

FOOD SCIENCE AND TECHNOLOGY

Lecture28

Lecture 28: Phytochemicals and Bioactives

Hello everyone, Namaste.





So, in this lecture today, we shall be talking about phytochemicals. We are now in the sixth module, where we are discussing micronutrients and bioactive compounds present in food.



So, in today's lecture on phytochemicals, the concepts that we will cover include the major classes and sources of phytochemicals. We will discuss the health benefits of phytochemicals, the mechanism of action of phytochemicals, and finally, we will also talk about the bioavailability and absorption of phytochemicals.

Phytochemicals

- Phytochemicals are bioactive compounds found in plants that contribute to their color, flavor, and disease resistance.
- Phytochemicals possess antioxidant, antimicrobial, antidiarrheal, anthelmintic, anti-allergic, antispasmodic, and antiviral activities.
- Source
Whole grains, fruits, vegetables, nuts, and herbs.
- Examples
Carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, and certain polysaccharides.
- Uses
Regulate gene transcription, enhance gap junction communication, improve immunity, and provide protection against lung & prostate cancers.



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So, let us talk about what phytochemicals are. Phytochemicals are bioactive compounds found in plants that contribute to the color, flavor, and various disease resistance-related properties in the plant. Phytochemicals possess antioxidant, antimicrobial, antidiarrheal, anthelmintic, antiallergic, antispasmodic, and antiviral activities, among many other health-promoting activities. Phytochemicals are mainly found in whole grains, fruits, vegetables, nuts, and herbs. Some common examples of phytochemicals include carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, and certain polysaccharides. As far as the usage of phytochemicals is concerned, they regulate gene transcription, enhance gap junction communication, improve immunity, and provide protection against lung and prostate cancers.

Major classes and sources of phytochemicals

- Some of the major classes of phytochemicals are

Carotenoids
Polyphenols
Isoprenoids
Phytosterols
Saponins
Dietary fibres and certain polysaccharides
Glucosinolates
Alkaloids



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The major classes of phytochemicals include carotenoids, polyphenols, isoprenoids, saponins, some dietary fibers, certain polysaccharides, glucosinolates, and alkaloids. So, we will discuss almost all major aspects of these phytochemicals briefly in the coming slides.

Carotenoids

- Carotenoids are natural lipophilic pigments and antioxidants.
- It can be classified as **carotenes** and **xanthophylls**.

Carotenes	Xanthophylls
Solubility: Organic or non-polar solvents	Solubility: Polar solvents
Types: α -carotene, β -carotene, γ -carotene, and lycopene	Types: Fucoxanthin, lutein and violaxanthin
Storage place: Chromoplasts of fruits, flowers and roots; amyloplasts and elaioplasts of grains and oilseeds	Storage place: Freely found in green plant tissues; as esters of fatty acids in fruits and flowers

NPTEL

So, let us first talk about carotenoids. Carotenoids are natural lipophilic pigments and antioxidants. They can be classified as carotenes and xanthophylls. The carotenes are soluble in organic and non-polar solvents. They are mainly alpha carotene, beta carotene, gamma carotene, and lycopene. They are generally found in chromoplasts of fruits, flowers, and roots, as well as in amyloplasts and elaioplasts of grains and oilseeds. Whereas, on the other hand, their types include fucoxanthin, lutein, and biloxanthin. They are normally found in green plant tissues. They are also found as esters of fatty acids in fruits and flowers.

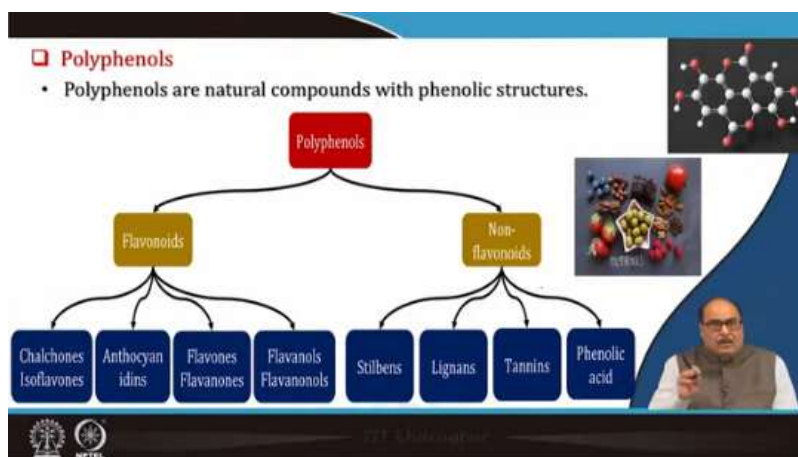
Major food sources of carotenoids

Zeaxanthin	Corn	Eggs	Orange peppers	Goji berries
Lycopene	Tomatoes	Papayas	Watermelons	Red carrots
Astaxanthin	Algae	Salmon	Shrimp	Trout
Beta-carotene	Carrots	Mangos	Pumpkin	Sweet potatoes
Lutein	Avocados	Egg yolks	Spinach	Basil



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The different major food sources of carotenoids, if you talk about zeaxanthin, it is majorly found in corn, eggs, orange peppers, and goji berries. Lycopene, a very popular source of lycopene, is tomatoes. It is also found in papaya, watermelons, and red carrots. Astaxanthins are found in algae, salmon, shrimp, and trout. Whereas beta-carotene, carrot is the major source of beta-carotene. It is also found in mangoes, pumpkins, and sweet potatoes. Lutein is mainly found in avocados, egg yolk, spinach, and basil.



Now, the polyphenols: what are polyphenols? They are basically natural compounds with a phenolic structure. They can be broadly classified into two major groups: one is the flavonoids, and the other is non-flavonoids. The flavonoids include chalcones, isoflavones, anthocyanidins, flavones, flavanones, and flavonols. Similarly, non-flavonoid polyphenols include stilbenes, lignins, tannins, and phenolic acids.

Polyphenols

- ✓ Act against free radicals.
- ✓ Reduce oxidative stress and protect cells from oxidative damage.
- ✓ Protect against cardiovascular diseases, cancers, and age-related conditions.
- ✓ Provide relief from inflammation and prevent allergy.

Sources

Artichoke, spinach, broccoli, chicory, flax, onion, apple, plum, pear, grape, cherry, and in beverages like olive oil, tea, and red wine

Polyphenols (Contd...)

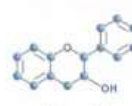

Polyphenols act against free radicals. They reduce oxidative stress and protect cells from oxidative damage. They protect against cardiovascular diseases, cancers, and age-related conditions. Polyphenols provide relief from inflammation and prevent allergies. Major sources of polyphenols include artichoke, spinach, broccoli, chicory, flax, onion, apple, plum, and pear. Grape, cherry, and also, they are found in some beverages like olive oil, tea, as well as red wine. Red wines are considered the major and very good sources of polyphenols.

❖ Flavonoids

- **Structure**
 - ✓ Composed of 15 carbon atoms arranged in a three-ring system. This structure can be described as $C_6-C_3-C_6$, which includes two benzene rings (A and B) and a heterocyclic ring (C).
- **Classifications**
 - ✓ Flavones, flavanones, flavonols, flavanonols, isoflavones, flavanols (catechins), and anthocyanidins.
- **Biological activities**
 - ✓ Antioxidant, anticarcinogenic, anti-inflammatory, and bone health effects.
- **Detrimental affect**
 - ✓ In certain situations flavonoids may interfere with thyroid function, estrogenic effect, gastrointestinal disturbances, etc. A diet high in flavonoids may, however, reduce the risk of type-2 diabetes.

Polyphenols (Contd...)

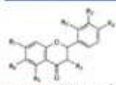
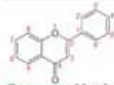
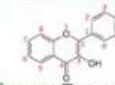
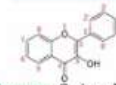
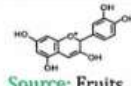
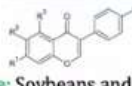
Flavanoid





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You can see here in this structure; they are composed of 15 carbon atoms arranged in a three-ring system. This structure can be described as C_6 , C_3 , and C_6 , which includes two benzene rings, that is A and B, and one heterocyclic ring, which is called C. As far as the classification of flavonoids is concerned, there are different types. Flavones, flavanones, flavonols, flavanonols, isoflavones, again flavanols, and there are catechins and anthocyanidins. Their biological activities include acting as antioxidants, anti-carcinogenic agents, anti-inflammatory, and also bone health effects. They have bone health effects. However, in certain situations, flavonoids may interfere with thyroid function., estrogenic effects they may have, or they may also have gastrointestinal disturbances, etcetera, and this may be considered that, particularly if they are taken in larger amounts, they may be detrimental. A diet high in flavonoids may, however, reduce the risk of type 2 diabetes, and there is sufficient literature which proves this.

Flavonoids (Contd...)

Flavanones  Source: Citrus fruits Example: Hesperidin	Flavones  Source: Herbs Example: Apigenin	Flavan-3-ols  Source: Tea, cocoa Example: Epicatechin	Flavonols  Source: Onion, berries Example: Quercetin
Anthocyanidins  Source: Fruits Example: Cyanidin		Isoflavones  Source: Soybeans and legumes Example: Genistein	



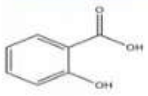
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Now, the different major types of flavonoids, like flavanones, are found mainly in citrus foods, and a very good example of the flavonoids found in citrus foods is hesperidin; its structure is provided here. Similarly, flavones are found in herbs, and apigenin is the major

one. Flavan-3-ols, for example, epicatechin, are mainly found in tea and cocoa; their structure is given here. Flavonols, a very good example of which is quercetin, are found in onions as well as in berries. Anthocyanidins, for example, cyanidin, are found mainly in fruits. Isoflavones, such as genistein, are found in soybeans and other legumes.

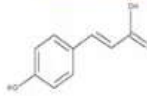
❖ **Phenolic acids**

Hydroxybenzoic Acids



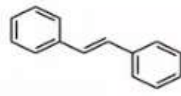
Source: Citrus fruits
Example: Hesperidin

Hydroxycinnamic Acids



Source: Fruits and vegetables
Example: Caffeic acid

❖ **Stilbenes**



Structure: Two phenyl rings connected by a vinylene group.

Source: Grapes, peanuts, rhubarb, berries, etc.

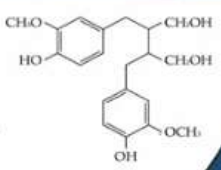
Example: Resveratrol

Biological activities: Antioxidant, anti-inflammatory, antitumor, antibacterial, and antiviral.

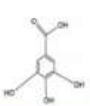
Phenolic acids, like hydroxybenzoic acids, have a common example in hesperidin, which is found in citrus fruits. Stilbenes, whose structure you can see here, have two phenyl rings connected by a vinylene group. Their sources include grapes, peanuts, rhubarb, berries, etc. An example of stilbenes is resveratrol. Their biological activities include strong antioxidant potential, anti-inflammatory properties, anti-tumor, antibacterial, and antiviral effects. Hydroxycinnamic acid has a major example in caffeic acid. It is found in fruits and vegetables. It also has very health-promoting activities.

❖ **Lignans**

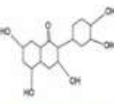
- Structure:** 2,3-dibenzylbutane structure and are made up of two phenylpropane units linked together by β , β -bonds.
- Example:** Secoisolariciresinol
- Sources:** Oilseeds, whole grains, legumes, berries, coffee, tea



❖ **Tannins**



Hydrolysable



Condensed

- Source:** Tea, coffee, pomegranates, grapes, etc.
- Example:** Hydrolysable and condensed tannins
- Detrimental effect:** Excessive consumption can inhibit the absorption of iron.
- Biological activities:** Neutralize free radicals and reduce oxidative stress.

Lignans, whose structure you can see here, have a lignan structure provided. They have a 2,3-dibenzyl butane structure and are made up of two phenyl propane units linked together by beta-beta bonds and their sources include oilseeds, whole grains, legumes, berries,

coffee, and tea. Another major group of compounds found in this polyphenol group is the tannin. This is mainly found in tea, coffee, pomegranate, grapes, etcetera, and the common examples of these tannins. includes hydrolyzable and condensed tannins. You can see the structure here: hydrolyzable and condensed tannins, and they have detrimental effects as well. Sometimes, for example, if one takes excessive consumption of these tannins, it can inhibit the absorption of iron in the body. The biological activities of tannin include neutralizing free radicals and reducing oxidative stress.

Isoprenoids or Terpenes

- Structure:** Molecules with multiple isoprene units
- Source:** Eucalyptus, juniper, rubber, cinnamon, cloves, and ginger

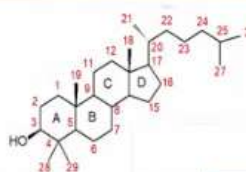
Gamma Terpinene	Linalool	Myrcene	1,3 Cineole	Limonene	alpha-Phellandrene	Beta-Phellandrene

- Biological activities:** Reducing appetite, alleviating stress and anxiety, supporting digestive health, exhibiting antioxidant potential, and offering pain relief.
- Example:**
 - ✓ Limonene found in aromatic plants and fruits, e.g. lemon flavor and scent.
 - ✓ Myrcene is known for its sedative effects in hops and lemongrass.

Then, another class is the isoprenoids or terpenes. They are molecules with multiple isoprene units. Their sources may be eucalyptus, juniper, rubber, cinnamon, cloves, and ginger. The major classes of compounds which are categorized in these isoprenoids or terpenes include gamma terpinene, linalool, myrcene, 1,3 cineole, limonene, alpha phellandrene, and beta phellandrene. These are their names and structures, which you can easily see provided here. Their biological activities include reducing appetite, elevating stress and anxiety, supporting digestive health, exhibiting antioxidant potential, and offering pain relief. We have already given the names here and the structure here, but some of the major isoprenoids or terpenes like limonene are found in aromatic plants and fruits. It is also a major compound that contributes to the flavor of lemon and the lemon scent, which is limonene. Similarly, myrcene is known for its sedative effects in hops and lemongrass.

Phytosterols

- **β -Sitosterol:** The most abundant phytosterol; exhibits anti-inflammatory, antioxidant, and immune-boosting properties and helps to lower LDL cholesterol levels.
- **Campesterol:** Aids in reducing cholesterol absorption and has anti-inflammatory effects.
- **Stigmasterol:** Known for its anti-inflammatory, antioxidant, and anticancer activities and helps in regulating cholesterol and has potential neuroprotective effects.
- **Brassicasterol:** Found in certain oils like canola, it has cholesterol-lowering properties and potential antioxidant activities.
- **Ergosterol:** Mainly found in fungi and yeasts; ergosterol can be converted to vitamin D₂ and has antioxidant properties.

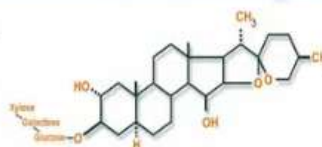


Dr. Khanna

Then, let us talk about phytosterols. There are different types of phytosterols like beta-sitosterol, campesterol, stigmasterol, brassicasterol, ergosterol, etc. Beta-sitosterol is the most abundant phytosterol. It exhibits anti-inflammatory, antioxidant, and immune-boosting properties and also helps to lower LDL cholesterol levels. Campesterol aids in reducing cholesterol absorption and has anti-inflammatory effects. Stigmasterol is known for its anti-inflammatory, antioxidant, and anti-cancer activities. It helps in regulating cholesterol and has potential neuroprotective effects. Brassicasterol is found in certain oils like canola oil. It has cholesterol-lowering properties and potential antioxidant activities. Ergosterol is mainly found in fungi and yeast. Ergosterol can be converted to vitamin D₂, and it has potential antioxidant activity.

Saponins

- **Structure:** Glycosides composed of sapogenin and sugar moieties.
- **Classification:** Steroidal and triterpenoid
- **Sources:** Legumes such as black gram, garden pea, pigeon pea, and common bean



Biological activities

- ✓ Reducing conditions like acute injuries, erectile dysfunction, venous edema, and systemic lupus erythematosus.
- ✓ Hypoglycaemic, antifungal, antimicrobial, and hypolipidemic properties.



Dr. Khanna

Then, saponins: Saponins are glycosides which are composed of sapogenin and sugar moieties like xylose, galactose, glucose, etcetera. You can see the structure is provided here. They can be classified into steroidal as well as triterpenoids. Sources of these saponins include legumes such as black gram, garden pea, pigeon pea, and even common beans, which contain a sufficient or good amount of saponins. The biological activities of

saponins include reducing conditions like acute injuries and erectile dysfunction. Venous edema and systemic lupus erythematosus. They have hypoglycemic, antifungal, antimicrobial, and hypolipidemic properties.

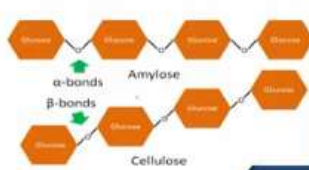

Polysaccharides and dietary fibers

Polysaccharides

- Source:** Rice, corn, wheat, potatoes and cell walls of plants (cellulose).
- Biological activities:** Storage of energy, regulation of immune system and metabolic diseases, anti-tumor activity, antiviral activity, antidiabetic properties, etc.

Dietary fibre

- Sources:** Carob beans, chicory, tamarind, barley, oats, and green beans.
- Biological activities:** Prevent cancer, inflammation, hypertension, and cardiovascular diseases, and improves insulin sensitivity and gut health.

Dr. Khanna

In another group of bioactive or active compounds which are found in food may include certain polysaccharides and dietary fibers. They are also sometimes considered, some of them, as phytochemicals. So, polysaccharides like those found in corn, wheat, potatoes, and the cell walls of plants like cellulose, etcetera. They have biological activities like the storage of energy, regulation of the immune system, and metabolic diseases. They have anti-tumor activity, anti-viral activity, and anti-diabetic properties, etcetera. Similarly, dietary fibers are found mainly in carob beans, chicory, tamarind, barley, oats, and green beans. Their biological activities include preventing cancer, inflammation, hypertension, and cardiovascular diseases. They also improve insulin sensitivity and gut health.

Glucosinolates

Glucose and an amino acid derives organic compounds, containing sulfur and nitrogen.

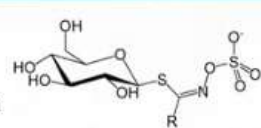

- Sources:** Seeds, roots, leaves, and stems of plant like broccoli cabbage, cauliflower, and mustard.

Classifications

- ✓ **Aliphatic glucosinolates:** Contains alanine, leucine, isoleucine, methionine, or valine side chains.
- ✓ **Aromatic glucosinolates:** Contains phenylalanine or tyrosine side chains.
- ✓ **Indole glucosinolates:** Contains tryptophan side chains.
- ✓ **Isothiocyanates:** Contains methionine and phenylalanine side chains.

Biological activities

- ✓ Anti-cancerous, anti-inflammatory, antioxidant and chemoprotective.
- ✓ Reduce cardiometabolic, neurological, and musculoskeletal disorders.

Dr. Khanna

Glucosinolates, a compound of glucose and an amino acid, are derived from glucose and an amino acid, forming organic compounds containing sulfur and nitrogen. These are the

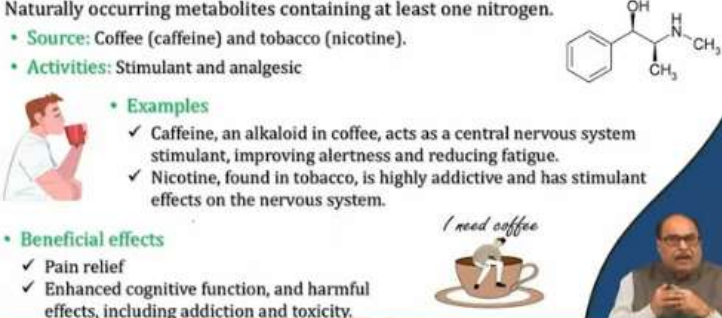
glucosinolates. They are found mainly in seeds, roots, leaves, and stems of plants like broccoli, cabbage, cauliflower, and mustard. Mustard seeds are a major source of glucosinolates. They can be classified into various groups, such as aliphatic glucosinolates. These contain alanine, leucine, isoleucine, methionine, or valine as side chains. Aromatic glucosinolates contain phenylalanine or tyrosine side chains. Indole glucosinolates contain tryptophan side chains and isothiocyanates contain methionine and phenylalanine side chains. So, depending on the type of amino acid present, they can be grouped into various categories. The biological activities of glucosinolates include being anti-cancerous, anti-inflammatory, antioxidant, and chemoprotective. They reduce cardiometabolic risks, neurological and musculoskeletal disorders.

Alkaloids

Naturally occurring metabolites containing at least one nitrogen.

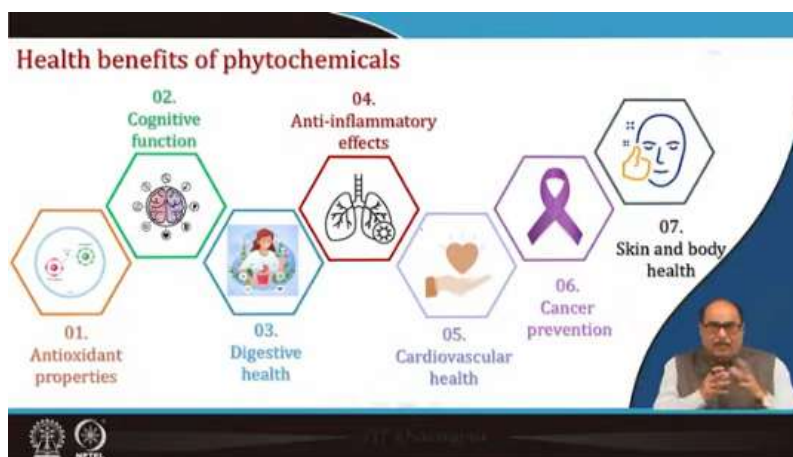
- **Source:** Coffee (caffeine) and tobacco (nicotine).
- **Activities:** Stimulant and analgesic
- **Examples**
 - ✓ Caffeine, an alkaloid in coffee, acts as a central nervous system stimulant, improving alertness and reducing fatigue.
 - ✓ Nicotine, found in tobacco, is highly addictive and has stimulant effects on the nervous system.
- **Beneficial effects**
 - ✓ Pain relief
 - ✓ Enhanced cognitive function, and harmful effects, including addiction and toxicity.

I need coffee



The slide features a chemical structure of caffeine (1,3,7-trimethylxanthine) in the top right corner. Below the text, there is a cartoon illustration of a man drinking from a red cup. In the bottom right, there is a small inset video of a man speaking. The slide also includes a logo for 'APTEL' in the bottom left corner.

Now, let us talk about alkaloids, another important group of phytochemicals. They are naturally occurring metabolites containing at least one nitrogen in their structure. Their sources mainly include caffeine, which is found in coffee, and nicotine, found in tobacco,. Their activities mainly include acting as stimulants and analgesics; they act as stimulants. For example, caffeine, which is an alkaloid in coffee, acts as a central nervous system stimulant, improving alertness and reducing fatigue. Similarly, nicotine, which is found in tobacco, is highly addictive and has a stimulant effect on the nervous system. The biological effects of alkaloids include pain relief, enhanced cognitive function, and harmful effects, including addiction and toxicity.



Now, let us talk about health benefits of the majority of phytochemical classes and major compounds we discussed. Now, as a whole, the health benefits of phytochemicals may be summarized as follows: Number one, they have antioxidant properties, they support cognitive functions, they promote digestive health, okay, they have anti-inflammatory effects, they improve cardiovascular health, they have cancer prevention properties, and finally, they have beneficial effects on the skin as well as the body. So, they improve skin and body health. So, these are the major health benefits of consuming phytochemicals.

Mechanism of action of phytochemicals

☐ Anti-oxidative protection

Paired Electrons
Stable molecule

Unpaired Electron
Free radical

- Phytochemicals **protect** cellular structures and macromolecules from **free radical damage** caused by natural processes, environmental factors, and lifestyle choices.
- **Free radicals** are any atom (or atom within a molecule) with at least one unpaired electron in its outermost shell/ orbital.

❖ **Free radical scavenging**

- Phytochemicals donate electrons to free radicals, neutralizing them and preventing cellular damage.

Example: Flavonoids such as **quercetin**, found in **onion, apples, berries**, neutralizing hydroxyl radical ($\bullet\text{OH}$).

$\text{Flavonoid-OH} + \bullet\text{OH} \rightarrow \text{Flavonoid-O}\bullet + \text{H}_2\text{O}$

Now let us talk about the mechanism by which these phytochemicals act in the body. When we consume any phytochemicals, what is the way by which they act? So, number one is the major activity, which is the antioxidative protection. They act as antioxidants, meaning they prevent the oxidation process. That is, phytochemicals protect the cellular structure and macromolecules from oxidation. Free radical damage caused by natural processes, environmental factors, and lifestyle choices. The free radicals, as you can see here, are any atom or atom within a molecule with at least one unpaired electron in the outermost orbital, okay. So, these phytochemicals have free radical scavenging activity, meaning the

phytochemicals donate electrons to these free radicals, neutralizing them and preventing cellular damage. For example, flavonoids such as quercetin, which is found in onions, apples, and berries, neutralize the hydroxyl free radical. The equation is given here: the hydroxyl free radical is finally converted into water, and the flavonoid becomes the flavonoid free radical.


Mechanism of action of phytochemicals (Contd...)

❖ **Metal chelation**

- Binding of metal ions (iron, copper, etc.) using phytochemicals helps in preventing free radical formation. This chelation reaction retards the formation of highly reactive hydroxyl radicals.


Example: Tannins chelating iron ions

$$\text{Tannin} + \text{Fe}^{2+} \rightarrow \text{Tannin-Fe}^{2+}$$




Iron

+



Tannin

=






Iron chelated

❖ **Regeneration of other antioxidants**

- Certain phytochemicals help regenerate other antioxidants, such as vitamin E and vitamin C, enhancing their antioxidant capacity.

Example: Flavonoids regenerating vitamin E

$$\alpha\text{-Tocopherol}^\bullet + \text{Flavonoid-OH} \rightarrow \alpha\text{-Tocopherol} + \text{Flavonoid-O}^\bullet$$


Similarly, they have metal chelation activity. Metal chelation means, as we discussed in earlier classes, what are the chelates? So, these phytochemicals bind metal ions like iron, copper, etcetera, and the chelation of the metal with the phytochemicals helps in preventing free radical formation, that is, these metals which promote the oxidation process. So, that is stopped. So, the free radical formation process is stopped, and this chelation reaction can retard the highly reactive hydroxy radicals, as you see that iron for tannins. Iron is chelated by these tannins, and therefore, the oxidation process is stopped. Also, they act as a regeneration of other antioxidants like certain phytochemicals, which help regenerate other antioxidants such as vitamin E and vitamin C, and therefore, enhance their antioxidant capacity. For example, flavonoids regenerate vitamin E. There is alpha-tocopherol and flavonoid free radicals.

Mechanism of action of phytochemicals (Contd...)

❖ **Modulation of antioxidant enzyme activity**

- Phytochemicals neutralize reactive oxygen species (ROS) by enhancing the activity of endogenous antioxidant enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase (GP).

Example: Polyphenols can enhance the activity of SOD, which converts superoxide radicals into hydrogen peroxide.

❖ **Inhibition of oxidative enzymes**

- Phytochemicals inhibit enzymes that generate ROS, such as lipoxygenase, xanthine oxidase, and NADPH oxidase and reduce the production of ROS in the body.

Example: Inhibition of xanthine oxidase by flavonoids

Xanthine oxidase

$$\text{Xanthine} + \text{O}_2 \rightarrow \text{Uric Acid} + \text{O}_2^{\bullet -}$$

Flavonoids can inhibit xanthine oxidase, reducing the production of superoxide radicals.

Source: Jomova et al. 2024

Then, they also modulate antioxidant enzyme activity that is, these phytochemicals neutralize reactive oxygen species by enhancing the activity of indigenous antioxidant enzymes like superoxide dismutase. catalase and glutathione peroxidase, commonly known as GP. For example, polyphenols can enhance the activity of superoxide dismutase which converts superoxide radicals into hydrogen peroxide, as you can see here in this reaction, it is shown in the cell. These phytochemicals act by inhibiting the oxidative enzymes. That is, the inhibition of the oxidative enzymes, which generate ROS, that is, reactive oxygen species. So, the phytochemicals inhibit these enzymes, such as lipoxygenase, xanthine oxidase, and NADPH oxidase, etc., and reduce the production of ROS in the body. As an example, you can see that these phytochemicals inhibit xanthine oxidase by flavonoids, which is the inhibition of xanthine oxidase by flavonoids. Flavonoids can inhibit xanthine oxidase and reduce the production of superoxide radicals or ROS.

Protection from DNA damage

Mechanism of action of phytochemicals (Contd...)

- Free radicals cause DNA damage (base alterations, strand breakage, mutations).
- Antioxidants can prevent, reduce, and reverse DNA damage.
- Phytochemicals protect DNA, maintaining genomic integrity.
- Beneficial for reducing the risk of genetic mutations and supporting cellular health.


Then, the other way they act is by preventing the DNA damage protection, that is, these phytochemicals protect the DNA and protect the cell from DNA damage. As you know,


free radicals cause DNA damage like base alteration, strand breakdown, mutations, etc., which has been shown in this slide. See this figure, alright, how these free radicals, etc., vary the structure of the DNA is damaged. So, these antioxidants, or these phytochemicals, can prevent, reduce, and reverse this DNA damage. Phytochemicals protect the DNA, maintaining genomic integrity, they are beneficial for reducing the risk of genetic mutation and supporting cellular health.


Mechanism of action of phytochemicals (Contd...)

Improved immune function

- Phytochemicals enhance immune function by increasing the number and activity of immune cells like natural killer cells, T-helper cells, and interleukin-2 dependent cells.
- Curcumin, a notable phytochemical, has immunomodulatory properties and has been shown to reverse multiple sclerosis in animal models.
- Phytochemicals strengthen the immune system, aiding the body in fending off infections and diseases.
- Improved immune function through phytochemicals helps protect against malignant and mutant cells.



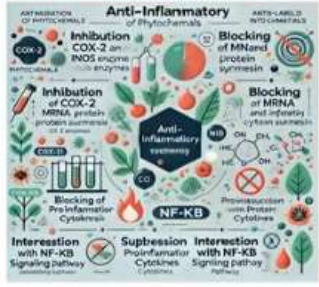





Then, another way these phytochemicals act, what is the mechanism, is that they improve immune function. Phytochemicals enhance immune function by increasing the number and activity of immune cells like natural killer cells, T helper cells, and interleukin-dependent cells. For example, curcumin, which is a notable phytochemical, has immunomodulatory properties and has been shown to reverse multiple sclerosis in animal models. Phytochemicals strengthen the immune system, aiding the body in fending off infections and diseases. They also improve immune function through phytochemicals and this improved immune function through phytochemicals helps protect against malignant and mutant cells.


Mechanism of action of phytochemicals (Contd...)

Anti-inflammatory effects



- Phytochemicals inhibit cyclooxygenase (COX-2) and inducible nitric oxide synthase (iNOS), key enzymes in inflammation.
- Help in blocking the synthesis of mRNA and proteins associated with COX-2 and iNOS.
- Inhibit pro-inflammatory cytokines that promote inflammation.
- Interfere with inflammatory signalling pathways and transcription factors such as nuclear factor-κB (NF-κB).





Another with the anti-inflammatory effect of the phytochemicals means the phytochemicals inhibit cyclooxygenase COX-2 and reduce inducible nitric oxide synthase like iNOS, which are the key enzymes for inflammation. So, these phytochemicals help in blocking the synthesis of mRNA and protein associated with COX-2 and iNOS. They also inhibit pro-inflammatory cytokines that promote inflammation. The phytochemicals interfere with the inflammatory signaling pathway and transcription factors such as nuclear factor KB, nuclear factor KB, INF KB.

Mechanism of action of phytochemicals (Contd...)

☐ Hormone modulation

- Phytochemicals modulate hormone levels, offering various health benefits.
- Phytoestrogens exhibit cancer-retardant properties and improve bone density.
- Lower elevated serum cholesterol by enhanced plasma lipid profiles.
- Phytoestrogens help alleviate menopausal symptoms and contribute to hormonal balance.
- Prevent cancer causes activities includes inhibiting angiogenesis (the formation of new blood vessels that support tumor growth) and tyrosine kinase activity (a key regulator of cell signaling involved in cancer progression).

Dr. Khanna

Then also the hormone modulations. Phytochemicals modulate hormone levels, offering nervous health benefits, offering various health benefits that phytoestrogens exhibit cancer-retardant properties and improve bone density, lower elevated serum cholesterol by enhancing plasma lipid profiles. Phytoestrogens help alleviate menopausal symptoms and contribute to hormonal balance. They prevent cancer and cause activity that is the cancer-causing activities prevention includes inhibiting angiogenesis that is the formation of new blood vessels that support tumor growth and also the tyrosine kinase activity which is a key regulator of cell signaling involved in cancer progression. So, these processes which aid in the formation of cancer bodies or cancer cells, these are prevented by the phytochemicals. They modulate the hormonal function process preventing the cancers.

Absorption and bioavailability of phytochemicals

The absorption and bioavailability of phytochemicals are affected by several factors which include

- ✓ Food matrix, such as emulsions, gels, and solid foods
- ✓ Interactions with food proteins, fats, and carbohydrates
- ✓ Size and matrix of phytochemicals' nanoparticles
- ✓ Chemical modification of food constituents
- ✓ Encapsulation technologies of phytochemicals, such as liposomes, solid lipid nanoparticles, and biopolymer nanoparticles
- ✓ Food preparation methods such as trimming, peeling, refining processes.



Parameters affecting the bioavailability of bioactive components

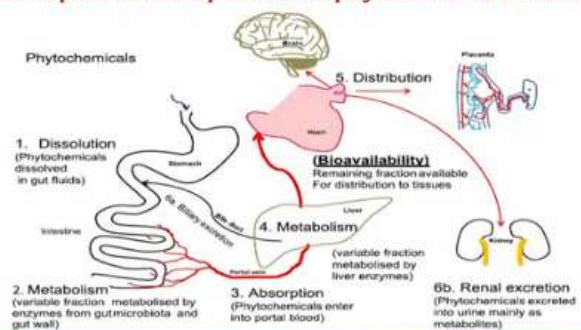
(Suresh Shi et al., 2022)



Dr. Khushboo

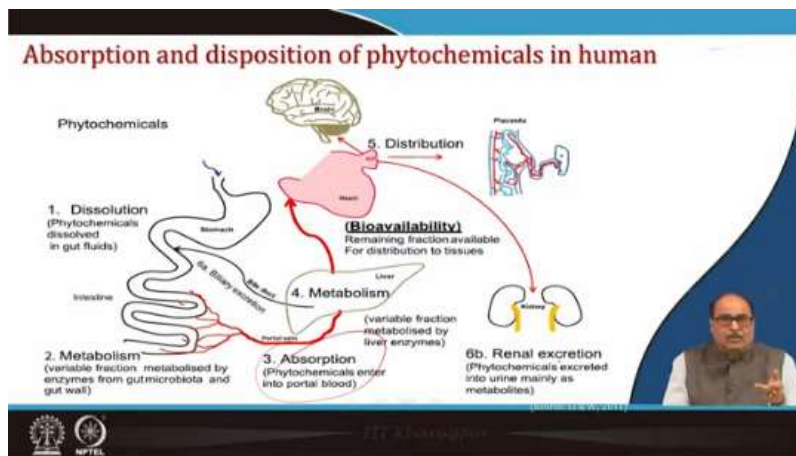
Now, let us talk about the absorption and bioavailability of phytochemicals in the body. Obviously, the absorption and bioavailability of phytochemicals are affected by several factors. These factors include the food matrix itself, such as the form in which the food is taken, whether it is in emulsion form, gel form, or solid foods. Then, interactions within the food constituents, such as food proteins, fats, carbohydrates, etcetera. So, their interactions, because they are generally found in association with these compounds. So, that also will influence how they interact with these components and nutrients or other constituents of the food, which also influences absorption and bioavailability. Then, the size and matrix of phytochemical nanoparticles, chemical modification of food constituents, encapsulation technologies of phytochemicals, such as liposomes, solid lipid nanoparticles, and biopolymer nanoparticles. Finally, the food preparation methods, such as trimming, peeling, refining processes, etcetera, because these preparation methods may influence the structure, properties, and characteristics of the food constituents including phytochemicals, etcetera, which are present inside the food, and that ultimately affects its absorption, its bioavailability, and so on.

Absorption and disposition of phytochemicals in human



Dr. Khushboo

So, then let us talk about the absorption and disposition of phytochemicals in human beings. When you take any food or any phytochemical in the form of food, what happens, how it goes inside our system, and at various functions, how it is converted, reformed, broken down, or metabolized. Then it gives its various effects, that is, the health-promoting effects. So, the first thing is that when you take it from the mouth, it comes into the stomach. Where the first action it takes is the dissolution of these phytochemicals. That is, they are dissolved in the gut fluid in the stomach and then from the stomach, it goes through the intestine. Where the metabolism starts, and as a result of metabolism, these phytochemicals are broken into various fractions and these are metabolized by enzymes from gut microbiota and the gut wall.



Then after that metabolism, the next step is absorption where these phytochemicals enter into portal blood, that is, they are absorbed and then come again into the liver. In the liver, metabolism takes place again, where the various functions are metabolized by liver enzymes. From the liver, it goes to the heart, where it is distributed mainly in the metabolized form. It comes to the heart, and from the heart, it is distributed to the brain, placenta, or kidney, where it performs all activity, like after the metabolism in the liver. It also goes to the bile duct, where it stimulates biliary excretion and improves bile production. Also, in the kidney, it has renal excretion, like phytochemicals excreted into urine mainly as metabolites or that is, in the bile, it is excreted in the bile. So, this is the way how these, in the different forces, particularly from the blood through the heart that is where its bioavailability remains the fraction available for distribution to tissue, it is bioabsorbed. Then it is distributed to different tissues like the brain, placenta, kidney, etcetera, where they perform their actual activities.

Summary

- Phytochemicals are non-nutritive secondary metabolites found in plant foods like fruits, vegetables, grains, herbs, and spices.
- They offer health-promoting effects such as anti-inflammatory action, cardiovascular support, cancer prevention, and immune system enhancement.
- Phytochemicals impact health by modulating hormones, affecting gene expression, and altering cell signaling pathways.
- Their absorption and effectiveness are influenced by factors like the food matrix, interactions with other nutrients, and individual metabolic processes.
- Genetics and overall health can affect how well phytochemicals are absorbed and utilized by the body.



Dr. P. K. Singh

Now, here is a summary of this lecture. I can tell you that these phytochemicals are non-nutritive secondary metabolites found in plant foods like fruits, vegetables, grains, herbs, and spices. So, although they are non-nutritive and do not have any nutritional value. They offer health-promoting effects such as anti-inflammatory action, cardiovascular support, cancer prevention, and immune system enhancement. So, they have very good health-promoting activities. Phytochemicals impact health by modulating hormones, affecting gene expression, and altering cell signaling pathways. Their absorption and effectiveness are influenced by factors like the food matrix, interaction with other nutrients, and also the individual metabolic process. Genetics and overall health can affect how well phytochemicals are absorbed and utilized by the body. So, it is a good thing that one should consider taking more natural phytochemicals like fruits, vegetables, or even grains, millet, etcetera which are good sources of phytochemicals. Also, these natural bio-phytochemicals obviously have more absorption and bioavailability than the synthetic ones.

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So, with this, these are the references which were used in this lecture.



Thank you very much for your patient hearing.