Lycopene: Structure and Functional role in human health

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Abstract

Tomato contains a major carotenoid i.e. lycopene. Tomato contains vitamin C, vitamin E and other carotenoids (Alpha, beta and gamma carotene) and flavonoids. Lycopene is important because of the color it imparts and health benefits associated with it. In red tomatoes 95% of lycopene is present in the most stable form i.e. all- trans form. While in tangerine tomatoes lycopene is present as tetra cis-lycopene, which is a geometrical isomer of all- trans isomer. Major component of blood serum is lycopene. Lycopene has antioxidant and cancer preventing properties. It also help in reducing heart disease as it reduces the accumulation of platelets which lead to blood clots, heart attacks and strokes. Lycopene is also protective against certain cancers like colorectal, prostrate, breast, pancreatic and lung cancers. This review deals with the lycopene and its potential functional role in human health.

Introduction

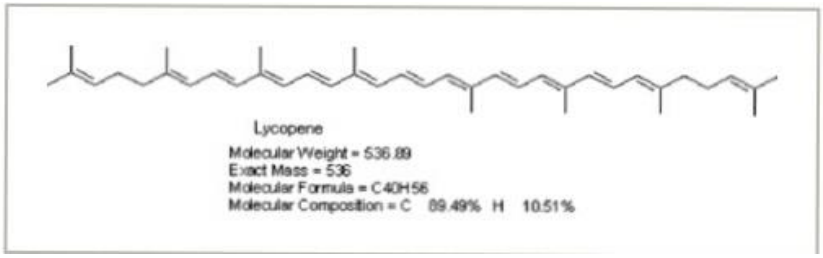
Lycopene is a bioactive carotenoid present in fruits and vegetables. It is a natural fat soluble pigment present in plants and microorganisms. Lycopene serves as a light gathering pigment and it helps in protection of these microorganisms against harmful effects of oxygen and light. Tomato mainly contains vitamin C, vitamin E, other carotenoids and flavonoids. Their symbiotic interactions are responsible for beneficial effects of tomato products. Symbiotic antioxidant activity is tested by liposome system. Lycopene and vitamin E shows greatest symbiotic antioxidant activity.

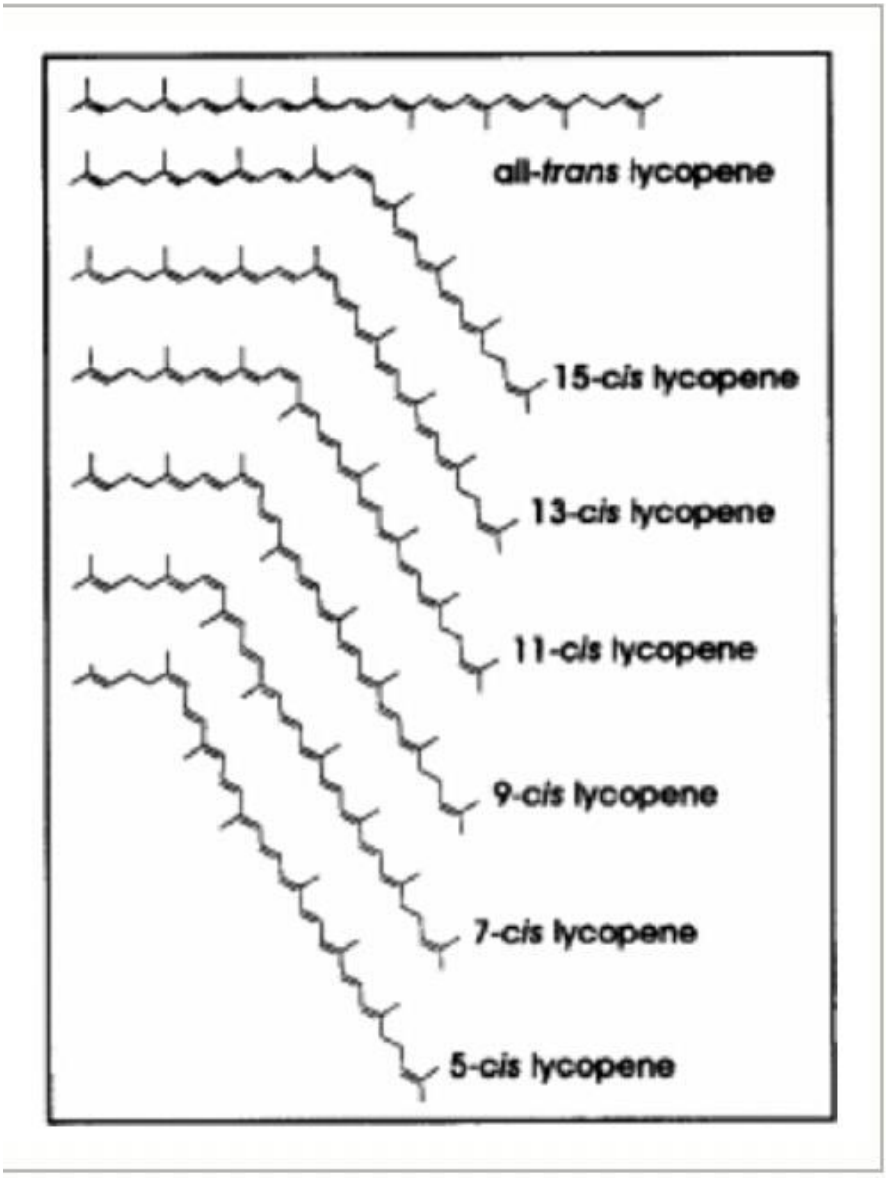
Lycopene and β carotene or oxycarotenoids are hydrocarbon carotenoids. Carotenoids have also emerged as important dietary phytochemicals. Out of 50 dietary carotenoids, lycopene is present in tomato and tomato products and most abundant in human serum. Lycopene name was assigned by Schunck (1903) as it shows different absorption spectrum than carotenes from carrots.

Lycopene: Structure

Lycopene is a natural pigment. It is synthesized by plants and microorganisms. It is an acyclic isomer of β carotene. It is highly unsaturated hydrocarbon containing 11 conjugated and 2 unconjugated double bonds. Like other alkenes it shows Cis-trans isomerization which is induced by light thermal energy and chemical reactions. Commonly identified isomers of lycopene are 5-

cis, 9-cis,13-cis,15cis and all trans.Stability sequence of these isomers is: 5 Cis>All trans>9-Cis>13-Cis>15-Cis>7Cis>11-Cis





Lycopene geometrical isomers

Characteristic red colour of lycopene is due to conjugated carbon double bonds. As the numbers of double bond increases in conjugation, the energy required for electron to transition to higher energy level will decreases and molecule absorb visible light of longer wavelengths. As it falls in visible range of spectrum, so it appears red. If lycopene is oxidized by acids, the double bonds between carbon atoms will be broken and molecule cleaved into smaller molecules. After oxidation carbon carbon double bond changed into carbon oxygen double bond. Carbon oxygen double bonds are chromophoric but they are smaller and unable to absorb light to come in visible range. When lycopene is reduced, reduction will saturate the molecule (double bonds are not in conjugation) and it is able to come in visible range. In lycopersicon esculentum (a common variety of tomato) lycopene is present in Trans configuration. This transform is thermodynamically stable. Lycopene is mainly present as cis form in human plasma (about 60%). Molecular formula of lycopene is $C_{40}H_{56}$. Chemical structure of lycopene was confirmed by Kuhn and Grundmann (1952) by relating its degradation products following chromic acid oxidation.

Enzymatic and Oxidative metabolites of lycopene

Lycopene has anticarcinogenic properties as (1) Lycopene works as an antioxidant. (2) Lycopene increases cell-cell communication. (3) It reduces mutagenesis. (4) It inhibits tumor cell proliferation. (5) It improves anti-tumor immune responses. In 1996, Clinton and his co-workers suggested the occurrence of in vivo isomerization of lycopene, since they detected higher amounts of cis-lycopene than all trans lycopene in human serum and in both benign and malignant prostrate tissue. In the first report of a metabolite in human plasma was that of 5, 6-dihydroxy-5', 6'-dihydrolycopene resulting from oxidation of lycopene. 2, 6- cyclolycopene-1, 5-diol A and B are also reported as oxidative metabolites of lycopene in humans.

Characterization of lycopene

Lycopene content in food and biological samples is determined by various analytical methods. These methods include UV-Vis spectrophotometry, atomic pressure ionization- mass spectroscopy, liquid chromatography connected to electrospray ionization mass spectroscopy liquid chromatography with spectrophotometric detection and HPLC. Extraction, storage, handling and analysis of lycopene should be carried out under controlled environmental conditions to minimize oxidative degradation and to avoid the introduction of artifactual level of isomers. Extracted lycopene should not be exposed to light. Only gold, yellow and red lights should be used for exposure. To control oxidation and isomerization reactions of lycopene, butylated hydroxytuolene (BHT) should be used as extracting and separating solvent. Nitrogen or Argon headspace should be used for minimum exposure of atmospheric oxygen. Methanolic potassium hydroxide is used for saponification of lycopene. Saponification is performed to

enhance lycopene's analysis as it eliminates chlorophyll and lipid materials, which can interfere with its chromatographic elution and detection.

Stability of lycopene

Bioavailability of lycopene increases as a result of moderate heating or enzymatic disruption of vegetable's cell wall structure. Processing causes no change to content and activity of naturally occurring antioxidants .Lycopene is very heat stable even after intense or prolonged heat treatments such as sterilization processes or cooking. Lycopene is acyclic and possesses symmetrical planarity. It is highly conjugated polyene and susceptible to oxidative degradation. Other carotenoids are degraded by physical and chemical factors like exposure to light, extremes in pH, Oxygen and molecules with active surfaces that can destabilize the double bonds. Cole and Kapur studied the lycopene degradation by oxygen, temperature and light intensity. Cole reported the significant loses of lycopene in serum- free tomato pulp samples. There is direct correlation between lycopene degradation and intensities of illumination, temperature. Due to undesirable degradation of lycopene; health benefit of tomato based foods for human body is affected. In fresh tomato fruits lycopene mainly occurs in the all-trans configuration. During processing, lycopene degradation occurs due to isomerization and oxidation. In isomerisation process all Trans isomers are converted into cis – isomers and result in unstable energy rich station.

Lycopene role in human health

Anticancer properties of carotenoids and lycopene are based on sound scientific facts. U.S.National Research Council of Academy of sciences(1989),the NCI(1987), and the World Cancer Research Fund, the American Institute of Cancer Research(1997),WHO(1990) have recommended that increasing dietary intake of green and yellow vegetables, Citrus fruits, Cruciferous vegetables and fruits and vegetables rich in vitamin A and C lead to lower cancer risk.

Lycopene is most powerful antioxidant and its quenching ability is twice as that of β carotene and 10 times that of α tocopherol. Biological and Physicochemical properties of lycopene are responsible for its antioxidant property so it should be present in our diet. It provides protection against epithelial cancers and coronary heart disease. Levy showed that lycopene is a more potent inhibitor of human cancer cell proliferation than either α carotene or β carotene. Lycopene provides protection against degenerative diseases like cancer and coronary heart disease which are influenced by free radical reactions .Lycopene is better inhibitor of human cancer cell proliferation than either α carotene or β carotene. Antioxidative activity of lycopene is because it acts like potent protector against oxidative damage to DNA, Proteins and lipids. It also inhibits all proliferation and resistance to bacterial infections.

Colorectal Cancer

Er hardt (2003) in his studies revealed that in patients, suffering from colorectal cancer there is a proliferation, colorectal adenomas, which is precursor of this cancer. Their blood levels of lycopene were 35% lower compared to study subjects with no proliferation. Their β carotene level was also 25.5% lower. In their final analysis, smoking and low level of plasma lycopene increased the risk of colorectal adenomas. Smoking increases the risk of colorectal cancer by 302% but low levels of lycopene can increase the risk by 230%.

Prostrate Cancer

Scientists suggest that tomato products and carotenoid lycopene involved in cancer prevention, reducing the risk of cardiovascular disease and limiting the mortality of other chronic diseases. Carotenoids react with oxygen free radicals by bleaching of carotenoids or by transfer of unpaired electron leaving the carotenoid in an excited triplet state. The later leaves the carotenoid intact and former results in decomposition of carotenoid. Actually, it the later that predominant. Lycopene has a large no. of double bonds and so it is the most potent scavenger of oxygen-free radical species like peroxyl radicals and also interacts with reactive oxygen species like H_2O_2 and NO_2. In this way it protects cells from oxidative damage. Lycopene is twice as efficient as β carotene in scavenging for NO_2. Lycopene is more efficient than any carotene in inhibiting insulin like growth factor type 1 (IGFI) induced proliferation of a number of tumor cell lenis and reduces the occurrence of both spontaneous and chemically induced memory tumors.

Lycopene is present in human prostrate at significant concentrations and men with higher concentrations of blood lycopene experience a lower risk of prostrate carcinoma.

Pancreatic Cancer

After detailed study scientists suggested that men consuming lycopene by tomatoes had a 31% reduction in the risk of pancreatic cancer. Persons, whose diets were richest in lycopene or carotenoids, and who had never smoked, reduced the risk of pancreatic cancer by 42% and 43% respectively.

Researchers recognized the mechanism by which lycopene protects against cancer: activating cancer preventive phase II enzymes. When breast and liver cancer cells are incubated with lycopene, the carotenoid triggered production of phase II detoxification enzymes. Lycopene upraised the production and activity of these enzymes by activating luciferase gene. This gene then activates the “antioxidant response element” in other genes that encodes the enzymes and in this way causes the genes to direct increased enzyme production. Other carotenoids didn’t have this effect. Many evidences indicate that protective effect of lycopene is because it acts synergistically with other phytochemicals. Recent studies have shown that taking lycopene alone is not so effective in preventive cancer as eating tomato products.

Coronary Heart Disease

Lycopene also provide cardiovascular benefits. Studies supported that risk of coronary heart disease can be reduced by consuming heat processed tomatoes. Actually lycopene interferes indifferently with the oxidative damage to DNA and low density lycoproteins. Lycopene act as an antioxidant and scavenges free radicals. These two properties of lycopene are associated with carcinogenesis. Researchers suggested that high dietary consumption of lycopene play a role in cardiovascular disease prevention and also show inverse association with various cancers. Researchers recommended that we can protect our cardiovascular system by consuming tomatoes raw or in form of tomato sauce or paste several times.

Synergic Effect of Lycopene with other Tomato Nutrients

In addition to lycopene tomatoes are an excellent source of vitamin C and Vitamin A and β carotene. These antioxidants neutralize dangerous free radicals that could damage cells and cell membranes and causes many diseases like atherosclerosis, diabetes, asthma and colorectal cancer. High intakes of these antioxidants reduce the risk of these illnesses. Tomato contains fibre which lowers high cholesterol levels, and keeps blood sugar level low and prevents colorectal cancer.

Tomato also contains potassium, niacin, vitamin B_6 and folate. Niacin lowers high cholesterol level. Potassium rich diet lowers high blood pressure and reduces the risk of heart disease. Homocysteine, a dangerous chemical is converted into other benign molecule by vitamin B_6 and folate. When concentration of homocysteine in blood increases, it damages blood vessel walls and leads to heart attack and stroke.

Risk of colorectal cancer is reduced by folate which is present in tomato. Riboflavin present in tomato reduces migraine attacks.

Conclusion

As the demand of healthy food product increases, lycopene rich food is one of the best options for this. Extraction and purification of lycopene should be environmentally friendly and there should be minimal loss of Bioactivities for man, benefit in food, cosmetic and pharmaceutical industries. Today dieticians recommend people to increase consumption of fruits and vegetables as they are rich in antioxidants and it has generated interest in important role of lycopene in disease prevention.

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