Functional Foods and Nutraceuticals

Lecture (3) by
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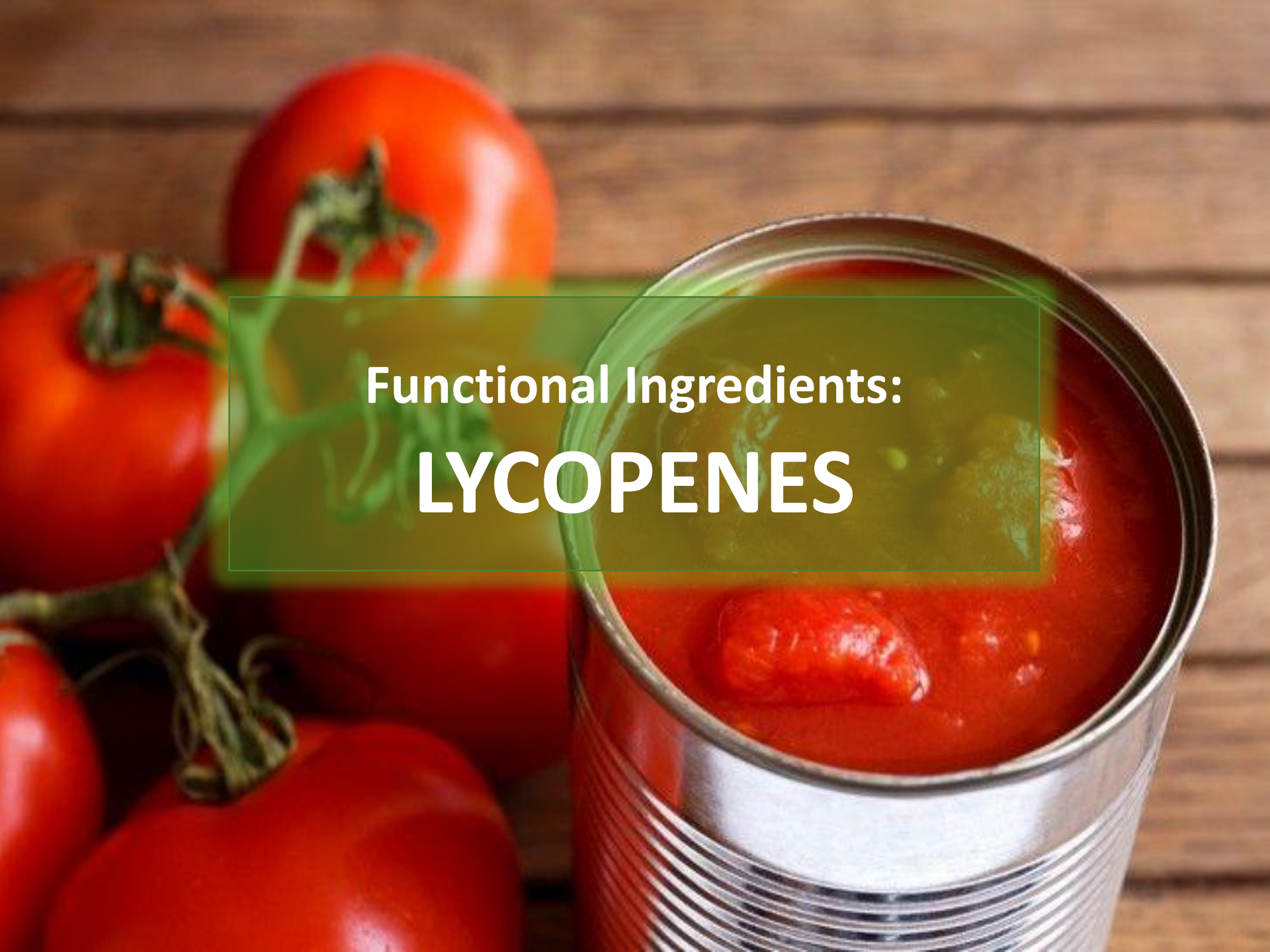

Functional Ingredients:
LYCOPENES

Introduction

- Lycopene is the red coloured lipophilic phytochemical belonging to a group of pigments known as carotenoids.
- Found abundantly in red colored F&V such as tomato, papaya, pink guava and water melon.
- It was first discovered in tomato by Millerdet (1876).
- The name ‘Lycopene’ was given later by Schunck.

Chemistry of Lycopene

- Lycopene - One pigment in a large family of plant pigments known as carotenoids.
- Range of colors produced by carotenoids: Yellow color of squash to orange color of pumpkins to red color of tomatoes.
- Carotenoids contribute to some plant food aromas, exhibit provitamin A activity and have shown potent antioxidant activity.

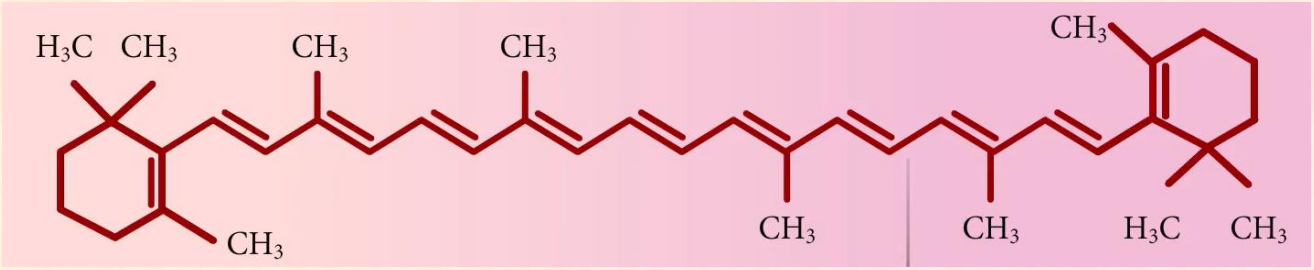
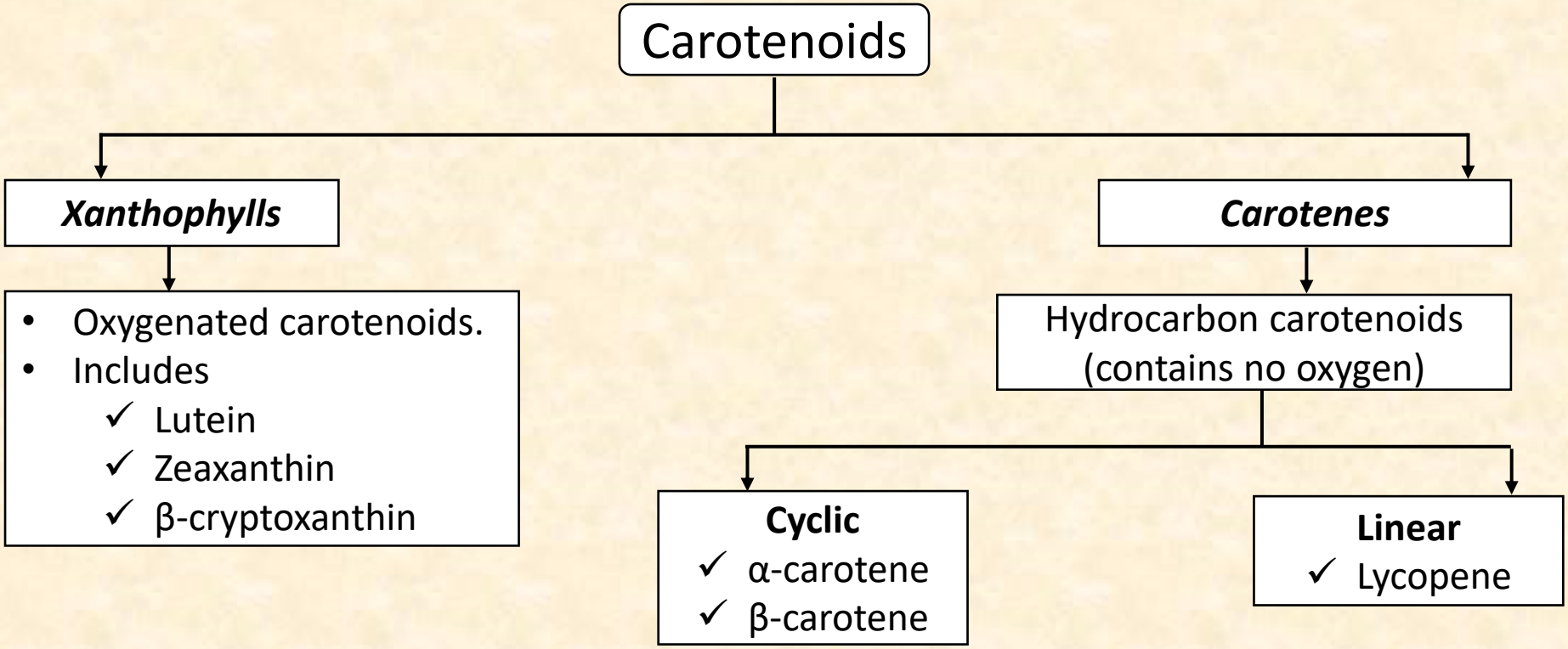


Figure: Structure of lycopene ($C_{40}H_{56}$)

Chemistry of Lycopene

❖ Carotenoids are divided into two groups: Xanthophylls and Carotenes.



Chemistry of Lycopene

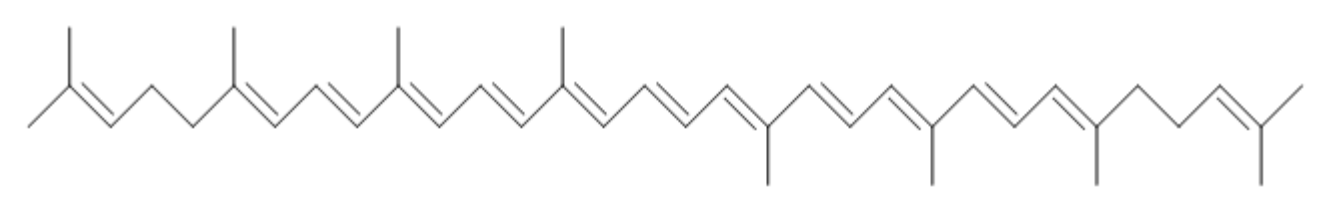


Figure: Structure of lycopene ($C_{40}H_{56}$)

- Structure: Highly unsaturated straight chain hydrocarbon.
- Total of 13 double bonds present
  - ✓ 11 linearly arranged conjugated double bonds
  - ✓ 2 non-conjugated double bonds
- The 11 conjugated and 2 non-conjugated double bonds facilitate extensive isomerization of lycopene, resulting in- 1056 theoretical *cis-trans* configurations.
- Presence of high number of conjugated double bonds made lycopene one of the most potent antioxidants due to its singlet-oxygen quenching ability.

Chemistry of Lycopene

- Lycopene occurs naturally as all trans form and its chain containing seven double bonds that can be isomerized to mono-cis or poly-cis due to exposure to
  - ✓ High temperatures
  - ✓ Light
  - ✓ Oxygen
  - ✓ Acids
  - ✓ Catalyst
  - ✓ Metal ions
- Lipophilic compound with hydrophobic characteristics due to its acyclic structure.
- 11 linear conjugated double bonds make it more soluble in organic solvents such as
  - ✓ Chloroform
  - ✓ Hexane
  - ✓ Benzene
  - ✓ Methylene chloride
  - ✓ Acetone
  - ✓ Petroleum ether

Physical Properties of Lycopene

Molecular formula	• $C_{40}H_{56}$
Molecular weight	• 536.85 Da
Melting point	• 172-175 °C
Colour	• Dark reddish brown in powder form.
Solubility	• Soluble in: Chloroform, hexane, benzene, carbon disulphide, acetone, petroleum ether and oil; • Insoluble in: Water, ethanol and methanol.
Stability	• Sensitive to light oxygen, high temperature, acids, catalysts and metal ions.

Sources of Lycopene

Major Source in diet:

- Tomato and tomato products.
- Tomatoes are:
  - Low in calories and fat
  - Good sources of Vit A, C & E

Other sources include:

Autumn olive

Pink grapefruit

Papaya

Wolfberry

Peaches

Watermelon

Pink guava

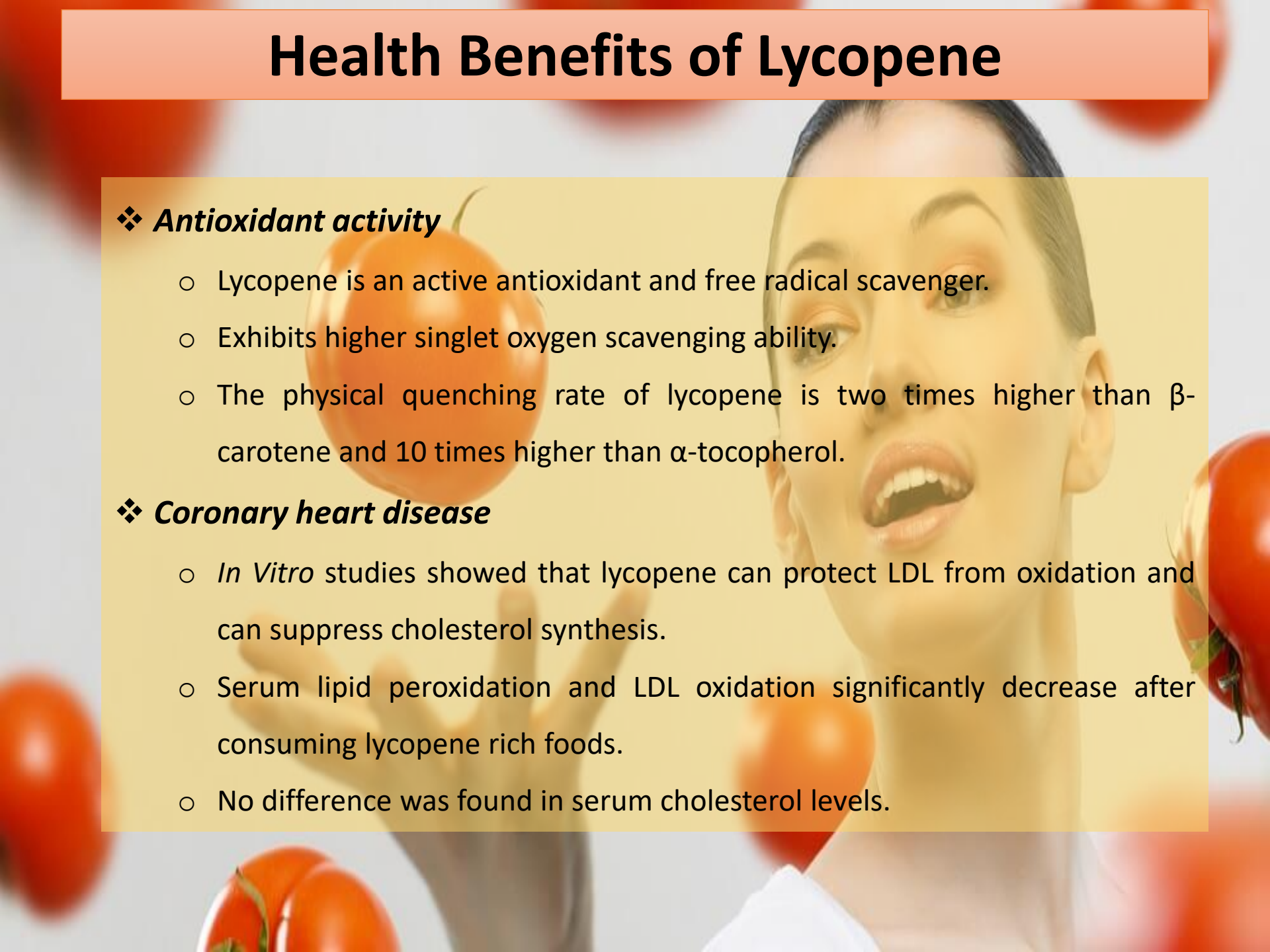
Sea buckthorn

Rosehip

Cranberry

Apricot

Health Benefits of Lycopene



- ***Antioxidant activity***
  - Lycopene is an active antioxidant and free radical scavenger.
  - Exhibits higher singlet oxygen scavenging ability.
  - The physical quenching rate of lycopene is two times higher than β-carotene and 10 times higher than α-tocopherol.
- ***Coronary heart disease***
  - *In Vitro* studies showed that lycopene can protect LDL from oxidation and can suppress cholesterol synthesis.
  - Serum lipid peroxidation and LDL oxidation significantly decrease after consuming lycopene rich foods.
  - No difference was found in serum cholesterol levels.

Health Benefits of Lycopene

- ***Cancer***
  - Lycopene found to be superior than β-carotene in inhibiting the cell proliferation in various human epithelial cancers.
  - Reduce the risk of prostate, lung, leukemic and digestive tract cancers.
- ***Diabetes***
  - Serum lycopene is inversely associated with type-2 diabetes and impaired glucose metabolism.
  - Plasma glucose and fasting insulin concentrations decreased significantly with increase in serum lycopene.
- ***Skin aging***
  - Singlet oxygen produced during exposure to ultra-violet light is a primary cause of skin aging.
  - Lycopene is a powerful quencher of singlet oxygen; 100 times more efficient than Vit E.

Extraction/Purification of Lycopene

Several researchers have extracted lycopene from various sources, mainly tomato. An overview of their work (of past one decade) are listed below:

Year	Source of extraction	Method of extraction/ purification	Optimum condition	Yield	References
2020	Tomato paste	• Solvent extraction using coconut oil, olive oil, soybean oil, palm oil and sunflower oil. • In the absence of light.	• Solvent/material ratio- 50:1 • Temperature- 45 °C • Extraction time- 45 min • Coconut oil gave maximum yield.	80%	Kunthakudee *et al.* (2020)
2020	Tomato peel and seeds	• Sample drying • Supercritical CO_2 extraction • Anaerobic digestion	• Higher moisture (102.7 g/kg, wet basis) • SFE-CO_2 extract: Emulsion rich in lycopene (69.3 mg/kg Trans 53.82:cis 46.17)	97%	Scaglia *et al.* (2020)
2019	Tomato pomace	Microemulsions using different proportions of lecithin, 1-propanol, olive oil and water.	• 1 g tomato pomace • 4 extraction cycles applying 5 g microemulsion composed of lecithin (53.33): 1-propanol (26.67): olive oil (10): water (10) [wt %]	88%	Amiri-Rigi and Abbasi (2019)
2019	Tomato waste	• Enzyme assisted solvent extraction. • Cellulase and pectinase used for pre-treatment. • Solvent: Ethyl acetate	• Temperature- 40 °C • Cellulase: Pectinase- 1:1 • Enzymatic reaction time- 5 h • Enzyme: Substrate- 0.2 ml/g • Solvent: Substrate- 5 ml/g • Extraction time- 1 h	11.5 mg/g	Catalkaya and Kahveci (2019)

Extraction/Purification of Lycopene

Year	Source of extraction	Method of extraction/ purification	Optimum condition	Yield	References
2018	Tomato peel	• Tomato peels were pre-treated using ultrasonication and co-immobilized enzymes. • Pectinase and cellulase immobilized on amino-functionalized magnetic nanoparticles (AMNPs) • Lycopene from the pre-treated mixture was extracted and separated using tri-solvent extraction method. • Presence of lycopene in the extract was confirmed by FT-IR, UV-vis spectroscopy and HPLC.	*Pre-treatment* • 3% (w/w) enzyme co-immobilized AMNPs • pH- 5 • Temperature- 50 °C • Ultrasound power- 10 W • Incubation time- 20 min *Tri-solvent extraction* • Temperature- 50 °C • Incubation time- 90 min • Agitation speed- 150 rpm	> 50% even after 6^{th} cycles of reuse.	Ladole *et al.* (2018)
2018					

Bioavailability of Lycopene

- Lycopene bioavailability is dependent on number of elemental factors:
  - Food processing
  - Dietary composition
- Lycopene can occur in different forms in fresh plant foods, including
  - Carotenoid-protein complexes
  - Crystalline form inside chromoplasts
- The effects of processing and storage on lycopene structure and stability are of interest for a number of reasons:
  - Improper processing or storage
  - Thermal processing generally improve lycopene bioavailabilty by disturbing cellular membrane, which allows lycopene to be released from tissue matrix
  - Since it is a lipophilic compound, consumption of lycopene with fat increases its bioavailability. E.g., consuming salad with full-fat dressing results in higher blood carotenoid level.

Bioavailability of Lycopene

- *In Vivo* studies indicated that the cis-isomers of lycopene appear to be more bioavailable than the all-trans isomer.
- *In Vitro* experiments inferred that increased bioavailability of lycopene cis-isomers is at least partially due to increased micellarization and increased uptake by the enterocyte relative to all-trans lycopene.
- In a human body:
  - Higher lycopene concentration in: Liver, testes, adrenal glands and adipose tissues.
  - Lower lycopene concentration in: Kidney, ovary, lung and prostate.
- Lycopene content increases as tomato mature.
- Lycopene concentration depends upon season too:
  - Higher in summer
  - Lower in winter.

Effect of Processing on Lycopene

- Heat, light, oxygen and diverse food matrix have effect on lycopene isomerization and auto-oxidation.
- Lycopene may isomerize to mono or poly cis form with the presence of heat, or oil or during hydration.
- Presence of oil during food preparation may increase the % of mono or poly cis lycopene in food.
- All trans lycopene found to decrease with the increasing illumination time. Exposure to light for about 14 h, resulted in 94% loss.
- Temp. > 100 °C and longer heating time lead to a higher percentage of lycopene degradation.

Effect of Processing on Lycopene

- Lycopene loss was highest in presence of air and light at 25 °C, and lowest under vacuum and dark.
- Dehydrated tomato products are sensitive to colour fading and loss of acceptability mainly due to
  - Lycopene isomerization
  - Oxidation
- When lycopene emulsion were diluted in foods, lycopene was found to be very stable.

Commercial Products of Lycopene

- Food processing by-products from the tomato puree and sauce industry are commonly used in the development of lycopene-rich products.
- Tomato skin/peel contains high amount of lycopene. Food scientists recycle the lycopene rich by-products as food ingredients.
- Popular commercial products from lycopene include:
  - Fortification of dry fermented sausage with tomato peels.
  - Development of processed snacks by producing barley-tomato blends with the help of extrusion.
  - Enrichment of low quality edible oils such as refined olive oil, extra virgin oil and refined sunflower oil by lycopene (from tomato peels or puree) induced thermal stability to these edible oils.
  - The production of lycopene enriched egg yolk by feeding hens with feed containing lycopene rich by-products.

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