diet.



So, these are the references used in this lecture.

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