FOOD CHEMISTRY: FRUITS & VEGETABLES

Chemical composition – nutritional contribution

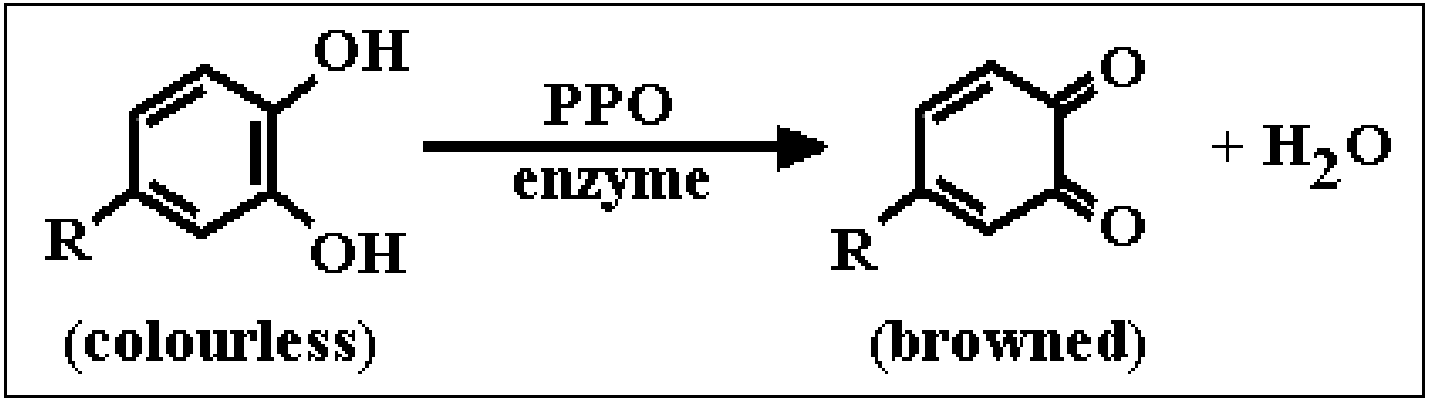
- **Energy** (Calories) - Carbohydrates and fats provide most of the calories the body requires
- **Carbohydrates**: carb rich fruits/vegetables: banana, persimmon, raisins, dates
- **Fats**: fat rich fruits/vegetables: avocado, olives, walnuts
- **Proteins & amino acids**: protein rich fruits/vegetables: walnuts, dried apricots, figs
  - ✓ Fruits contain <1% protein (as opposed to 9-20% in nuts)
  - ✓ Enzymes that catalyze metabolic processes in fruit are essential for carrying out the reactions associated with ripening and aging
  - ✓ Some of the enzymes that are of great importance for the quality of fruits and their products are the following:

Enzymes

Enzyme

Polyphenol oxidase (PPO)

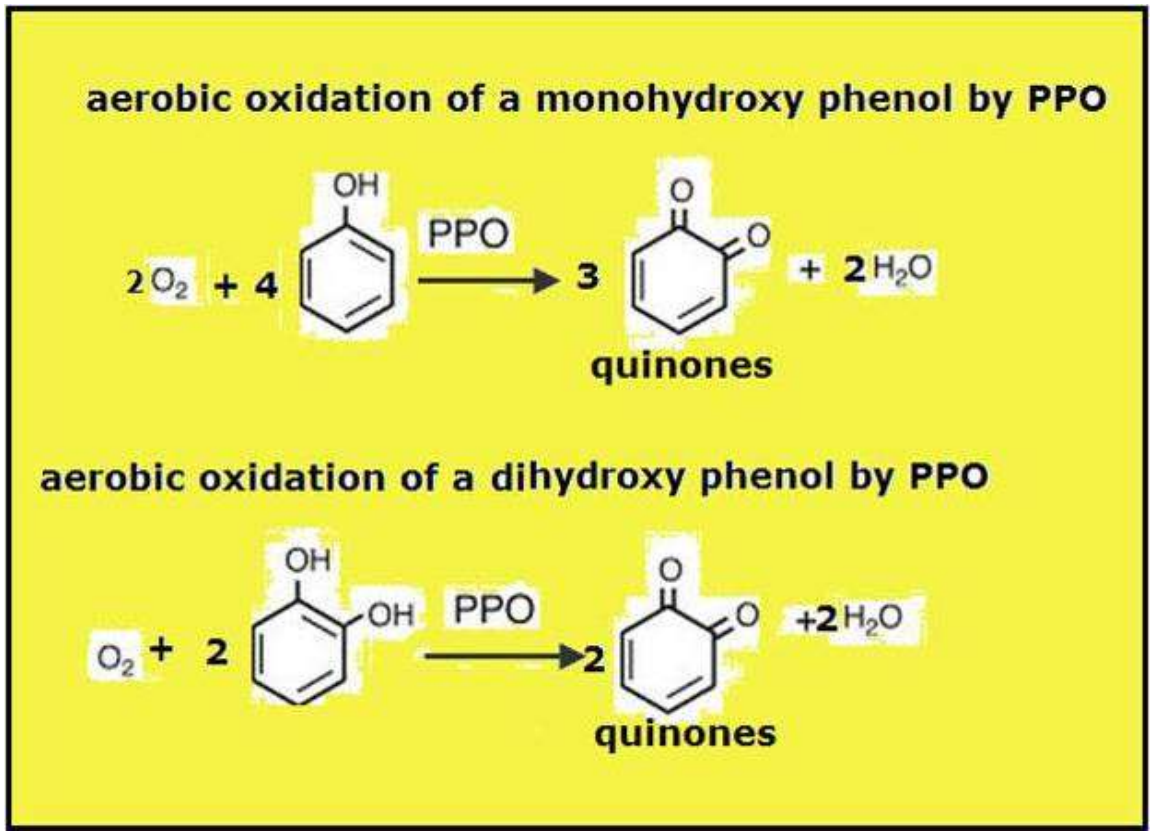
Catalyzes the **oxidation of phenols** into brown polymers



o-diphenol **o-benzoquinone**

Phenolics

- Enzymatic browning in plant products is a result of the oxidation of the phenolic components and is carried out, in the presence of O_2, by polyphenol oxidase (PPO)
- The initial product is usually an o-quinone, which is unstable and undergoes polymerization to give brown, higher MW pigments
- PPO catalyzes the following two reactions:

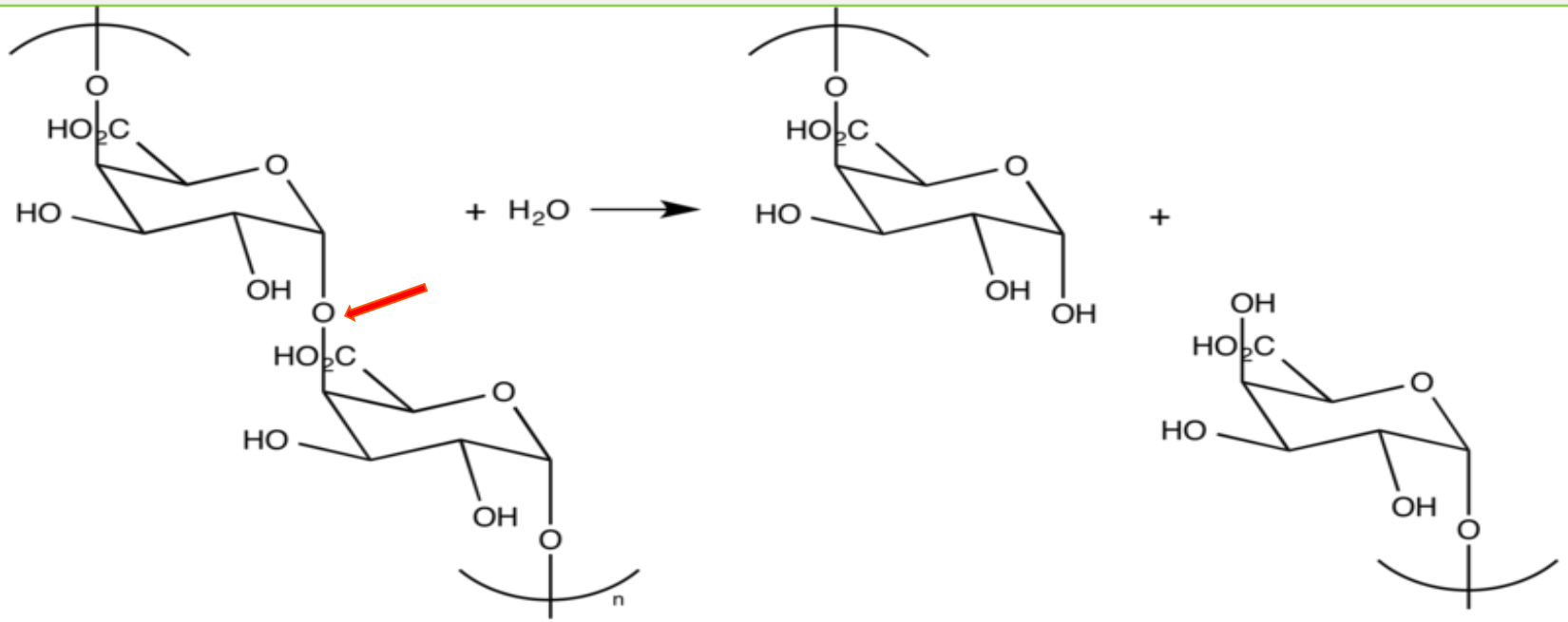


Enzymes

Enzyme

Polygalacturonase (PG)

Catalyzes the hydrolysis of the α(1→4) glucosidic bonds of **polygalacturonic acid (pectin)**, leading to a reduction in pectin size and making tissues softer

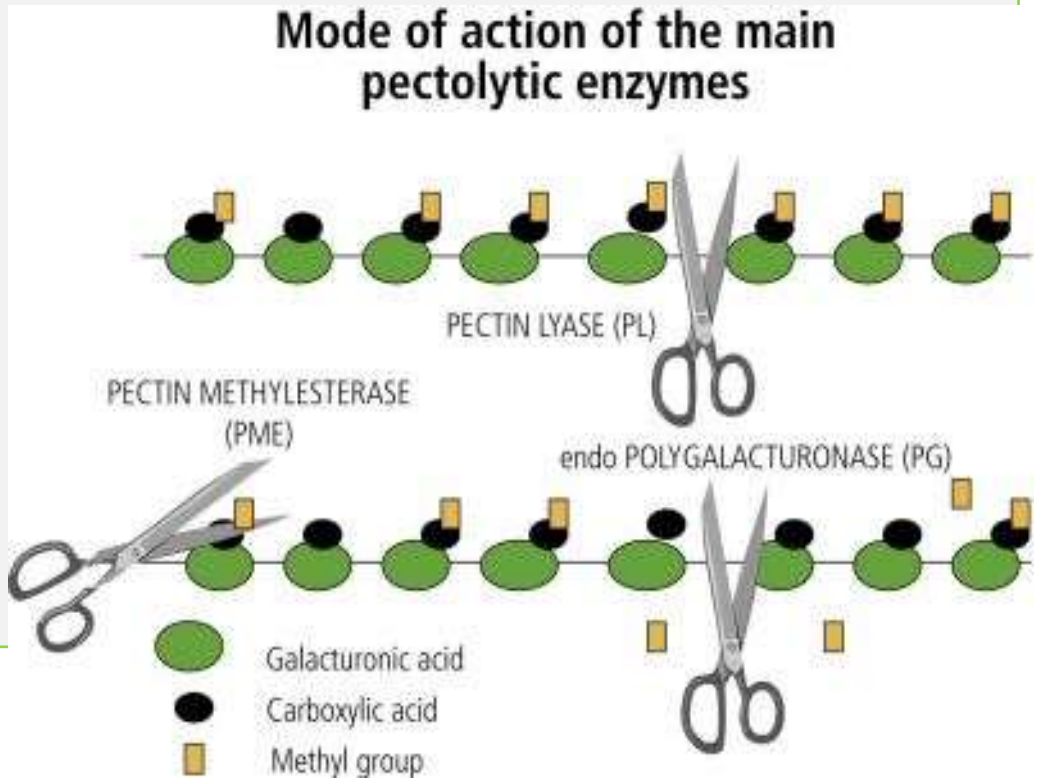


Enzymes

Enzyme

Pectin lyase (PL)

Catalyzes the hydrolysis of the α(1→4) glycosidic bonds of pectin (**acts after a methyester unit of galacturonic acid**)

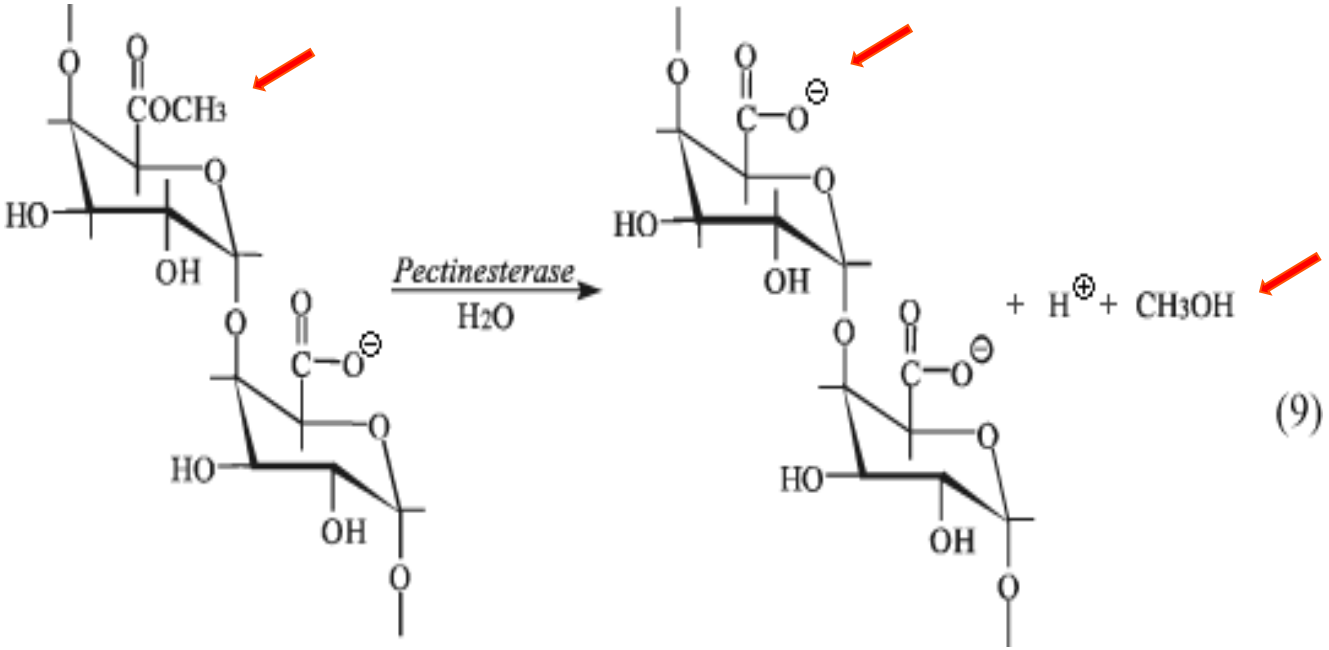


Enzymes

Enzyme

Pectinesterase (PE) (or Pectinmethylesterase)

Catalyzes the **transesterification** of **galacturonans into pectin**, leading to tissue hardening or vice versa

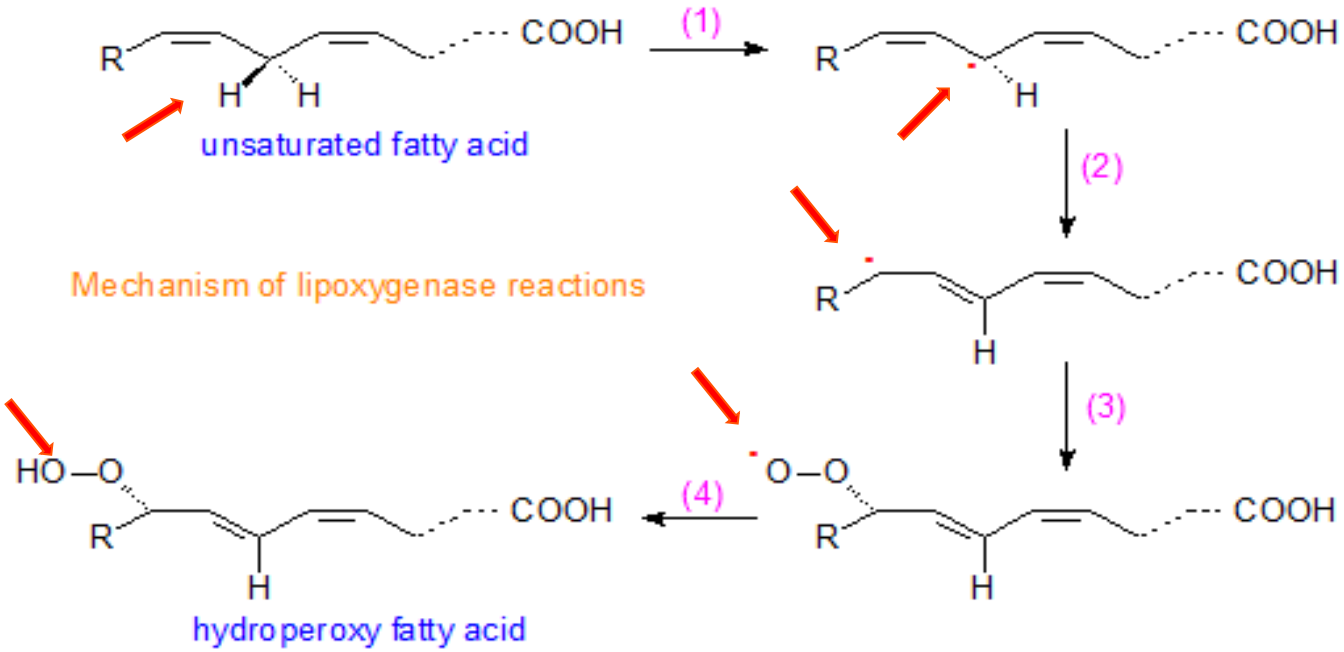


Enzymes

Enzyme

Lipoxygenase

Catalyzes the **oxidation of lipids**, leading to the creation of unpleasant odors

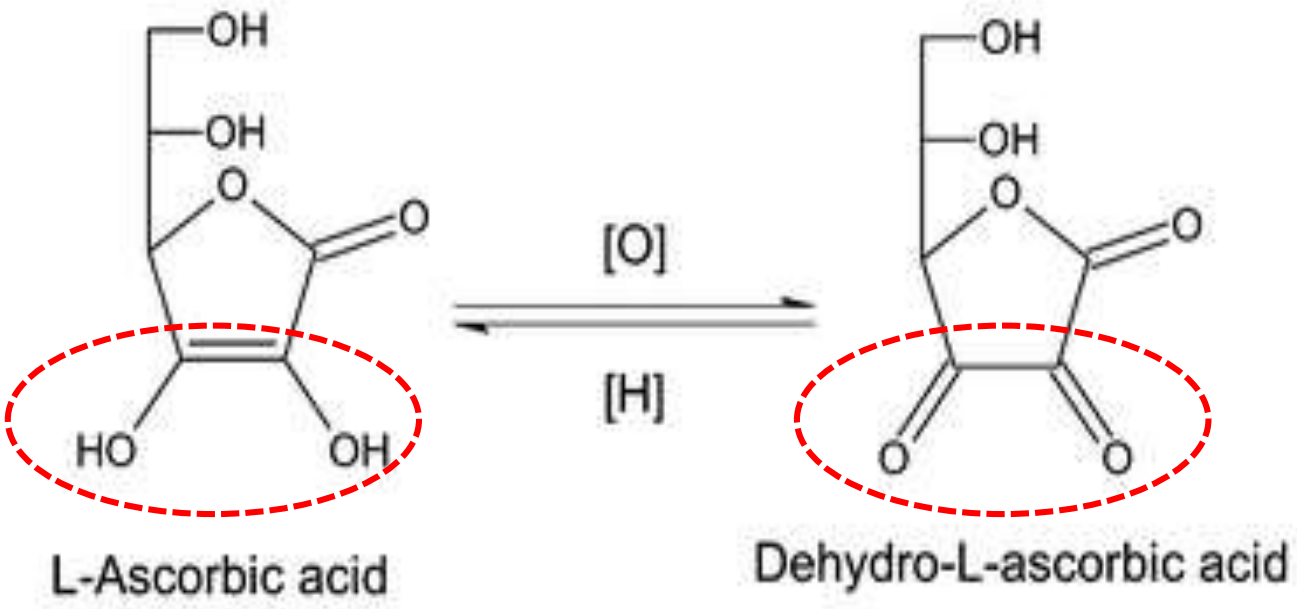


Enzymes

Enzyme

Ascorbic Oxidase

Catalyzes the **oxidation of ascorbic acid**, leading to a reduction in nutritional value

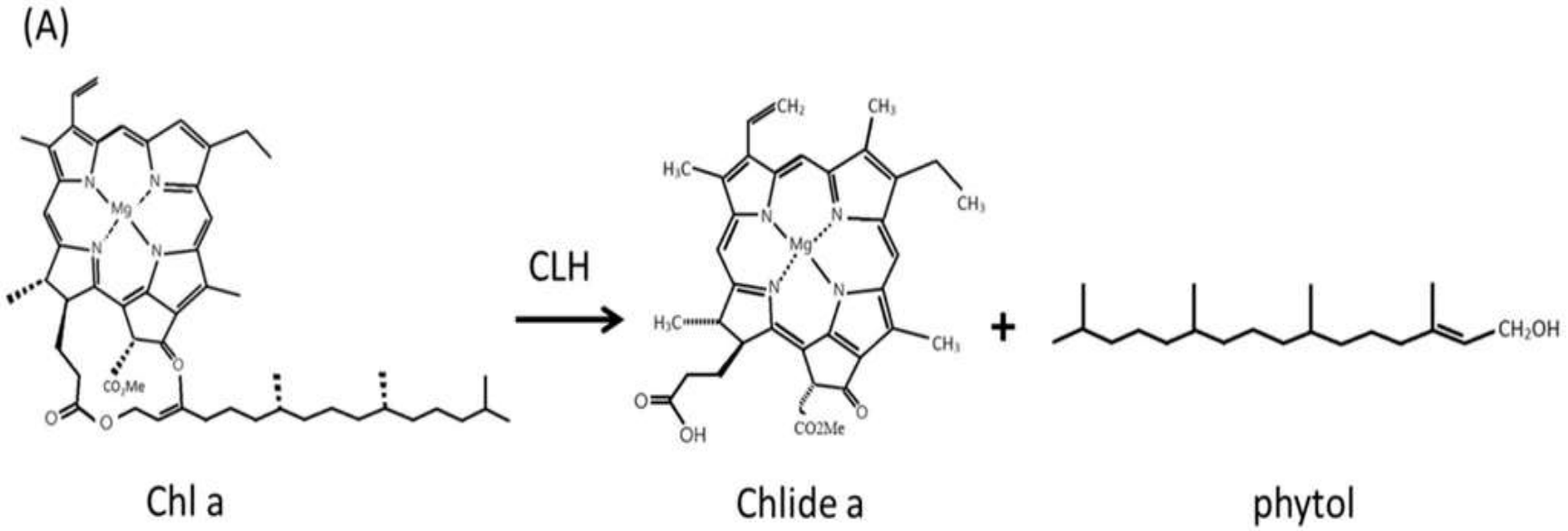


Enzymes

Enzyme

Chlorophyllas

Catalyses the **breakdown of chlorophyll** into chlorophyllin and phytol, leading to loss of green color

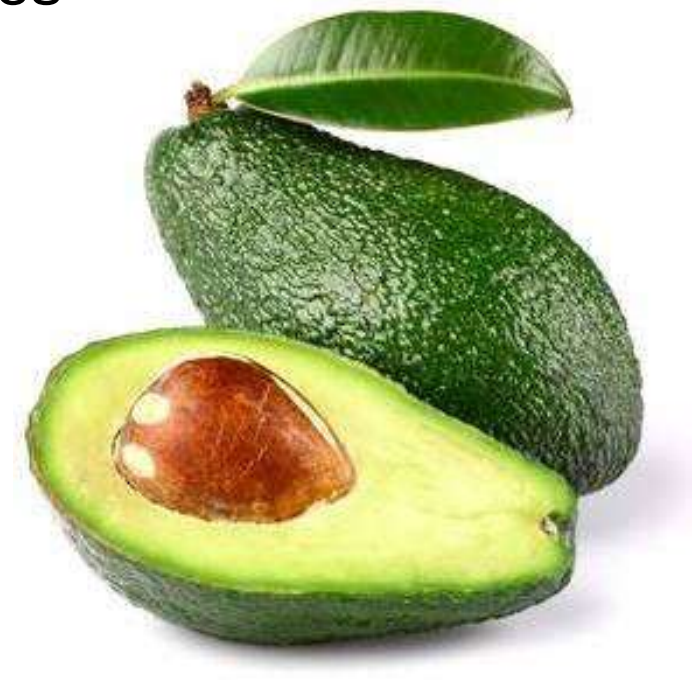


Sugars

- It is the most abundant and widespread component of foods of plant origin
- Their content varies in fresh fruit and generally ranges between 10-25%
- **Sucrose**, **glucose** & **fructose**, are major sugars found in fruit –mainly in the cytoplasm in concentrations from 0.9% in lemons to 16% in fresh figs
- **Sucrose** is contained in traces in cherries, grapes and pomegranates and > 8% in ripe bananas and pineapples affecting the taste accordingly as fructose is sweeter than sucrose
- **Starch** appears in the form of small grains in unripe fruit, and turns into sugar when the fruit ripens
- Other fruit polysaccharides are **cellulose**, **hemicellulose**, & **pectin**, found mainly (up to 50%) in cell walls
- When they are broken down (mainly pectins) into smaller and more soluble components the fruit softens

Lipids

- Make up only 0.1-0.2% of most fresh fruits & vegetables, except avocados, olives & nuts
- They are components of cell membranes and the waxy surface, which contributes to the appearance of the fruit and its protection from evaporation and diseases
- The degree of saturation of the fatty acids determines the elasticity of the membranes (the higher it is, the lower the elasticity)

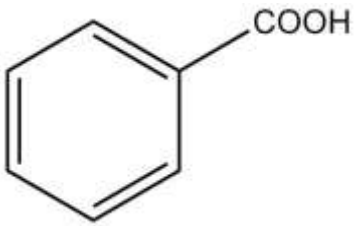


Organic acids

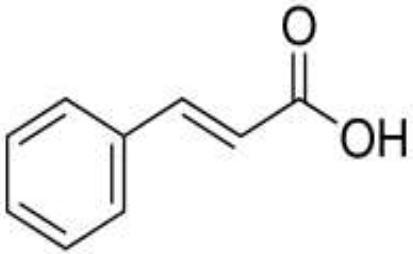
- They are important intermediate products of metabolism
- The **Krebs cycle** is the main oxidation pathway of of organic acids to living cells, and provides the energy needed for their maintenance
- They are metabolized to various components, such as amino acids, the building blocks of proteins
- Most fresh fruits are acidic - Some (e.g. lemons, limes) contain acid as much as 2-3% of their total wet weight
- The acid content is reduced during ripening due to the conversion of acids into sugars or their consumption during respiration

Organic acids

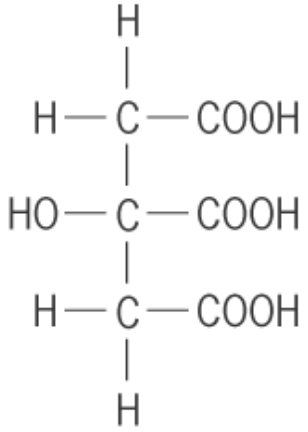
Malic and **citric** acids are the most abundant acids in fruit, except grapes (where **tartaric** acid predominates) and kiwis (where **quinic** acid predominates)



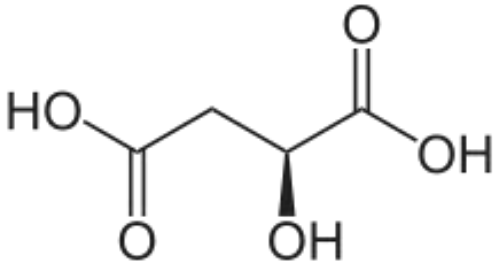
Benzoic acid (some berries)



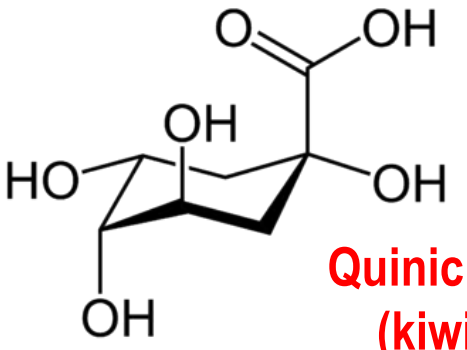
Cinnamic (cinnamon)



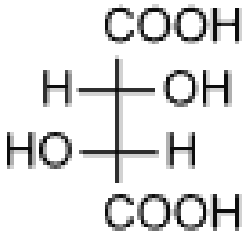
Citric acid (citrus)



L-malic acid (apples, grapes)



Quinic acid (kiwis)



L-(+)-tartaric acid (grapes)

Phenolics

- Phenolic constituents in plants include many kinds of compounds with many functional properties in food:
- **Organoleptic properties** (astrigency, bitterness) & **color** (mainly due to enzymatic browning)
- **Potential health benefits** (Antioxidant properties, Antimicrobial action)

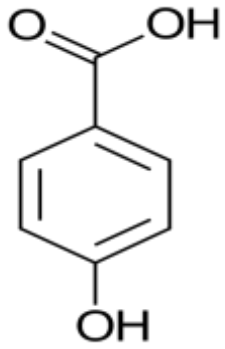
- Phenolic compounds are **hydroxylated derivatives** of compounds such as phenol, p-cresol and 3-ethylphenol and phenolic acids such as caffeic, coumaric and ferulic
- Total phenolic content is highest in unripe fruits (~0.1-2 g\100 g fresh weight.

Phenolics

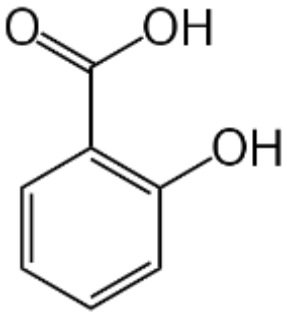
Fruit/vegetable phenolics include:

- **Chlorogenic acid** (derivative of caffeic acid, widespread in fruits and a major substrate of enzymatic browning when they are cut or generally when their tissues are exposed to oxygen)
- **Flavonoids** (such as flavonols, catechin, epicatechin, cyanidin)
- **Anthocyanins** (glycosides of anthocyanidins)
- **Cinnamic acid** derivatives
- **Simple phenols**

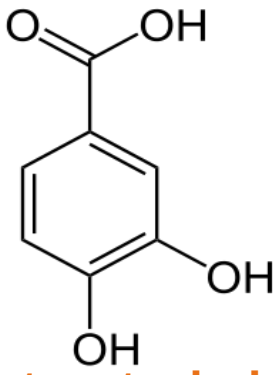
Phenolics



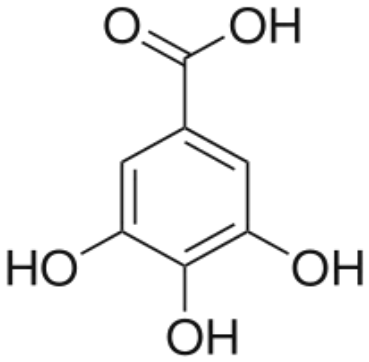
p-Hydroxybenzoic



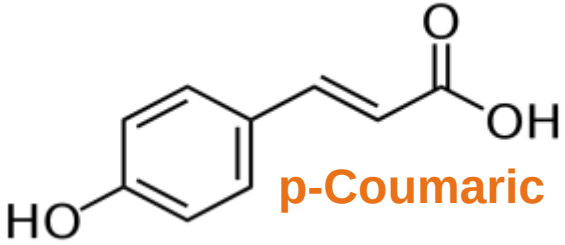
Salicylic



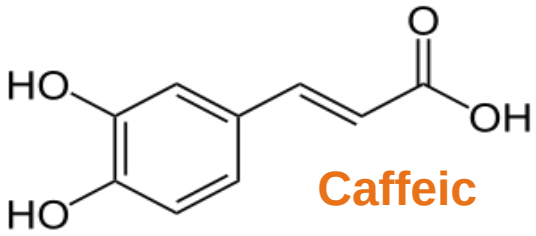
Protocatechuic



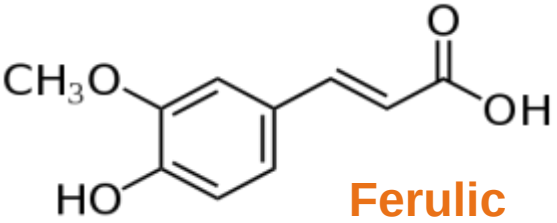
Gallic acid



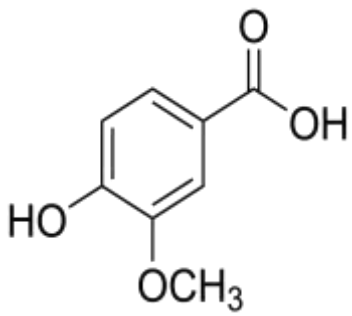
p-Coumaric



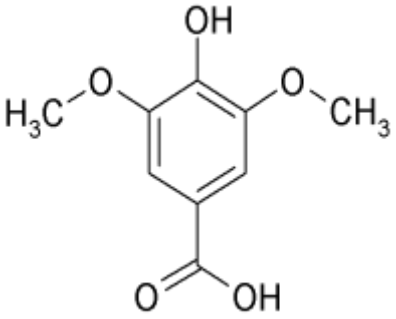
Caffeic



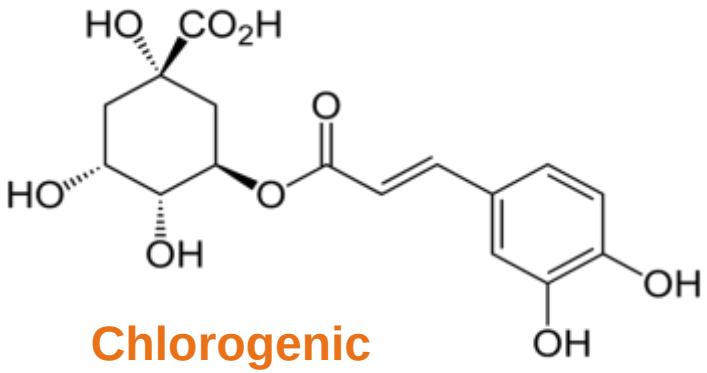
Ferulic



Vanillic



Syringic

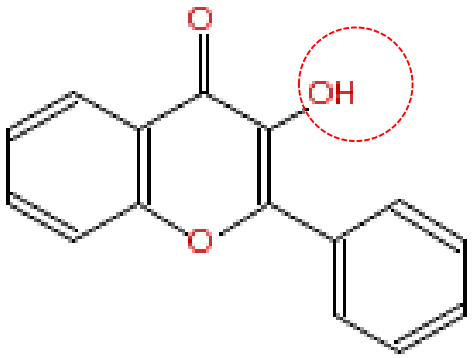


Chlorogenic

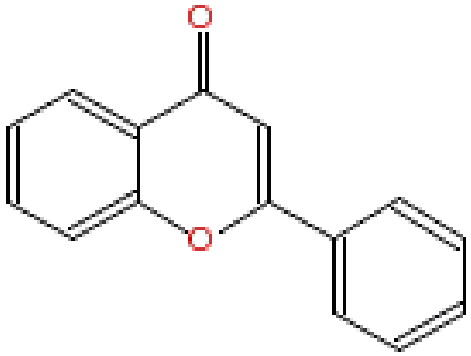
Phenolic acids

Phenolics

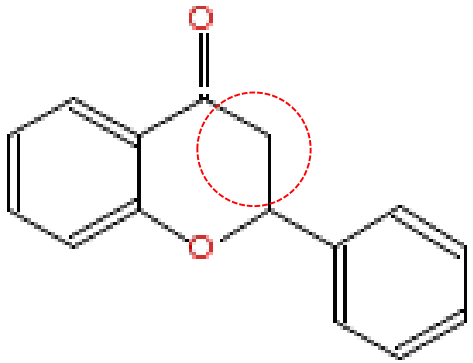
Flavonoids



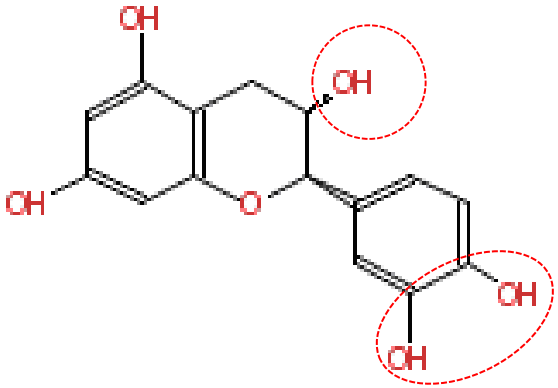
Flavonol



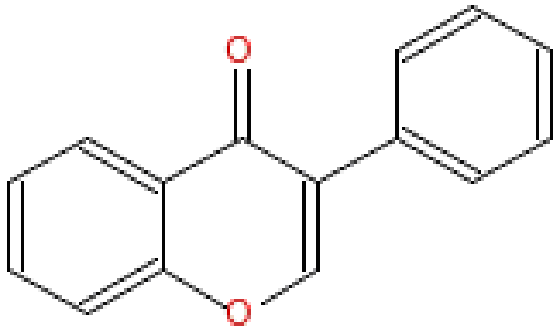
Flavone



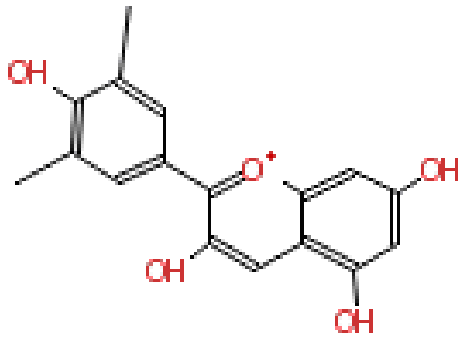
Flavanone



Flavanol (Catechins)



Isoflavone

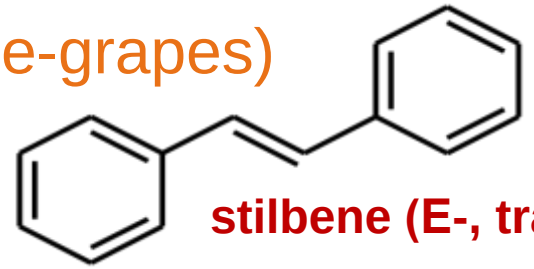


Anthocyanidine

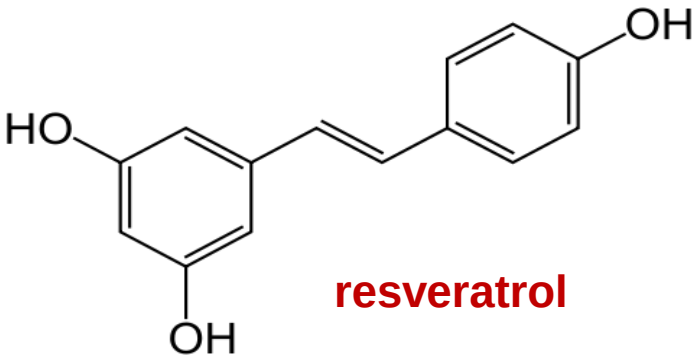
Phenolics

Stilbenes

(wine-grapes)

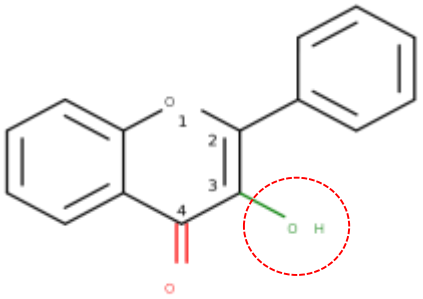


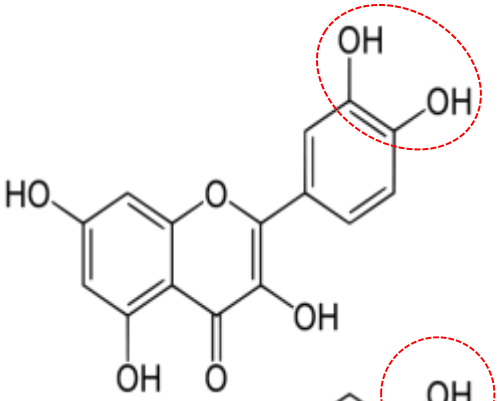
stilbene (E-, trans-)



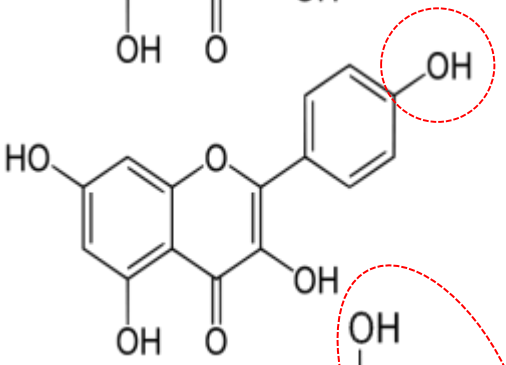
resveratrol

Flavanols

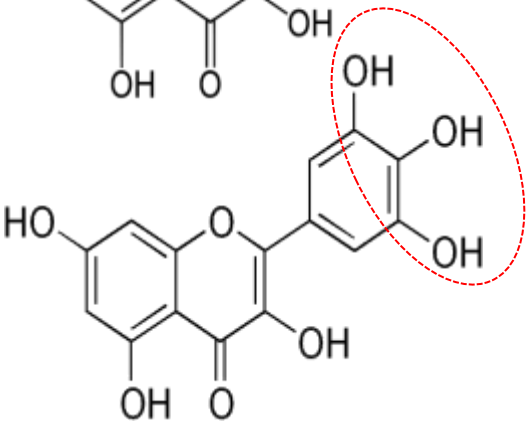




Quercetin



Kaempferol



Myricetin

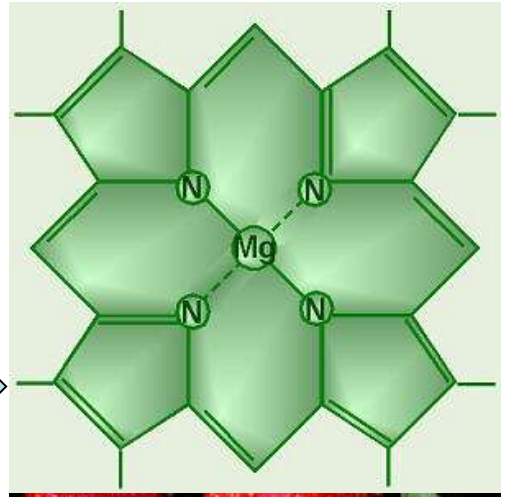
Phenolics

- Enzymatic browning in plant products is a result of the oxidation of the phenolics by polyphenol oxidase (PPO)
- The extent of browning depends on the total amount of phenols in the tissue and the activity of PPO
- Astringent flavor is directly dependent on the phenolic load and usually weakens with ripening due to conversion of soluble phenolics to insoluble, non-astringent forms
- Although enzymatic browning is desirable in processes such as tea & cocoa fermentation, it is undesirable in fruits and vegetables because it causes discoloration
- Methods to avoid enzymatic browning include:
  - ✓ Exclusion of oxygen
  - ✓ Use of acids
  - ✓ Deactivation by heating (blanching)
  - ✓ Use of sulphites etc.

Colors

- The chemicals responsible for **fruit color** undergo many changes during ripening, which include:

- **Loss of chlorophyll** (green color), affected by pH changes, redox reactions, chlorophyllase enzyme activity



- **Synthesis of anthocyanins** (red, blue & purple colors)

- **Carotenoid synthesis** (yellow & orange colors)

Volatiles (aroma)

- Volatile compounds are responsible for the characteristic fruit aroma
- They are mainly **esters**, **alcohols**, **organic acids**, **aldehydes**, **ketones**
- They are present at very low concentrations (<100 µg/g fresh weight)
- The main volatile component produced by climacteric fruits is **ethylene** (50-75% of total C of all volatiles) – it has no strong aroma and does not contribute to typical fruit aroma
- A huge number of volatiles have been identified in fruits by gas chromatographic methods of analysis, but few, key compounds, are important for the specific aroma of a fruit, e.g. **terpenic** compounds

Examples of exercise questions

1. What is dietary fiber & what is its nutritional value?
2. Name the enzymes that are of great importance for the quality of fruits/vegetables and their products.
3. What are the most common organic acids in fruits/vegetables?
4. What are the main classes of phenolic compounds in fruits/vegetables?
5. What is the aroma of fruits/vegetables composed of?
6. What is the color of fruits/vegetables composed of?

Thank u!