

FOOD SCIENCE AND TECHNOLOGY

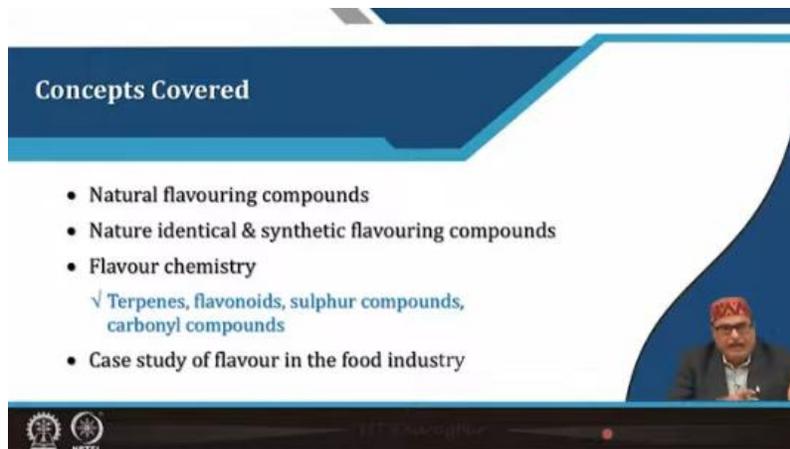
Lecture30

Lecture 30: Flavouring Compounds

Hello friends, Namaste. Now, in this last lecture of module 6, we will discuss flavouring compounds.



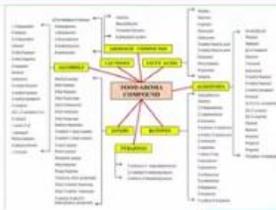
The concepts which we are discussing in today's lecture include natural flavouring compounds and nature-identical and synthetic flavouring compounds. Then, we will discuss the chemistry of flavouring compounds like terpenes, flavonoids, sulfur compounds, carbonyl compounds, etcetera, and finally, we will also take a few case studies of flavour in the food industry.



So, let us see what the flavour compounds in food are. I hope you know that many thousands of flavour compounds have been found in foods. And in any one food, there may be hundreds or thousands of different compounds which contribute to its flavour.

Flavour compounds in foods

- Many thousands of flavour compounds have been found in foods, and in any one food there may be hundreds of different compounds contributing to its flavour.
- Flavour molecules constitute a heterogeneous group of compounds with straight chain, branched chain, aromatic and hetero-aromatic backbones bearing diverse chemical groups such as hydroxyl, carboxyl, carbonyl, ester, lactone, amine, and thiol functions.
- Some important groups of flavoring compounds in foods include terpenoids, flavonoids, sulphur compounds and other volatile organic compounds.
- Thousands of such compounds are known which contribute to the flavour and aroma of foods.




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Flavour molecules constitute a heterogeneous group of compounds with straight chain, branched chain, aromatic, and hetero-aromatic backbones bearing diverse chemical groups. Such as hydroxyl, carboxyl, carbonyl, ester, lactone, amine, and thiol functions, and many other such carbonyl groups. Some important groups of flavouring compounds in foods include terpenoids, flavonoids, sulphur compounds, and other volatile organic compounds. Thousands of such compounds are known which contribute to the flavour and aroma of foods.

The flavoring compounds can be classified based on their origin, which is the origin-based classification of flavoring compounds.

Classification of flavouring compounds based on their origin

Types	Description
▪ Natural flavouring compounds	✓ Compounds that are extracted from plant or animal materials and are not further chemically modified or changed. <i>Example:</i> Vanilla extract from vanilla pods.
▪ Nature-identical flavouring compounds	✓ Compounds that are chemically identical to natural substances but are obtained by chemical processes or by chemical modification of natural substances. <i>Example:</i> Vanillin, which is identical to vanillin in vanilla pods.
▪ Artificial/Synthetic flavouring compounds	✓ Compounds obtained by chemical synthesis or chemical modification of natural substances, but which are not present in natural products. <i>Example:</i> Ethyl vanillin, which is artificial and smells and tastes like vanillin.

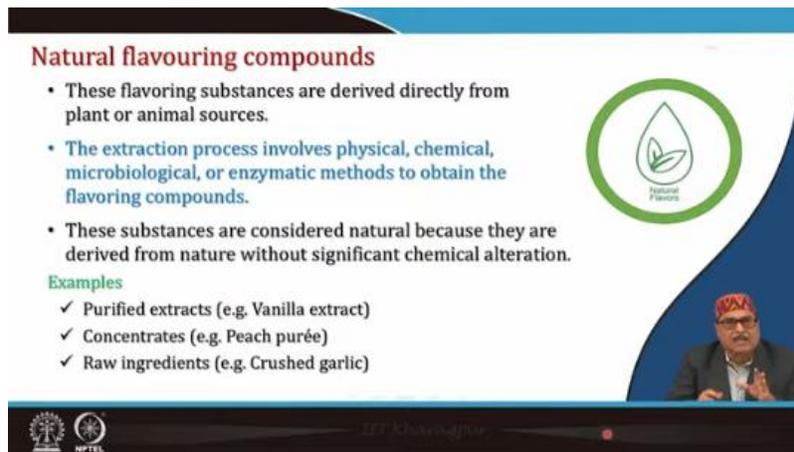



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So, in this, there are mainly three categories: one is the natural flavoring compounds, which are the compounds that are extracted from plant or animal materials and are not chemically

modified or changed further. An example of this type of natural flavoring compound may be vanilla extract, which is obtained from vanilla pods. It is extracted from vanilla pods as natural vanillin. Then, there is another category of flavoring compound, which is nature-identical. Nature-identical flavoring compounds are those that are chemically identical to natural substances but are obtained by chemical processes or by chemical modification of natural substances. For example, again, here is vanillin. The vanillin is identical to the vanillin obtained from the vanilla pods, but this vanillin is obtained by chemical synthesis from either paper industry-based materials or other such chemical ingredients. It is synthesized and manufactured in the industry. Then, there is a third category of flavoring compounds, which includes artificial or synthetic flavoring compounds. Here, this category includes the compounds obtained by chemical synthesis or chemical modification of natural substances. but which are not present in natural products, that is, these compounds contribute to the flavor of the food material, but naturally, they might not be present in that, and that is, here again, an example is ethyl vanillin. which is artificial, totally artificial, it is not found in the food material naturally, but it smells and tastes like vanillin, which is naturally obtained from vanilla pods. So, we will take up one by one and describe a little detail of each of these compounds.

Natural flavouring compounds are derived directly from plant or animal sources. The extraction process involves physical, chemical, microbiological, or enzymatic methods to obtain these flavouring compounds. These substances are considered natural because they are derived from nature without significant chemical modification.



Natural flavouring compounds

- These flavoring substances are derived directly from plant or animal sources.
- The extraction process involves physical, chemical, microbiological, or enzymatic methods to obtain the flavoring compounds.
- These substances are considered natural because they are derived from nature without significant chemical alteration.

Examples

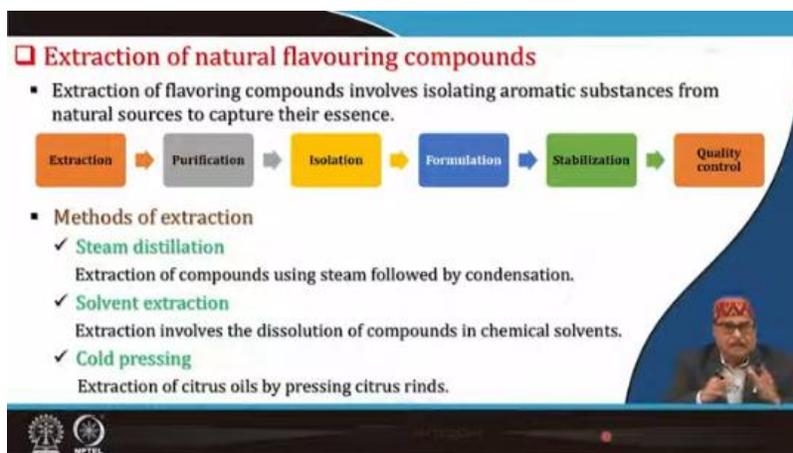
- ✓ Purified extracts (e.g. Vanilla extract)
- ✓ Concentrates (e.g. Peach purée)
- ✓ Raw ingredients (e.g. Crushed garlic)

The slide features a green circular logo with a leaf and the text 'Natural Flavors' on the right side. At the bottom right, there is a small inset image of a man in a red turban. The bottom left corner contains logos for IIT Bombay and NPTEL.

Examples of natural flavouring compounds include purified extracts such as vanilla extract, as well as concentrates like peach puree, tomato puree, and other natural concentrates.

Additionally, raw ingredients like crushed garlic or garlic paste are widely used as flavouring materials in various food products.

These natural flavouring compounds are extracted using different methods, and once extracted, they may undergo processes such as purification and isolation. The purified and isolated flavoring compounds are then used in a variety of food materials, followed by processes like formulation, stabilization, and final quality control to ensure their optimal use.



So, this may be the sequence of the process by which these flavouring materials are extracted from their natural ingredients and subsequently used in other food materials. The quantity in which they should be used, the methods of usage, the identification of their pure form, and finally, quality control—these aspects are all standardized. To elaborate a little on the methods of extraction, there are various techniques. Details of all these processes have been thoroughly covered in my other course on the post-harvest operations and processing of fruits, vegetables, spices, and plantation crop products—that is another NPTEL course.

Here, I will briefly mention that the extraction process includes steam distillation, solvent extraction, cold pressing, and enfleurage, which involves the absorption of fragrance into fat followed by extraction with alcohol.

Extraction of natural flavouring compounds (Contd.)

- ✓ **Enfleurage**
Absorption of fragrance into fat, followed by extraction with alcohol.
- ✓ **Soxhlet extraction**
It is a continuous extraction process; ensures the thorough extraction of flavour compounds.
- ✓ **Ultrasonic extraction**
It uses ultrasonic waves to disrupt the cell structure and thereby enhance the extraction efficiency.
- ✓ **Microwave-assisted extraction**
It accelerates the extraction process by using microwave energy to rapidly heat the sample and solvent.
- ✓ **Pressurized liquid extraction**
Extracts compounds using high pressure and temperature.



Dr. Divyashree



Other methods include Soxhlet extraction, ultrasonic extraction using ultrasonic waves to disrupt cell structure and enhance extraction efficiency, microwave-assisted extraction, and pressurized liquid extraction. So, these are the various novel methods of extraction of the valuable material that is flavoring compound from the natural agricultural and biomaterials and they are used mostly by the industry to get good quality flavoring natural flavoring components.

The other category of flavorings is nature-identical flavoring compounds, and these substances, as I mentioned earlier, are chemically synthesized to replicate the exact chemical structure of natural flavoring compounds. Although they are produced artificially, they are identical to their natural counterparts. These compounds are more consistent and cost-effective compared to extraction from natural sources, especially when aiming for purity and high quality in the extracted materials, as the process becomes expensive in economic terms.

Nature-identical flavouring compounds

- These substances are chemically synthesized to mimic the exact chemical structure of natural flavour compounds.
- Although they are produced artificially, they are identical to their natural counterparts.
- These are more consistent and cost-effective compared to extraction from natural sources.

Examples

- ✓ **Vanillin:** It can be extracted from vanilla beans or synthesized in a lab, with the synthetic version being chemically identical to the natural one.
- ✓ **Limonene:** A compound found in citrus fruits that can also be synthesized for use in flavorings.



Dr. Divyashree



From this perspective, nature-identical flavoring compounds may be preferable due to their consistency and affordability. For example, vanillin can be extracted from vanilla beans or synthesized in a lab, with the synthetic version being chemically identical to the natural one. Similarly, limonene, a compound found in citrus fruits that contributes to the flavor of citrus juices like the flavor you get when you squeeze lemon for juice, can also be chemically synthesized for use in flavoring.

Artificial flavoring compounds are substances created through chemical processes that do not have natural equivalents. They are formulated to replicate or simulate natural flavors but are not found in nature. These compounds provide a wide range of flavors and are often more stable and cost-effective.

Artificial flavouring compounds

- These substances are created through chemical processes and do not have natural equivalents.
- They are designed to replicate or simulate natural flavours but are not found in nature.
- They offer a wide range of flavors and are often more stable and cost-effective.

Examples

- ✓ **Ethyl vanillin** has a stronger vanilla flavor than natural vanillin. It is used in various food products to impart a vanilla-like flavour.
- ✓ **Methyl anthranilate** used to create grape flavour in candies and soft drinks, despite not being found naturally in grapes.

For instance, ethyl vanillin, as mentioned earlier, has a stronger vanilla flavor compared to natural vanillin and is used in various food products to impart a vanilla-like flavor. Another example is methyl anthranilate, which is used to create a grape flavor in candies and soft drinks, even though it does not occur naturally in grapes. These are examples of artificial flavoring compounds.

As far as the manufacturing of nature-identical or synthetic flavoring compounds is concerned, they can be produced using various methods. These include synthesis through controlled chemical reactions, such as organic chemical reactions like esterification, which involves combining an alcohol and a carboxylic acid to form an ester and create fruity or floral flavors. Thermal reactions, which use heat to induce chemical changes like caramelization, impart distinct flavors to sugars. Microbial fermentation is another method, utilizing microorganisms like bacteria, yeast, or fungi to produce flavor compounds through their metabolic processes. Biotechnological production also plays a role, using

enzymes or genetically modified cells to produce desired flavor compounds. By any of these methods, the compounds are synthesized and subsequently purified.

Manufacturing of nature identical/synthetic flavour compounds

- Synthesis through controlled chemical reactions, such as
 - Organic chemical reactions:** Includes reactions such as esterification (combining an alcohol and a carboxylic acid to form an ester) to create fruity or floral flavours.
 - Thermal reactions:** Uses heat to induce chemical changes, such as caramelization, which imparts a distinct flavour to sugars.
 - Microbial fermentation:** Utilizes microorganisms (bacteria, yeast, or fungi) to produce flavour compounds through their metabolic processes.
 - Biotechnological production:** Uses enzymes or genetically modified cells to produce desired flavour compounds.
- Purify by removing impurities and by-products to isolate the desired flavor compound.
- Blending the purified compounds with other ingredients to achieve the desired flavour profile.
- Testing the flavour for consistency, potency, and stability.



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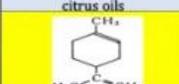
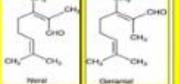
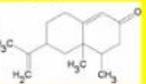
Purification involves removing impurities and byproducts to isolate the desired flavor compounds. Following this, the purified compounds are blended with other ingredients to achieve the desired flavor profile. Finally, the flavor is tested for consistency, potency, and stability. In brief, these are the essential steps involved in the manufacture of nature-identical or synthetic flavor compounds.

Now let us talk about flavor chemistry.

Flavour chemistry

Terpenes

- Terpenes, formed by linking isoprene units, are major compounds in citrus oils, with lemonene, a monoterpene, making up about 90% of most citrus oils and giving a lemon-like odour.
- Oxygenated terpenes, such as alcohols, aldehydes, and ketones, provide the distinctive flavours of individual citrus species, with neral and geranial contributing to lemon flavour and nootkatone giving grapefruit its characteristic taste.

Limonene	Neral & geranial	Nootkatone
A monoterpene hydrocarbon having a lemon like odour accounts for 90% of the citrus oils	Constitute to the distinctive flavour of Lemons	A bicyclic sesquiterpene contributes to the flavour of grape fruits
		

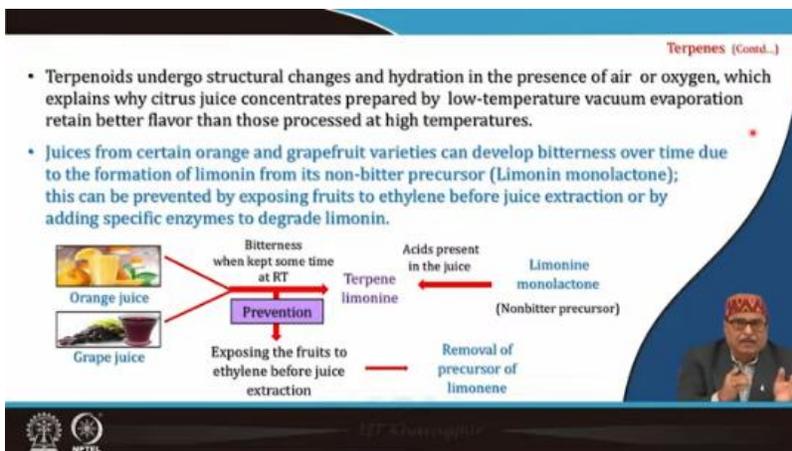


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As I mentioned earlier, there are various groups of compounds that contribute to flavor, and among them are terpenes. Terpenes are a class of compounds formed by linking isoprene units. These isoprene units are the primary components of citrus oils, with limonene being a prominent example. Limonene, a monoterpene, constitutes about 90 percent of most citrus oils and imparts a lemon-like odor. Oxygenated terpenes, including alcohols, aldehydes, and ketones, are responsible for the distinctive flavors of individual

citrus species. For instance, neral and geranial contribute to the characteristic flavors of lemon, while nootkatone, a bicyclic sesquiterpene, imparts the unique flavor of grapefruits. It gives grapefruits their characteristic taste and flavor. Limonene, as mentioned earlier, is a monoterpene hydrocarbon with a lemon-like odor and constitutes about 90 percent of the flavor in citrus oils.

They undergo structural changes and hydration when exposed to air or oxygen. This explains why citrus juice concentrates prepared through low-temperature vacuum evaporation retain flavor better than those processed at high temperatures or under natural atmospheric conditions. When oxygen is present during the extraction process, such as during evaporation under atmospheric conditions, it causes changes in the structure of terpenes, along with hydration reactions that result in structural modifications. These changes affect the flavoring potential. However, when the same process is conducted in a vacuum, the absence of oxygen minimizes structural changes, allowing the aroma and flavor of the vacuum-concentrated juice to be retained more effectively.



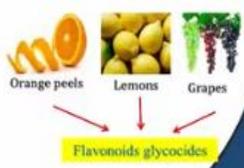
Juices from certain orange and grape varieties can develop bitterness over time, primarily due to the formation of limonene from its non-bitter precursor, limonene monolactone. These specific varieties naturally contain limonene monolactone, which is non-bitter. However, once the juice is extracted and left in an open atmosphere, the limonene monolactone undergoes conversion into terpene limonene, which is the main compound responsible for the juice's bitterness. This bitterness can be mitigated by exposing the fruits to ethylene before juice extraction or by adding specific enzymes to degrade limonene, as limonene is the cause of the bitterness. Even after the juice is extracted, enzymes can be added to degrade limonene and reduce bitterness. Alternatively, exposing the fruit to an

ethylene atmosphere before juice extraction can prevent the conversion of limonene monolactone, thereby preventing the development of bitterness.

Another group of flavoring compounds includes flavonoids, which are natural plant compounds contributing to the flavor, aroma, and color of many foods, especially fruits like orange peel, lemon, and grapes. In these fruits, flavonoids play a significant role in their sensory attributes.

Flavonoids

- Flavonoids are natural plant compounds that contribute to the flavour, aroma, and colour of foods, and thus play a crucial role in enhancing sensory experiences.
- They belong to a larger group of polyphenols and are found in a wide variety of fruits, vegetables, and beverages.
Examples: Quercetin in apples and onions, catechins in green tea, and anthocyanins in berries.
- Flavonoids can be heat-sensitive, affecting their flavour profile during cooking.
Examples: Bitterness in grapefruit (naringin) can change with heat, while sautéing onions reduces the pungency of quercetin.
- Flavonoids possess antioxidant, anti-inflammatory, and cardiovascular protective properties, making them beneficial for health.



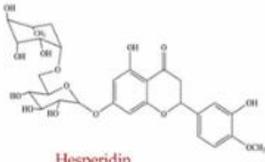
The diagram shows three categories of fruits: Orange peels, Lemons, and Grapes. Red arrows from each category point to a central box labeled 'Flavonoids glycosides'. Below the diagram is a small inset image of a man speaking.

These flavonoids belong to a larger group of polyphenols and are present in a wide range of fruits, vegetables, and beverages. For example, quercetin is found in apples and onions, catechins in green tea, and anthocyanins in berries, all of which contribute to their unique flavors. Flavonoids are heat-sensitive, which can affect their flavor profile during cooking. For instance, the bitterness of naringin in grapefruits may change with heat, while sprouting onions reduces the pungency of quercetin. In addition to their role in flavor, flavonoids possess antioxidant, anti-inflammatory, and cardiovascular protective properties, as we discussed earlier. This dual benefit makes flavonoids valuable—not only do they enhance flavor, but they also provide significant health advantages.

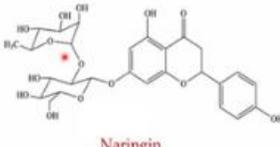
Flavonoids include hesperidin, found in orange and lemon peels, and naringin, found in grapefruits. Hesperidin is tasteless, while naringin has an intensely bitter taste. During the ripening process in certain grape varieties, naringin undergoes conversion into its chalcone compound. This conversion transforms the extreme bitterness of naringin into an intensely sweet flavor. Thus, the transformation of naringin into naringin chalcone enhances the sweetness of the grapes.

Flavanoids (Contd...)

- The most common flavanoid — **Hesperidin**, present in oranges and lemons and **naringin** is present in grape fruits.
- **Hesperidin is tasteless, whereas naringin has an extremely bitter taste.**
- Conversion of naringin into its chalcone compound changes the intense bitterness to an intensely sweet upon ripening.



Hesperidin



Naringin



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Sulfur compounds are another significant group of flavor-contributing substances. Volatile sulfur compounds add flavor to fruits and vegetables such as onion, garlic, cabbage, cauliflower, and others. However, these sulfur volatiles are not naturally present in intact vegetable tissues. Instead, their precursors, which are sulfur-containing compounds, exist alongside the enzymes needed to produce these volatiles. In intact tissues, the precursors and enzymes are located in separate compartments. When the tissue is damaged—such as during cutting or crushing—the enzymes come into contact with the precursors, leading to the formation of volatile sulfur compounds that contribute to the distinctive flavors of these vegetables.

□ Sulphur compounds

- They possess powerful and distinctive odours which contribute to both pleasant and unpleasant characters to many foods. They are not normally present in the intact vegetable tissue, but appear rapidly when the vegetable is disrupted or during chewing.
- They form from a precursor by the action of an enzyme. The precursor and the enzymes are present in different compartments of the tissue and they come into contact when the cellular system is disrupted.
- Sulphur compounds are responsible for the distinctive and powerful aromas of vegetables from the **Allium** (e.g. onions, garlic) and **Brassica** (e.g. cabbage, broccoli) genera, contributing to both pleasant and unpleasant food odors.



Onion



Garlic

Volatile Sulphur Compounds



Cabbage



Cauliflower

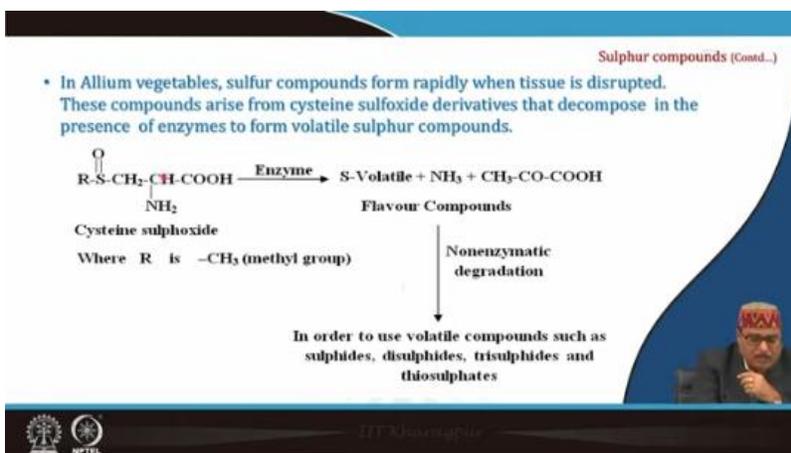


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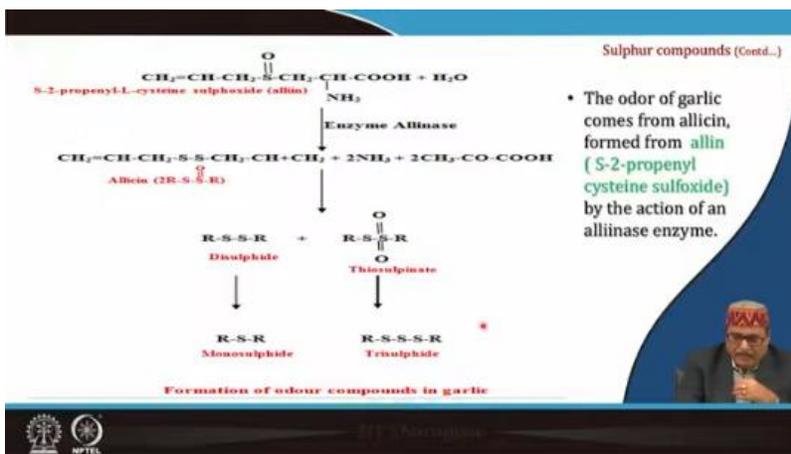
When these vegetables are cut or their tissues are damaged during processing or even chewing, the enzyme and precursor are released from their separate compartments in the presence of atmospheric oxygen. An instant enzymatic oxidation reaction occurs, converting these precursors into sulfur compounds. Subsequent chemical and biochemical reactions further develop these volatile sulfur flavor compounds. These compounds are

responsible for imparting the characteristic flavors to vegetables like allium genera - onions and garlic and brassica genera: cabbage and broccoli.

Vegetable sulfur compounds form quickly upon tissue disruption, as I mentioned earlier, and these compounds originate from cysteine sulfoxide. Cysteine sulfoxide acts as the precursor present in these vegetables. When disrupted, it is enzymatically converted into sulfur volatiles, along with the release of ammonia and other compounds such as $\text{CH}_3\text{COCO}_2\text{H}$, which further contribute to the flavor profile of the vegetables.



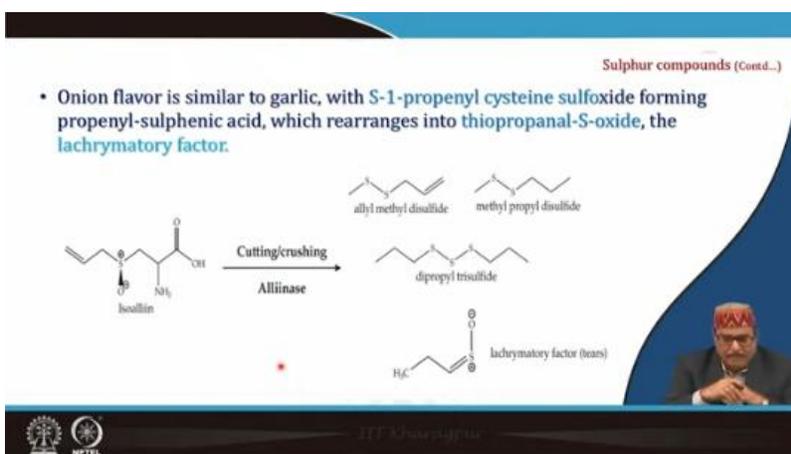
As I mentioned earlier, non-enzymatic degradation leads to the formation of volatile compounds like sulfides, disulfides, thiosulfides, thiosulfates, and others. These volatile sulfur compounds are the key contributors to the characteristic flavors of allium vegetables. For example, the distinctive odor of garlic arises from allicin, which is one of these sulfur-volatile compounds.



The precursor, S-2-propenyl-L-cysteine sulfoxide, also known as alliin, plays a crucial role in the flavor development of garlic. When the tissues are disrupted—such as during cutting

or crushing—the enzyme alliinase is released and acts upon alliin, converting it into allicin. Allicin, in turn, undergoes non-enzymatic decomposition to form various compounds, including disulfide, thiosulfinate, monosulfide, and trisulfide. Together, these compounds contribute to the distinctive and rich flavors of garlic and onion.

In onions, the flavor development is quite similar to that of garlic. While in garlic the precursor is S-2-propenyl-L-cysteine sulfoxide, in onions, the precursor is S-1-propenyl cysteine sulfoxide. This precursor undergoes rearrangement to form thiopropanal S-oxide, commonly known as the lacrimatory factor, which is responsible for the tearing effect experienced when cutting onions.



When onions are cut, a pungent gas is released that causes tears to well up in our eyes. This happens due to thiopropanal S-oxide, the lacrimatory factor, which is formed from the precursor S-1-propenyl cysteine sulfoxide. The process involves enzymatic reactions that convert S-1-propenyl cysteine sulfoxide into propenyl sulfenic acid, followed by non-enzymatic reactions that transform propenyl sulfenic acid into thiopropanal S-oxide. This distinctive reaction accounts for the characteristic tear-inducing effect of onions.

The other vegetables of the Brassica family, that Brassica vegetables they also contain sulfur compounds, but it is S-methyl-cysteine-sulfoxide and thioglucosides. So, this S-methyl-cysteine-sulfoxide and thioglucoside and their decomposition products contribute to the flavor of this Brassica family.

Sulphur compounds (Contd...)

- Brassica vegetables contain sulfur compounds like **S-methyl-cysteine sulfoxide** and **thioglucosides**, which contribute to their flavour.
- Brassica flavour mainly comes from **isothiocyanates** formed from thioglucosides after cellular disruption, with the reaction involving unstable **thiohydroxamic-O-sulphate** that degrades into isothiocyanates.

The diagram illustrates the enzymatic conversion of glucosinolate to various sulfur-containing compounds. Physical damage to brassica vegetables releases the enzyme myrosinase, which acts on glucosinolate to form thiohydroxamic-O-sulphate. This intermediate then degrades into several products: Epithionitrile, Thiocyanate, Isothiocyanate, Nitrile, and Oxazolidine thione. The chemical structures for these products are shown, along with the enzyme myrosinase and the starting material glucosinolate.

Brassica flavor mainly comes from isothiocyanates, which are formed from thioglucosides after cellular disruption with the reactions involving unstable thiohydroxamic O-sulfate that degrades into isothiocyanates. So, basically, the reaction process is shown here: various epithionitrile, thiocyanate, isothiocyanate, nitrile, or oxazolidine thione. These different compounds are formed from the glucosinolates, and they contribute to the final flavor.

There is another group of volatile organic compounds that contribute to the flavor of various foods. Let us go through some important ones, starting with alcohols. Alcohols, as you know, are organic compounds that have one or more hydroxyl (OH) groups attached to a carbon atom. They can provide a wide range of flavors, from sweet to herbal. For example, *cis*-3-hexene-1-ol imparts a fresh green aroma to foods like tomatoes and raspberries.

Other volatile flavour compounds

Alcohols

- Alcohols are organic compounds with one or more **hydroxyl (-OH) groups** attached to a carbon atom. They can impart a wide range of flavours, from sweet to herbal.

Compound	Flavor contribution
Cis-3-Hexen-1-ol	Imparts a fresh, green aroma to tomatoes and raspberries.
L-Octen-3-ol	Enhances the earthy, mushroom-like flavour of mushrooms.
Geosmin	Contributes a musty, earthy note in beetroots and dry beans.

The slide shows the chemical structures of three alcohols and their flavor contributions. Cis-3-Hexen-1-ol is associated with tomatoes and raspberries. L-Octen-3-ol is associated with mushrooms. Geosmin is associated with beet roots and dry beans.

L-octene-3-ol enhances the earthy, mushroom-like flavor characteristic of mushrooms. Geosmin adds a distinct mushy, earthy note to foods like beetroots and dry beans.

Phenols represent another group of organic compounds, characterized by a hydroxyl group directly bonded to an aromatic benzene ring, as illustrated. Phenol itself contributes a medicinal or smoky flavor, often found in certain cheeses. All these compounds play unique roles in shaping the sensory profiles of these foods.

❖ Phenols Other volatile flavour compounds (Contd...)

- Class of organic compounds that contain a hydroxyl group (-OH) bonded directly to an aromatic benzene ring.

Compound	Flavor contribution
Phenol	Medicinal or smoky flavour to certain cheeses.
Vinyguaiaicol	Spicy, clove-like flavor found in various foods and beer.
Eugenol	Imparts a warm, spicy aroma, key in clove oil.
L-(p-Hydroxyphenyl)-3-butanone	Fruity, raspberry-like scent, enhancing raspberry flavour.
Thymol	Aromatic, slightly medicinal flavour in tangerines and thyme.

Chemical structures shown: Phenol (Cheese), P-vinyl guaiacol (Clove oil), Eugenol (Clove oil), 1-(p-hydroxyphenyl)-3-butanone (Raspberries), and Thymol (Tangerines/Thyme).

Vinyl guaiacol adds a spicy, clove-like flavor, commonly found in foods and beer. Eugenol imparts a warm, spicy aroma and is the key compound responsible for the distinctive scent of clove oil. L-parahydroxyphenyl-3-butanone contributes a fruity, raspberry-like scent, enhancing the flavor of raspberries. Thymol, another phenol, provides an aromatic, slightly medicinal flavor, which is characteristic of tangerines and thyme.

Aldehydes are organic compounds characterized by a carbonyl group bonded to at least one hydrogen atom. Among the prominent aldehydes are citral and cinnamaldehyde. Citral is a primary flavor compound in lemons and consists of isomers such as geranial and neral, which contribute to the strong lemony flavor. As we discussed earlier, geranial and neral are optical isomers of citral.

❖ Aldehydes Other volatile flavour compounds (Contd...)

- Aldehydes are organic compounds with a carbonyl group (=CO) bonded to at least one hydrogen atom.

Citral

✓ A key flavor component in lemon, citral consists of the isomers **geranial** and **neral**, contributing to its strong lemony taste.

Cinnamaldehyde

✓ Found in both cassia and cinnamon oils, cinnamaldehyde is responsible for the characteristic spicy-sweet flavour associated with cinnamon.

Chemical structures shown: Geranial and Neral (optical isomers), and Cinnamaldehyde.

Cinnamaldehyde, on the other hand, is present in both cassia and cinnamon oil, imparting the distinct flavor and aroma associated with cinnamon. Cinnamaldehyde is responsible for the characteristic spicy, sweet flavor associated with cinnamon.

Benzaldehyde mimics cherry flavor and is extensively used to produce cherry flavoring, despite not being naturally present in cherries. Similarly, vanillin, which is also an aldehyde, is a key compound providing flavor and fragrance to food products, recognized for its distinct vanilla-like scent and taste. Hexenal contributes to the flavor of apples, trans-2-cis-6-nonadienal imparts the flavor of cucumbers, cis-4-heptenal enhances the flavor of cream, and 5-methyl-2-phenyl-2-hexenal contributes to the flavor of chocolates. These are just a few examples of aldehydes that play a vital role in flavor profiles.

Aldehydes (Contd...)

Benzaldehyde
 ✓ It mimics cherry flavour and widely used to produce cherry flavour, even though it is not naturally available in cherry.

Vanillin
 ✓ Vanillin is a key compound in flavoring and fragrance of food products, recognized for its strong vanilla scent and flavour.

Hexenal
 Apples

Cis-4-Heptenal
 Cream

trans-2-cis-6-Nonadienal
 Cucumbers

5-methyl-2-phenyl-2-hexenal
 Chocolates

Similarly, ketones are another group of volatile compounds.

Other volatile flavour compounds (Contd...)

❖ **Ketones**

- Ketones are organic compounds with a **carbonyl group (=CO)** bonded to two carbon atoms.
- 2,3-butanedione contributes to the flavour of butter, celery and many other foods.
- 2-heptanone and 2-nonanone are flavour compounds of blue cheese

2,3-Butanedione
 Butter
 Many other foods

2-Nonanone
 Blue cheese

2-Heptanone

Acetophenone
 Many foods

They are organic compounds with a carbonyl group bonded to two carbon atoms. 2,3-butanedione contributes to the characteristic flavor of butter, celery, and many other foods. 2-heptanone and 2-nonanone are key flavor compounds in blue cheese. Additionally, 2-heptanone and acetophenone contribute to the flavor profiles of a wide range of foods.

Esters are a large group of compounds that are organic in nature, formed from the reaction of an alcohol and a carboxylic acid. Various esters play a significant role in contributing to the flavors of different foods and beverages. For instance, ethyl formate contributes to the flavor of rum, isopentyl acetate imparts the classic banana flavor, and octyl acetate provides the characteristic flavor of orange. Similarly, ethyl butyrate gives the tropical flavor of pineapple, methyl butyrate enhances the flavor of apple, and isobutyl formate adds the flavor of raspberry.

Other volatile flavour compounds (Contd..)

❖ Esters

- Esters are organic compounds formed from the reaction of an alcohol and a carboxylic acid.
- The followings are some ester compounds and their uses in food products.

Name	Flavour
Ethyl formate	Rum
Isopentyl acetate	Banana
Octyl acetate	Orange
Ethyl butyrate	Pineapple
Methyl butyrate	Apple
Isobutyl formate	Raspberry
Methyl anthranilate	Grape
Methyl salicylate	Winter green

Pentyl acetate

$$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{-C} \\ \backslash \\ \text{O}-\text{C}_5\text{-H}_{11} \end{array}$$

C_5H_{11} , branched-Banana

Butyl acetate

$$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{-C} \\ \backslash \\ \text{O}-\text{C}_4\text{-H}_9 \end{array}$$

C_4H_9 straight chain-Raspberries
 C_4H_9 branched-Strawberries

Octyl acetate

$$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{-C} \\ \backslash \\ \text{O}-\text{C}_8\text{-H}_{17} \end{array}$$

Orange

Pentyl valerate

$$\begin{array}{c} \text{O} \\ \parallel \\ \text{C}_5\text{H}_9\text{-C} \\ \backslash \\ \text{O}-\text{C}_2\text{-H}_5 \end{array}$$

Strawberries



Methyl anthranilate contributes to the flavor of grapes; methyl salicylate contributes to the flavor of wintergreen. Butyl acetate, when it has a straight-chain C_4H_9 , contributes to the flavor of raspberries, while the branched-chain version imparts the flavor of strawberries. Octyl acetate contributes to the flavor of orange. Pentyl valerate adds the flavor of strawberries, while pentyl acetate contributes to the flavor of bananas. There are indeed many esters that significantly enhance flavors in various foods and beverages.

Acids, again, are flavoring compounds and are organic molecules that contain one or more carboxylic groups. There are numerous examples, with a very popular and common one being acetic acid, which contributes to the flavor of vinegar. 2-methylbutyric acid is another example, contributing to the flavor of cranberries. Additionally, many branched-chain and unsaturated acids are responsible for the flavor of mutton. Amines, including O, N, and S heterocycles, also contribute to the flavors of many foods.

Other volatile flavour compounds (Contd..)

❖ Acids

- Acid flavoring compounds are organic molecules that contain one or more carboxyl groups (-COOH).

Acid flavouring compound	Source
Acetic acid	Vinegar
2-Methyl butyric acid	Cranberries
Many branched chain and unsaturated acids	Mutton

Amines and O, N and S-Heterocyclics } → Many foods



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Finally, the flavor wheel is a visual tool that categorizes and organizes various flavors and aromas into a circular diagram. It includes categories such as fruity, sour fermented, green vegetative, roasted, spicy, nutty, cocoa, sweet, and floral, often represented with corresponding colors. Originally developed for wine and coffee tasting, the flavor wheel helps both professionals and consumers consistently describe their sensory experiences. It serves as a valuable guide in understanding and articulating the complexity of flavors and aromas.

Flavour wheel



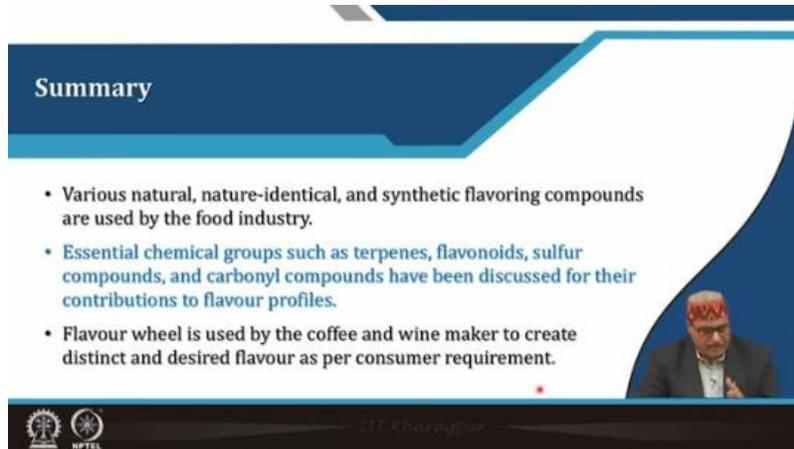
- It is a visual tool that categorizes and organizes various flavours and aromas into a circular diagram.
- It is primarily developed for wine and coffee tasting to help professionals and consumers describe sensory experiences consistently.
- Provides a common language to describe flavour profiles across different products.
- Assists in identifying and evaluating subtle differences in flavours for food and beverage quality assessments.
- Aids in formulating and enhancing flavours in the food industry by identifying key notes.



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The flavor wheel provides a common language to describe flavor profiles across various products. It plays a crucial role in identifying and evaluating differences in the flavors of foods and beverages, making it invaluable for quality assessments. Additionally, it aids in the formulation and enhancement of flavors in the food industry by highlighting and identifying key flavor notes.

To summarize, various natural, nature-identical, and synthetic flavoring compounds are widely utilized in the food industry. Essential chemical groups such as terpenes, flavonoids, sulfur compounds, and carbonyl compounds significantly contribute to the flavor profiles of various fruits. Additionally, the flavor wheel serves as a valuable tool for coffee and winemakers, helping them craft distinct and desired flavors tailored to consumer preferences. This intricate understanding of flavor chemistry enables the creation of innovative and appealing food and beverage products.



Summary

- Various natural, nature-identical, and synthetic flavoring compounds are used by the food industry.
- Essential chemical groups such as terpenes, flavonoids, sulfur compounds, and carbonyl compounds have been discussed for their contributions to flavour profiles.
- Flavour wheel is used by the coffee and wine maker to create distinct and desired flavour as per consumer requirement.

These are the references that are used in this lecture.



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Thank you.

