FOOD SCIENCE AND TECHNOLOGY

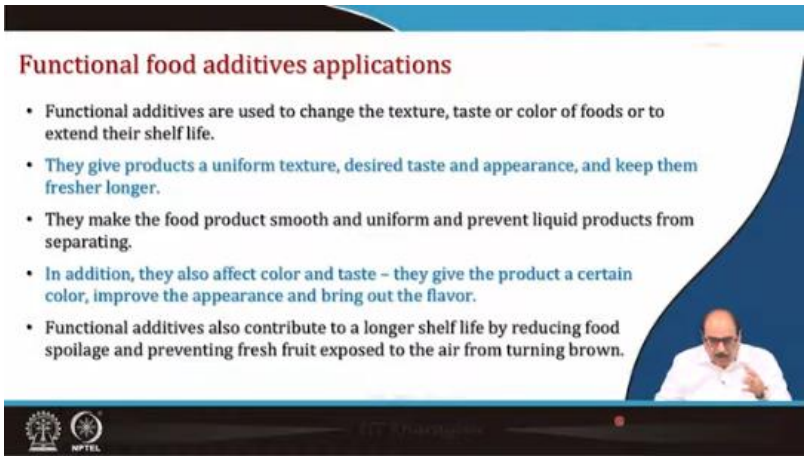
Lecture 37

Lecture 37: Functional Food Additives

Hello everyone, Namaskar.

Today in this lecture, which is the second lecture of the eighth module or overall lecture number 37, we will talk about functional food additives in the next half an hour or so.

We will discuss what the various functional food additive applications are and what we actually mean by functional food additives. And then we will discuss specific functional additives like flour improvers, flavor enhancers, curing agents, coloring agents, emulsifiers, leavening agents, humectants, and anti-caking agents. We will also talk about some physiological process modulators and ripening agents.

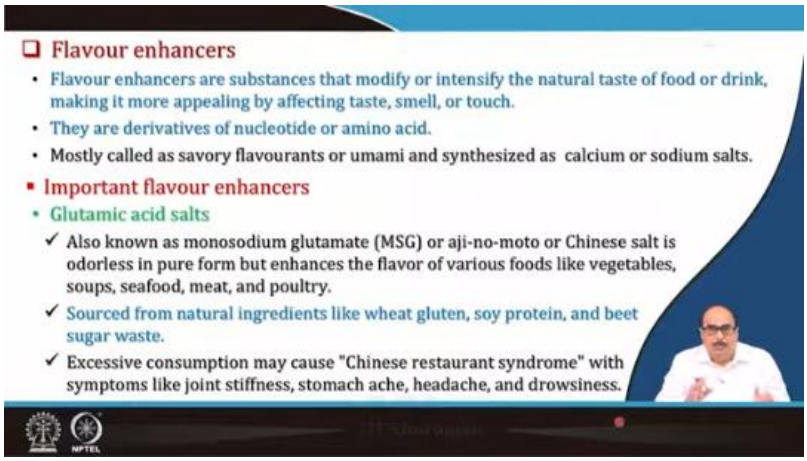


So, let us first see what the functional food additive applications are, and what we actually mean when we talk about functional food additives. So, basically, these functional additives are used to improve different functional characteristics, functionality of the food that may improve its texture, taste, or color. Or even sometimes, these functional additives may also result in the enhancement of the shelf life of food.

These functional additives give a product a uniform texture, desired taste, and appearance, and keep them fresher for longer periods of time. Functional additives make the food product smooth and uniform and prevent especially lipid products or even liquid

products from separating. As we will discuss later in the lecture, even two immiscible liquids can be kept intact together using functional additives. In addition, functional additives also affect the color and taste of the food, and they give the product a certain color, improve the appearance, and bring out or amplify the flavor of the food.

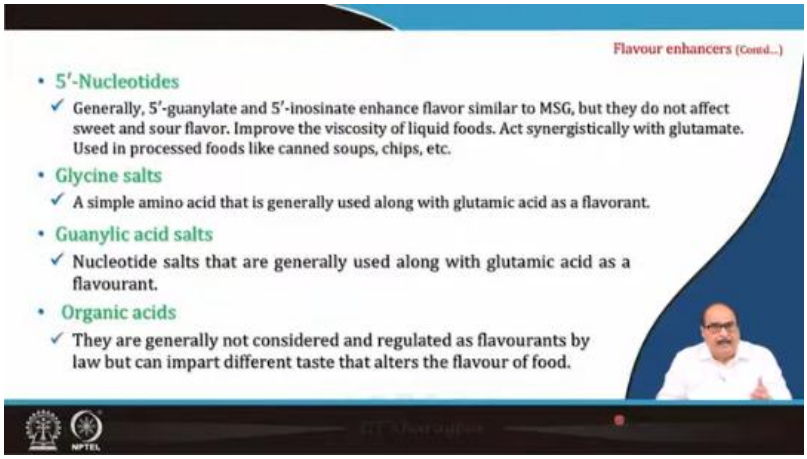
Functional additives also contribute to a longer shelf life as I told you earlier also by reducing food spoilage and preventing fresh fruit exposed to the air from turning brown. So, they may be these functional additives may be used to regulate the enzymatic processes or other physiological processes etc. and which ultimately may result in the extension of the shelf life of the food.



So, now let us talk about specific functional additive applications and first we will start with the flavor enhancers. That is you know that the flavor of a food is mainly because of the presence of various compounds in them organic compound, volatile organic compounds, etc., but the flavor enhancers, they are actually not the flavor, but they are the substances which boost or amplify the flavor or modify or intensify the natural taste and flavor of a food or drink and making it more appealing by affecting its taste, smell or touch. Flavor enhancers are derivatives of nucleotides or amino acids and they are mostly called as savory flavorants or umami and synthesized. They are normally synthesized as the calcium and sodium salts of glutamic acids or umami etc.

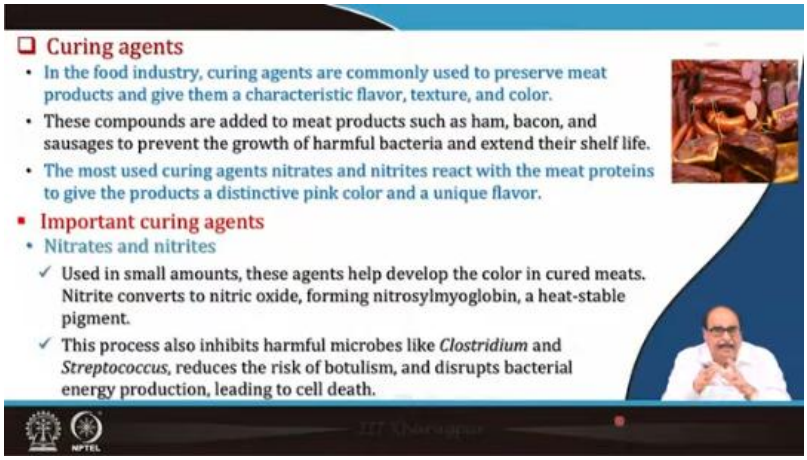
So, some of the important flavor enhancers include glutamic acid salts that is these glutamic acids and its salts, also known as monosodium glutamate, popularly known as MSG or Ajinomoto or even Chinese salt. It is basically an odorless in pure form, but it

enhances the flavor of various foods like vegetable soups, seafood, meat and poultry. And in fact, monosodium glutamate is used in several products to enhance or amplify its flavor. It is sourced from natural ingredients like wheat gluten, soy protein and beet sugar waste. However, excessive consumption of monosodium glutamate may cause Chinese restaurant syndrome, with symptoms like joint stiffness, stomach ache, headache, or drowsiness.

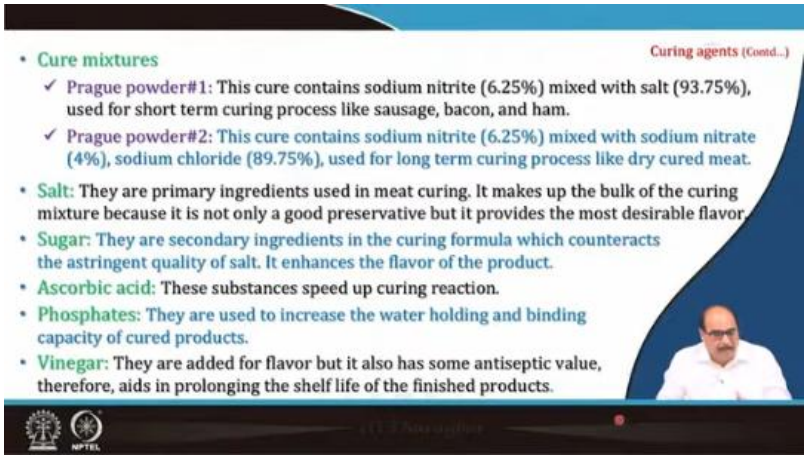


Other flavor enhancers may include 5 nucleotides; generally, these 5 guanylates or 5 inosinate enhance the flavor similar to MSG, but they do not affect sweet and sour flavors. They improve the viscosity of liquid foods, act synergistically with glutamate, and are used in processed foods like canned soups, chips, etc. Another important class of flavor additive used by the industry may be glycine salts, guanylic acid salts, organic acids, and many more. Glycine salts are simple amino acids that are generally used along with glutamic acid as flavorants.

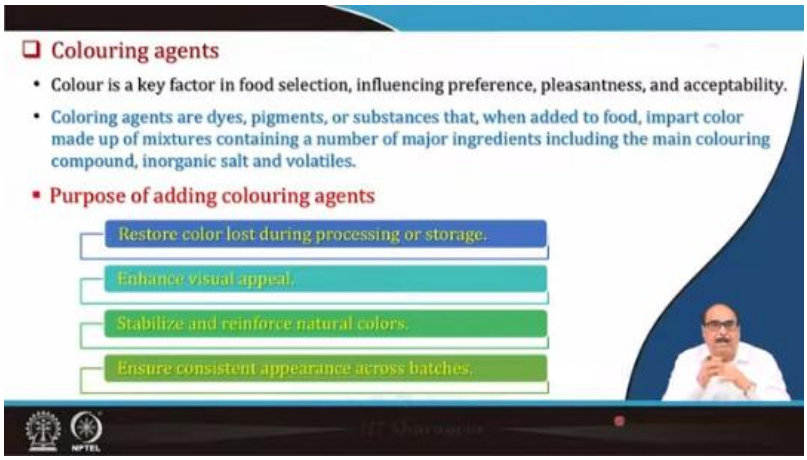
Guanylic acid salts are nucleotide salts that are generally used along with glutamic acid. Organic acids are generally not considered or regulated as flavorants by law, but they can impart different tastes that alter the flavor of the food. So, they may amplify the organic acids. Also, they may amplify or add certain tastes and flavors, although, by law or regulations, these organic acids are not considered as flavors. Another important category of functional food additive application is the curing agents.



In fact, in the food industry, these curing agents are commonly used to preserve meat products and give them a characteristic flavor, texture, and color. Meat curing is a very important preservation process. These curing agents are added to meat products such as ham, bacon, and sausages to prevent the growth of harmful bacteria and extend their shelf life. The most used curing agents, nitrates and nitrites, react with the meat proteins and give the product a distinctive pink color and a unique flavor. So, again, if we talk about some important curing agents, the first names that come up are nitrates and nitrites. These are used in small amounts; these agents help develop the color in cured meats. Nitrite converts to nitric oxide, forming nitrosomyoglobin, a stable pigment. These nitrates and nitrites are used in small amounts. These agents help develop the color in cured meats. Nitrite, when used in meat and meat products, converts to nitric oxide and then forms nitrosomyoglobin, which is a heat-stable pigment and stabilizes the red color of the meat. This process also inhibits harmful microbes like Clostridium and Streptococcus, reduces the risk of botulism, and disrupts bacterial energy production, leading to cell death.



The other mixture, which is a curing agent, may be cure mixtures like Prague Powder 1 or Prague Powder 2, and these are basically mixtures of sodium nitrite and salt. Even Prague Powder 2 contains sodium nitrite (around 6.25%), mixed with sodium nitrate (4%) and sodium chloride (89.75%). Prague Powder 2 is normally used for long-term curing processes like dry-cured meats, whereas Prague Powder 1 is used for short-term curing processes, such as in sausages, bacon, and ham. Then, salt, sugar, ascorbic acid, phosphates, vinegars—all these are used along with the curing agent to impart various desirable characteristics like flavor and color. Ascorbic acid is used to speed up the curing reaction. Phosphates are used to increase the water-holding and water-binding capacity of cured meats. Vinegar is added for flavor, but it also sometimes provides antiseptic value to the meat, thereby prolonging the shelf life of the finished product. So, these are the various curing agents.



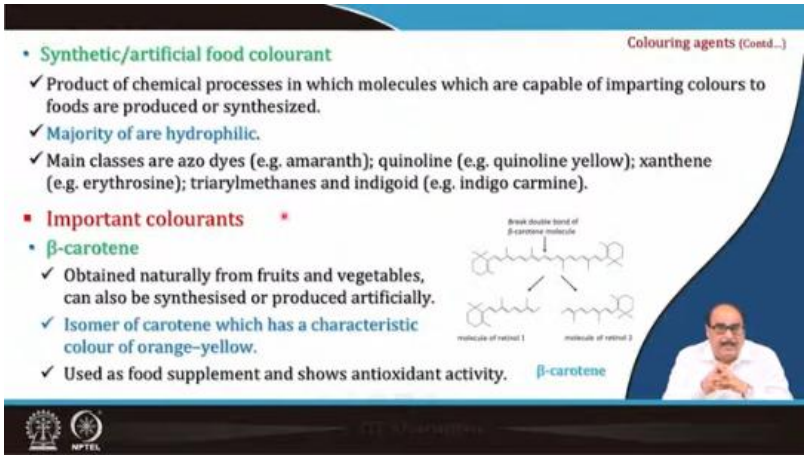
Now, let us talk about coloring agents. Again, like flavors, color is also due to the presence of various organic compounds in the food, which are called pigments, natural pigments. So, this color is a key factor in food selection, influencing preference, pleasantness, and acceptability. In fact, when the first impression of a food is from the color, the coloring agents, various dyes, pigments, or substances are added to food to impart color. And these coloring agents are made up of mixtures containing a number of major ingredients, including the main coloring compounds, inorganic salts, as well as certain volatiles. So, the coloring agents are added to food for various purposes. One important purpose may be to restore the color that is lost during processing or storage. They can also be used to enhance the visual appeal, stabilize and reinforce natural colors,

or ensure consistent appearance across batches. So, these are the various purposes for which coloring agents can be used in food during processing or storage.

So, if you want to classify the coloring agents, there are different ways, like they can be classified based on their origin such as natural coloring agents like pigments or even synthetic coloring agents. Then, these coloring agents can be classified based on their chemical structure, like azo, nitro, xanthene, etc. Another way of classification may be based on their application that is, they can be classified as acidic, basic, direct, moderate, dispersed, alpha, and so on. Natural food colorants are actually derived from plants, animals, or mineral sources, and they are normally unstable toward pH, heat, or light. They have good color appeal, but many times they are unstable due to various processing and storage conditions, or they change with pH or when exposed to heat or UV radiation, etc., leading to changes in these pigments. These natural food colorants are composed of a number of major and minor pigment classes, and they may come from plants such as leaves, bark, fruit, flowers, etc. They have various colors including green, red, orange, even tomatoes, for example, contain lycopene, which is a natural pigment.

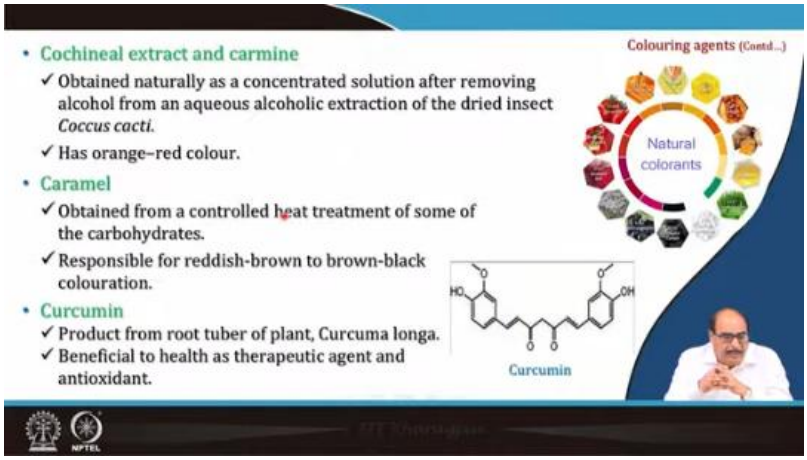
Then, from animal products like dried insects, shells of sea snails, etc., they are used to get some color because of the presence of various pigments. Even minerals like rock salt, earth crust, etc., they have certain colors. Microorganisms, particularly algae—there are red algae, brown algae, blue algae, etc.—they have some green algae. So, these are the different colors you can see here in the picture of various commodities like chili, etc., or saffron, tomato. All these are colors which are mainly natural colors or pigments. And many times, these colorants or coloring material pigments are extracted using one or

another technology like supercritical food extraction or such other technology, and they are used in various food preparations and processing as natural coloring agents.



Then comes another important category or wide category of coloring material: the synthetic or artificial food colorants. So, these are generally synthesized; they are the products of chemical processes in which molecules capable of imparting colors to the food product are produced by chemical reactions or synthesized using chemical or biochemical processes. So, the majority of these coloring agents, synthetic coloring agents, are hydrophilic. The main classes of synthetic coloring agents include azo dyes, quinoline, xanthene, triarylmethanes, indigoid, and so on, for example, indigo carmine, etc. So, if we discuss briefly the important coloring materials, both natural as well as synthetic.

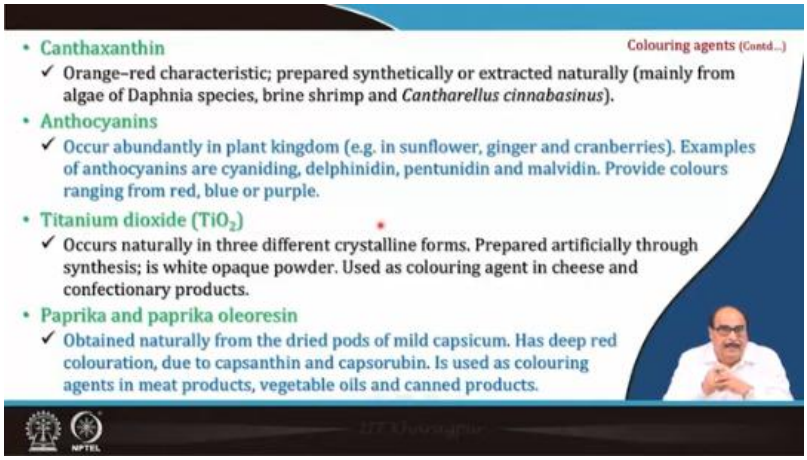
So, first comes beta-carotene, which is obtained naturally from fruits and vegetables; however, it can also be synthesized or produced artificially. Beta-carotene are isomers of carotene which have a characteristic color of orange or yellow, i.e., most orange-colored flowers or yellow-colored fruits, vegetables, etc., have beta-carotene. This is used as a food supplement and also shows antioxidant properties. So, this natural pigment, beta-carotene, also has an antioxidant effect.



Then, cochineal extract and carmine. This is obtained naturally as a concentrated solution after removing alcohol from an aqueous alcoholic extraction of dried insects. As I told you, these pigments, etc., are used and extracted using various methods, and in many cases, alcohol is used as a substrate or as a base material for extraction, or even supercritical carbon dioxide. So, this cochineal extract has orange to red colors, etc.

Then, caramel, caramel is another very important class of color, which is obtained from controlled heat treatment of carbohydrates. In fact, you know that caramelization is an important process where sugars, whether in dry form, concentrated form, or solution form, are heated to various degrees, producing different colors. In fact, in the industry, specific caramelization processes are used by controlling the parameters to produce caramel colors for different purposes and various uses in the food industry. For example, in the beer industry, cola drink industry, bakery products, etc., these caramel colors are used. So, these are responsible for reddish-brown and brown-black colors in various processed food products.

Then, another important coloring agent is curcumin. You know, this is derived from the root tuber of the plant Curcuma longa. It is beneficial to health as it is also used as a therapeutic agent and has antioxidant potential. Curcumin is a yellow-colored compound with significant medicinal properties.

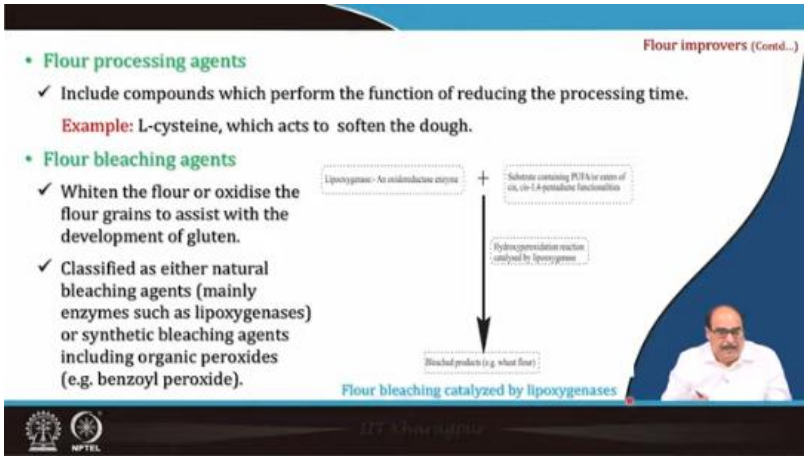


Then, canthaxanthin, it is an orange-red characteristic color, prepared synthetically or extracted naturally, particularly from algae of the Daphnia species or even brine shrimp, and so on. Then, anthocyanins, these occur abundantly in the plant kingdom, particularly in sunflower, ginger, cranberry, etc. Examples of these anthocyanins are cyanidin, delphinidin, petunidin, or malvidin, and they provide colors ranging from red, blue, to purple. So, many of the flowers we see with natural colors are due to anthocyanins. Then, titanium dioxide, it occurs naturally in three different crystalline forms and is also prepared artificially through synthesis. It is a white, opaque powder, generally used as a coloring agent in cheese and confectionery products.

Then, paprika and paprika oleoresin, these are obtained naturally from the dried pods of mild capsicum. It has deep red coloration due to capsanthin and capsorubin. It is used as coloring agent in meat products, vegetable oils and canned products.

Now, another important class of functional food additive is floor improver, which is used in the bakery and confectionery industry. These flour improvers are basically the additives which are added to flour, wheat flour or dough to improves its baking quality or even sometimes color. They are used as a coloring agent, they are used as a maturing agent, they are used as a bleaching agent and so on.

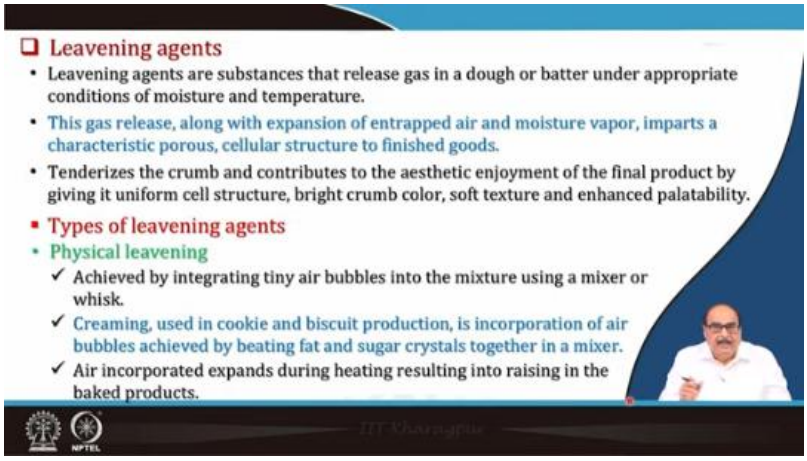
So, these flour improvers are used for the preparation of various food products in the bakery industry. So, important flour improvers include, i.e., there are as I told you two three classes, i.e., one class of the flour improvers is used as a maturing agent, means that is which are used to assist with the gluten development, they mature the flour. So, the flour improver which falls in this category may include azodicarbonamide, it improves the rheological properties of the flour dough, or formamidine disulphide hydrochloride has excellent flour maturing properties due to its ability to block the sulfhydryl group in the flour dough. Potassium bromate acts as a maturing agent in flour as well as in the dough. It is also used as a dough conditioner. So, these chemicals mean, maturing agents means, when they are used, they result in the better development of the dough, alright.



Maturing of the dough and then later on give a good characteristic, i.e., contribute to the good textural characteristics or other characteristics to the baked product. Then, flour processing agent this is another class of the improvers which is commonly used to perform the function of reducing the processing time. Like for example, L 16 it is used to soften the dough and therefore, ultimately reduce the dough development time or leaving time or finally, baking time as well. Then the other important category of floor improvers include floor bleaching agent means, they modify the color of the floor. They whiten the

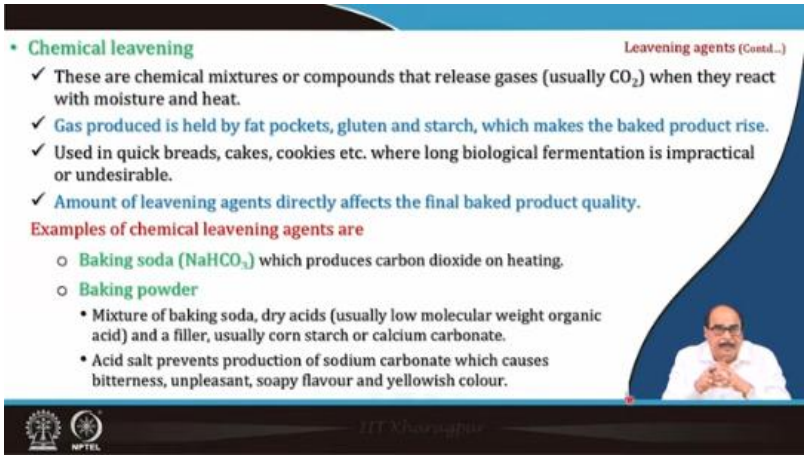
color, actually if you take the fresh wheat flour which is milled after the freshly harvested wheat then it has slightly yellowish tint may be because of the presence of the carotene or carotenoids etc., it is slightly yellowish tint.

So, these bleaching agents are added which modify these carotenes which are present in the wheat and they are converted into white color or colorless compounds. So, they oxidize the carotenoids and the fluor grains to assist with the development of the gluten as well. They are classified as either natural bleaching agents that is mainly enzymes such as lipoxygenase etc. or even synthetic bleaching agents including organic peroxide like benzoyl peroxide or so. So, lipoxygenase or benzoyl peroxides are commonly used as a fluid bleaching agent and then lipoxygenase when it is used, it acts with the polyunsaturated fatty acids or esters of the cis-1,4 pentadiene functionalities and these hydro peroxidation reactions takes place. That is these hydro peroxidation reactions are catalyzed by basically the enzyme lipoxygenase and then it gives to the product various bleached products in the wheat flour and which improves not only the colour of the wheat or its dough, but also finally, the baked products.



Then comes the leavening agent, leavening agents again is a very important class of functional food additive in the industry. These are substances that release gas in a dough or batter under appropriate conditions of moisture and temperature. This gas release, along with expansion of entrapped air and moisture vapour imparts a characteristic cellular structure to finished goods. It tenderizes the crumb and contributes to the aesthetic enjoyment of the final product by giving it uniform cell structure, bright crumb color, soft texture and enhanced palatability.

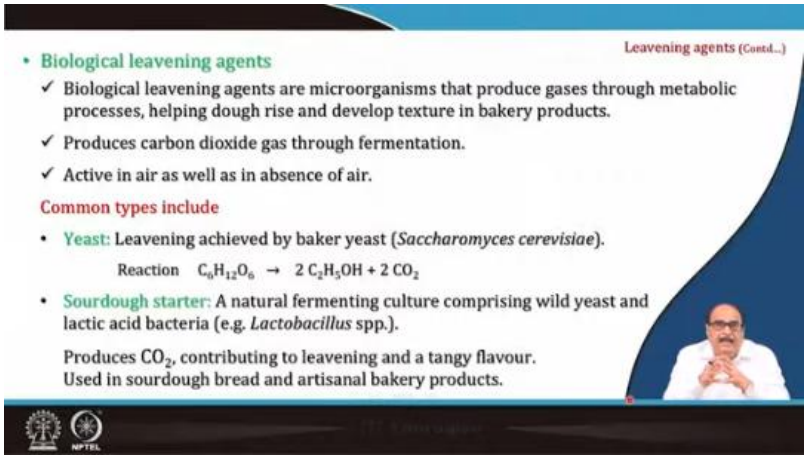
And then these leavening agents are also used extensively in the bakery industry or another other snack food industry etc. It may be leavening may be of various type one may be physical leavening, chemical leavening or biological leavening. The physical leavening basically is achieved by integrating tiny air bubbles into the mixture using a mixture or whisk. Creaming which is used in cookie or biscuit production, is the incorporation of air bubbles that is achieved by beating fat and sugar crystals together in a mixture. And the air incorporates when in for particularly for cake making etc., when various fat and sugars are worked together, whipped, then air gets incorporated into it. And then, this air, during the baking process, when it is heated, it expands and rises, giving the product a fluffy texture and good taste. So, these are basically the physical leavening agents, and the air, you can say, may be a physical leavening agent.



Then, chemical leavening agents are basically chemical mixtures or compounds that release gases, particularly carbon dioxide, when they react with moisture and heat. So, the gas, particularly carbon dioxide, produced is held by the fat pockets in the product or even the gluten and starch network matrix, making the baked product rise. These chemical leavening agents are generally used in quick breads, cakes, cookies, etc., where long biological fermentation is impractical or undesirable.

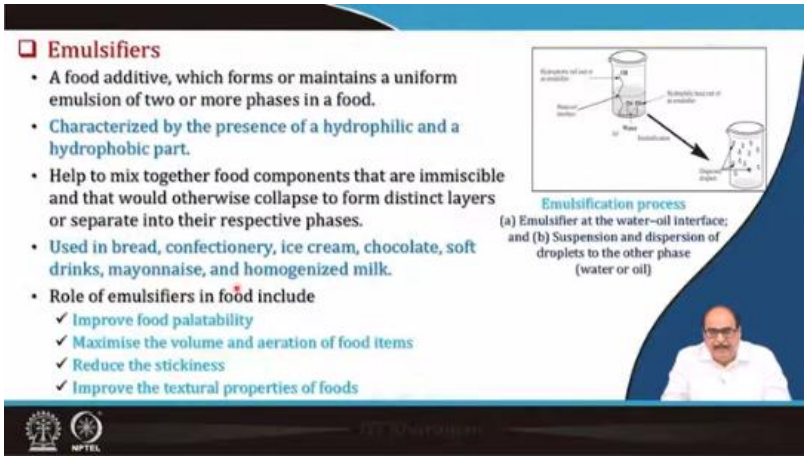
The amount of leavening agents directly affects the final baked product quality. So, important examples of chemical leavening agents include baking soda, which is sodium bicarbonate, producing carbon dioxide on heating, or baking powder, the most common chemical leavening agent. Baking powder is a mixture of baking soda, dry acids (usually low molecular weight organic acids), and a filler material, which is usually corn starch or

calcium carbonate. The acid salt also prevents the production of sodium carbonate, which causes bitterness, an unpleasant soapy flavor, or yellowish colors. Baking soda and baking powder are important chemical leavening agents.



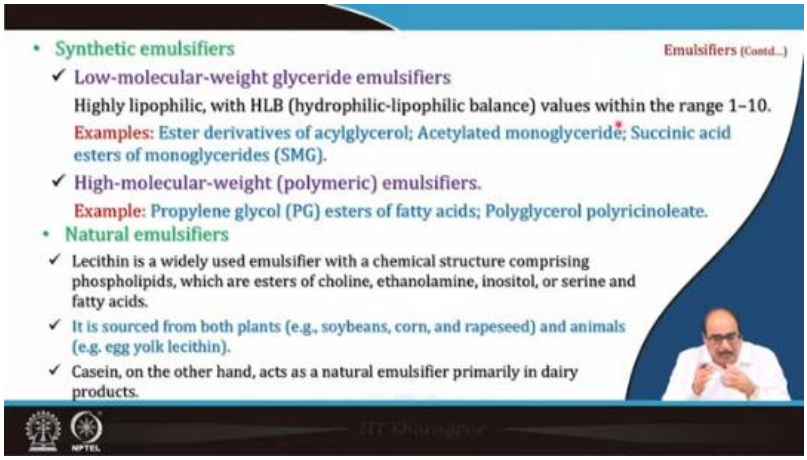
Then come the biological leavening agents, like yeast, which is commonly used in wheat flour for bread making. So, here, yeast is a biological leavening agent. When used in the dough, yeast, as you can see here in the reaction, acts on sugar (glucose), converting it into ethyl alcohol and carbon dioxide gas, releasing energy and carbon dioxide. So, that is one important leavening agent, and this gas causes the expansion of the dough, which is also called the leavening or rising of the bread dough. Another important biological leavening agent is the sourdough starter, which is a natural fermenting culture comprising wild yeast and lactic acid bacteria, like *lactobacillus* species.

It produces carbon dioxide contributing to leavening and a tangy flavor. It is used in sourdough bread and artisanal bakery products. Then comes another important functional additive application is emulsifiers. It is a additive, which forms or maintains a uniform emulsion of two or more phases in a food. It is characterized by the presence of a hydrophilic and a hydrophobic agent.



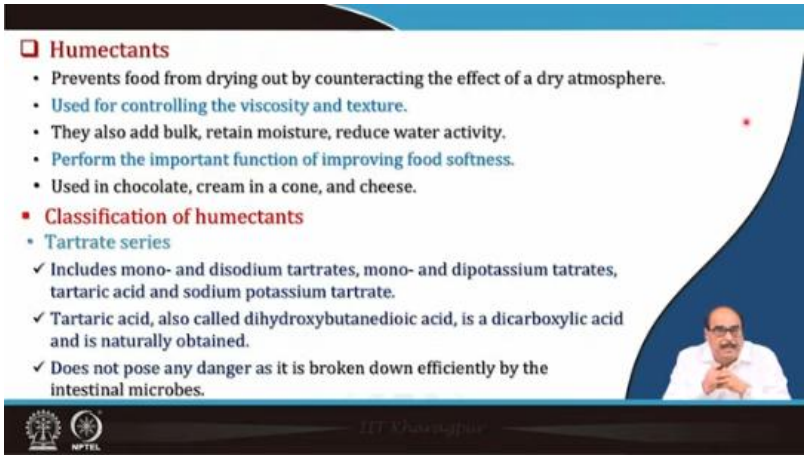
As you can see here, mostly these emulsifiers, they are used to keep the two immiscible liquids. For example, oil and water to remain in a stable solution for stable emulsion form or stabilized form. So, as you see that these emulsifiers, they have hydrophilic and hydrophobic both parts. So, these hydrophobic parts hold the oil. And the hydrophilic part holds the water, and then it acts as a bridge between these two as you can see here in this figure and keep the water and oil molecules intact together and does not allow it to separate.

This is extensively used in the bread making, confectionery, ice cream, chocolate, soft drink, mayonnaise or even homogenized milk etc. The various roles which these emulsifiers play in the food include improving food palatability, maximizing the volume and aeration of food items, reducing the stickiness or improving the textural properties of the foods. The emulsifiers may be of synthetic in nature, they may be natural emulsifier, synthetic emulsifier may be low molecular weight glyceride emulsifiers, they are highly lipophilic. They have a HLV value, hydrophilic-lipophilic balance value within the range of 1 is to 10, wide range of HLB value. And the ester derivatives of acylglycerols like acetylated monoglycerides, succinic acid esters of monoglycerides etc. are examples of low molecular weight glycerine emulsifier.



Esters of fatty acids, propylene glycol, polyglycerol polyricinoleate etc. are the examples of high molecular weight polymeric emulsifiers. We will discuss natural emulsifier, the first name comes is the lecithin. Lecithin is a widely used natural emulsifier with a chemical structure comprising of phospholipids, which are the esters of choline, ethanolamine, inositol, serine and fatty acids. This lecithin is source from both plants like soybean, corn, rapeseed oil or from the animal industry like egg yolk, lecithin and so on. Even casein, on the other hand, it also act as a natural emulsifier primarily in the dairy products.

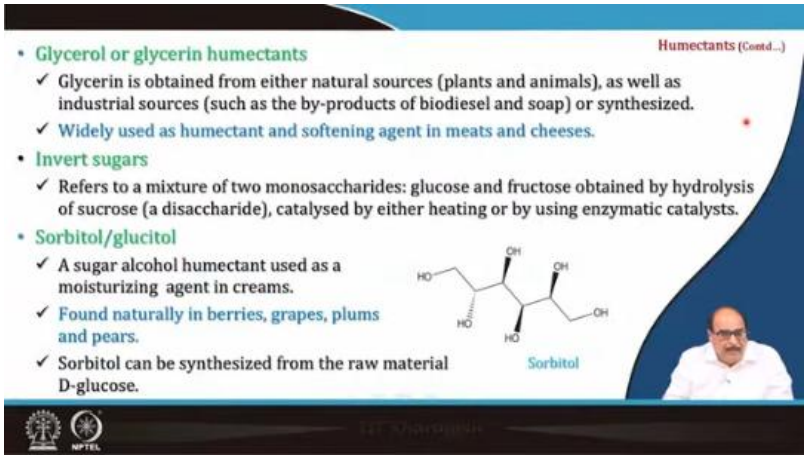
So, lecithin is the one which keeps the fat globules and water together in the milk. It is naturally present in the milk and it does not allow fat to separate.



Humectant is another important class of functional additives which prevents food from drying out by counteracting the effect of a dry atmosphere. It is used for controlling the

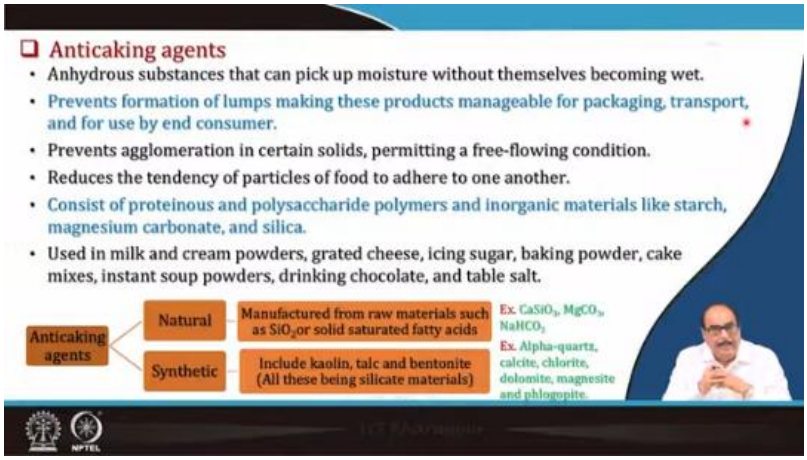
viscosity and texture. They also add bulk, retain moisture, and reduce water activity. These are used in chocolate, cream in a cone or also in cheeses.

So, the various type of humectants may be tartrate series includes mono and disodium tartrate, mono and dipotassium tartrate, tartaric acid, sodium potassium tartrate etc. Tartaric acid also called as dihydroxybutanedioic acid is a dicarboxylic acid and it is obtained naturally. Tartrate does not pose any danger as it is broken down efficiently by the intestinal microbes.



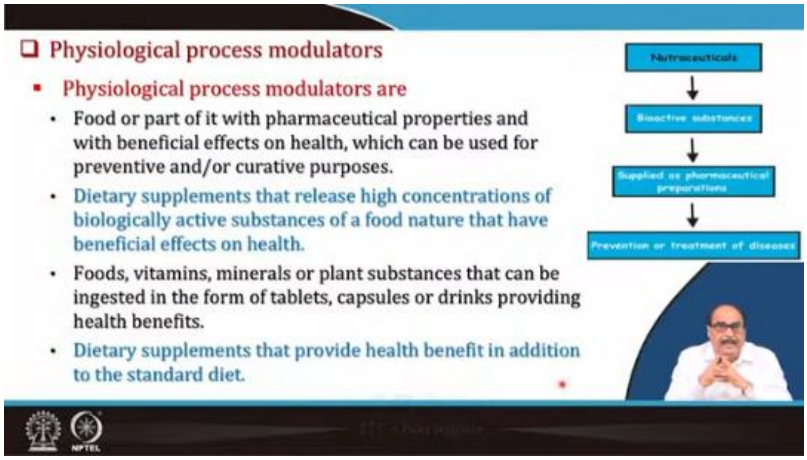
Glycerol or glycerine humectant, invert sugars, sorbitol/glucitol, these are other important category of humectants or materials. That is sorbitol or glucitol. It is a sugar alcohol, which is used widely in a confectionery and bakery products to keep it moist all right.

So, basically, these humectants are the materials which are used in the product that we want to prevent from drying during storage or processing. Sorbitol is found naturally in berries, grapes, plums, etc. Sorbitol can also be synthesized from raw materials like glucose, etc.

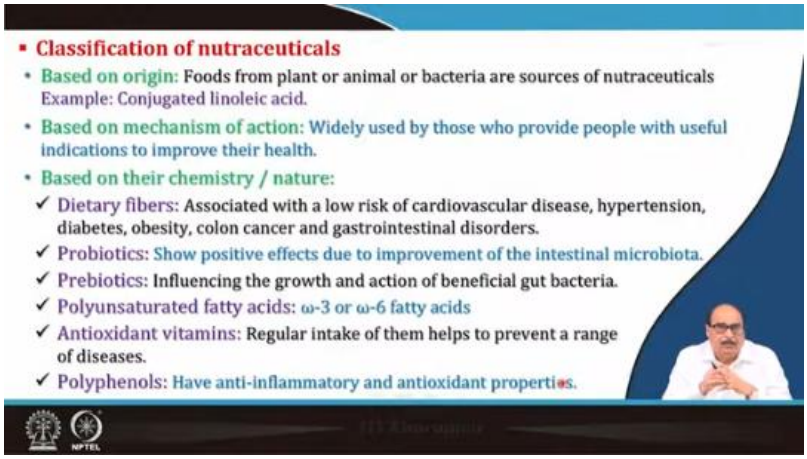


Another category is anticaking agents. These are anhydrous substances that can pick up moisture without becoming wet themselves. These are used in food powders, salts, etc., to prevent lump formation, making these products manageable for packaging, transport, and use by end consumers. They prevent agglomeration in certain solids, permitting a free-flowing condition. Anticaking agents reduce the tendency of food particles to adhere to one another. They consist of proteinous and polysaccharide polymers and inorganic materials like starch, magnesium carbonate, and silica. So, these anticaking agents are used in milk and cream powders, grated cheese, icing sugar, baking powder, cake mixes, instant soup mixes, soup powders, drinking chocolate, table salt, and so on.

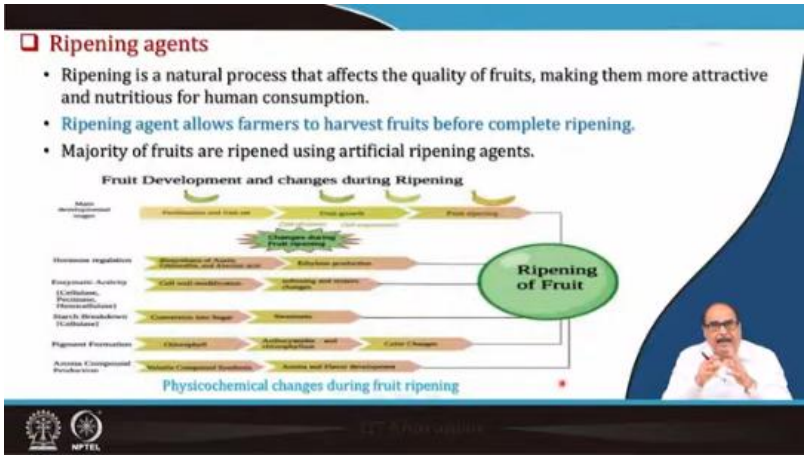
All types of materials where we want them to remain free-flowing—where the powder should not form lumps—may use anticaking agents, which can be natural or synthetic. Natural anticaking agents are mostly manufactured from raw materials such as silicon oxide or solid saturated fatty acids like calcium silicate, magnesium carbonate, sodium bicarbonate, etc. Synthetic anticaking agents include kaolin, talc, and bentonite, and examples like alpha quartz, calcite, chloride, dolomite, magnesite, etc., are synthetic anticaking agents.



Then, another important class of functional food, particularly in fruit and vegetable processing, is physiological process modulators. These physiological process modulators are foods or parts of foods with pharmaceutical properties. And they have a beneficial effect on health, which can be used for preventive and/or curative purposes. In other words, you can say they can also be nutraceuticals or may be an important class of this type of functional additive application. Dietary supplements that release high concentrations of biologically active substances of a food nature, which have beneficial effects on health—foods, vitamins, minerals, or plant substances. These can be ingested in the form of tablets, capsules, or drinks, providing health benefits or dietary supplements that offer health benefits in addition to the standard saturated diet. They all can be considered as physiological process modulators, meaning they regulate our gut processes. Or physiological processes, particularly in fruits and vegetables, helping them improve one or the other characteristic properties.



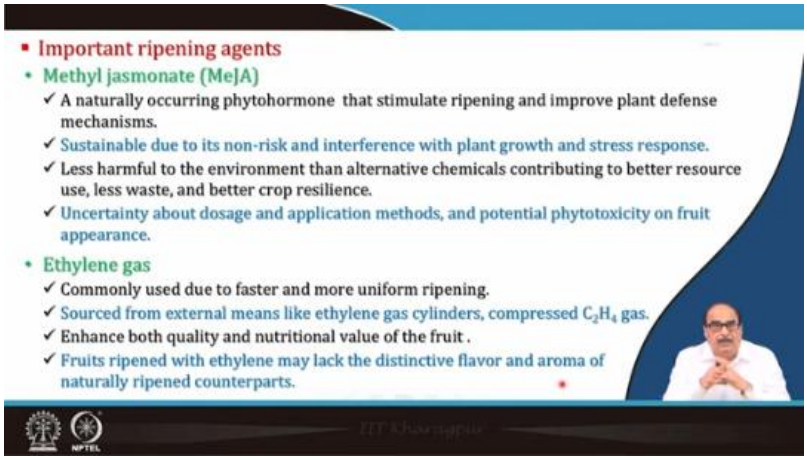
The various classifications of these nutraceuticals may be based on their origin, mechanism of action, or even their chemistry or nature. For example, polyunsaturated fatty acids, antioxidant vitamins, polyphenols—all these are included in the classification of nutraceuticals, etc. Ripening agents are another important class; they can also function as physiological process modulators. But this is a category of chemicals, biochemicals, or additives you can say, which are widely used to enhance the ripening process of fruits.



Ripening is a natural process that affects the quality of the fruit, making it more attractive and nutritious for human consumption. So, in the fruit at the maturity stage, there is ethylene, which is a natural ripening hormone. It initiates the ripening process, and during the ripening of the fruit, various enzymes are formed, and starches are converted into sugars. Various coloring materials are formed, and flavoring materials are also formed. During the ripening process, a lot of physiological actions take place, and ultimately, the fruit you get is a ripe fruit.

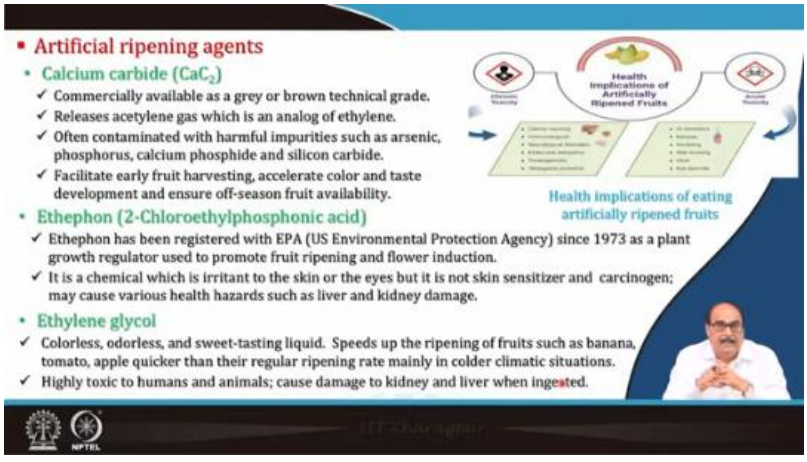
It may be having good colour, good flavour, good taste, sweet and all those things. These processes there are and it is a natural process. There are certain ripening agents which are used to amplify or enhance this ripening process. Majority of the fruit particularly in the market and many a times you find that is unseasonal that is a ripe fruit is available out of its season, beyond its season. So, here that artificial ripening agents are used to make these fruits ripen etcetera.

Ripening agents allow farmers to harvest fruits even before they are complete ripening.



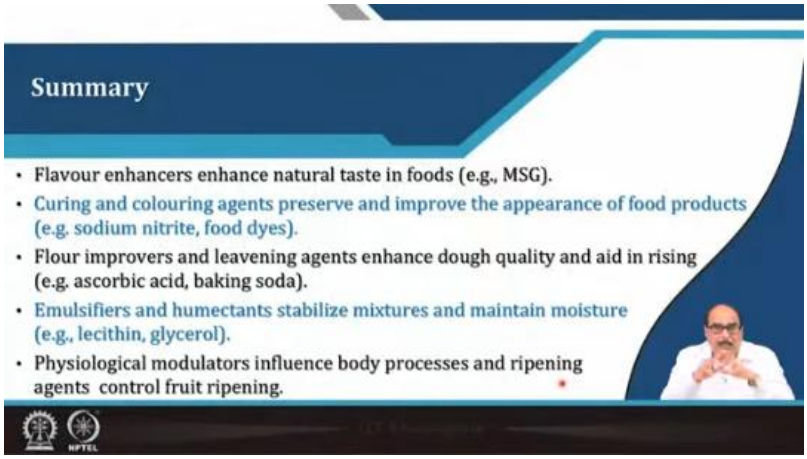
These important ripening agents include there is a natural as well as synthetic artificial ripening. In the natural, you can say it is a methyl jasmonate is the one important ripening agent. It is a naturally occurring phytohormone that stimulates the ripening and improves the plant defense mechanism. It is sustainable due to its non-risk and interference with the plant growth and stress response. It is less harmful to the environment, and it is its uncertainty about dosage and application methods and its potentially phytotoxicity and the fruit appearance, but it is used. It is an alternative chemical contributing to the better resource, use less waste and better crop resilience.

Another is the ethylene gas. It is commonly used due to faster and more uniform ripening. It is source from external means like ethylene gas cylinders, compressed ethylene gas. It enhances both the quality and nutritional value of the fruit. Fruit ripened with ethylene may lack the distinctive flavor and aroma of naturally ripened counterparts.



Then there are artificial ripening agents like calcium carbide, ethephon (2-chloroethylphosphonic acid), or ethylene glycol. These artificial ripening agents are commercially available; calcium carbide is commercially available as a grey or brown technical grade. There is released acetylene gas, which is an analogue of ethylene. However, this is often contaminated with harmful impurities such as arsenic, phosphorus, calcium phosphate, silicon, carbon dioxide, etcetera. So, it facilitates fruit harvesting, accelerates color and taste development, and ensures off-season fruit availability. Similarly, Ethephon has been registered with the EPA, the US Environmental Protection Agency, since 1973. As a plant growth regulator, it is used to promote fruit ripening and flower induction. It is a chemical that is irritant to the skin or the eyes, but it is not a skin sensitizer and not a carcinogen. However, it may cause various health hazards such as liver and kidney damage. Even ethylene glycol, which is a colorless, odorless, and sweet-tasting liquid. It speeds up the ripening of fruits such as bananas, tomatoes, apples, etc. However, it is highly toxic to humans and animals. It may cause damage to the kidneys and liver when ingested.

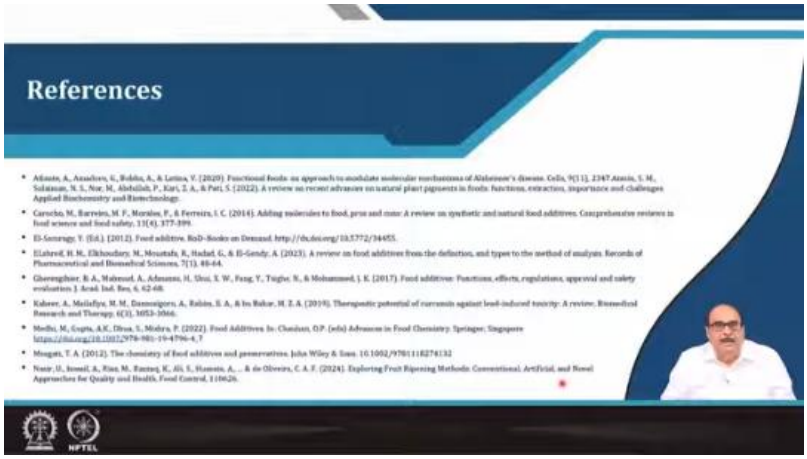
So, these artificial ripening agents, although they may enhance the ripening and add value, are generally not good from a health perspective.



Finally, I would like to summarize this lecture. There is a wide category, a wide list of GRAS chemicals—generally recognized as safe chemicals— available both as natural as well as synthetic or synthesized chemicals, which are used to improve or enhance various functionalities, to provide functional properties, or to add functional characteristics, etc., to food. Moisture retention agents or physiological process modulators, etc., but one thing

is always clear: natural chemicals, etc., are not used much. However, many times, artificial ones, although they may improve functionality, can have other side effects. So, particularly synthetic functional additives, synthetic chemicals, or synthesized chemicals used in food should be applied with utmost care. And, of course, regulatory provisions are in place.

So, one must follow regulations while using these various chemicals or additives, whether for improving functionality, enhancing other characteristics, or even for extending shelf life as a preservation method for food.



These were the references used to prepare this lecture.

With this, I thank you very much for your patient listening. Thank you.