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RESEARCH ARTICLE

LYCOPENE: A PLANT PIGMENT WITH PROMINENT ROLE ON HUMAN HEALTH

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ABSTRACT

Now-a-days colored pigments of plant origin gained ample worldwide importance. These are essential role players in exposing different colors and are formed from different phyto chemicals commonly found in food matrix. Lycopene is a tetra-terpenic C_{40} carotenoid having protective effects against prostate cancer, skin cancer and other types of cancers, cardiovascular diseases and reduction of oxidative stress. Its bioavailability is majorly focused on tomato products, while other sources include watermelon, guava, pink grapefruit, apricots, persimmons and red-fleshed papaya. Because of its high number of conjugated dienes it is most potent singlet oxygen quencher among other carotenoids and possess ability to scavenge nitrogen dioxide (NO_2^*), thiyl (RS^*) and sulphonyl (RSO_2^*) radicals. As research on lycopene is becoming intensive and extracting logical conclusions in various aspects, there is a immediate need to undertake application based research endeavours to make this gold nugget of neutraceutical nature reach out to the masses for enhancing health and ameliorate disease.

INTRODUCTION

Natural colored pigments derived from plant products have gained huge importance now-a-days globally, which are essential role players in exposing different colors and are formed from different phyto chemicals commonly found in food matrix (Mortensen, 2006). Lycopene is a tetraterpenic C_{40} carotenoid with renowned property to reduce oxidative stress. Red colored lycopene pigment was first discovered in tomato by Millardet in 1876 and was named by Schunck as lycopene (Vogele, 1937). Lycopene can be considered as “the vitamin of the twenty-first century” because of its significant physiological effect on the human diet. Lycopene is a non- pro vitamin A carotenoid, which has up to twice the antioxidant capacity compared to β- carotene in vitro (Di Mascio *et al.,* 1989; Miller *et al.,* 1996; Bohm *et al.,* 2002). Lycopene has been of nutritional interest since it was first suggested as having protective effects against prostate cancer (Campbell *et al.,* 2004), skin cancer (Sies and Stah, 2004) and other types of cancers (Giovannucci *et al.,* 1995; Helzlsouer *et al.,* 1989; Burney *et al.,* 1989; VanEeenwyk *et al.,* 1991), cardiovascular diseases (Kohlmeier *et al.,* 1997; Klipstein-Grobusch *et al.,* 2000) and reduction of oxidative stress (Basu and Imrhan, 2007; Porrini *et al.,* 2005).

Structure

Lycopene is a hydrocarbon carotenoid, with extended conjugated double bond system which is in turn responsible for the attractive colors by formation of light absorbing chromophore (Rodriguez and Kimura, 2004). The pigment molecule is an acyclic carotenoid, which possess about 11 linear conjugated and two non-conjugated double bonds and due to these it hails property of being a most efficient singlet oxygen quencher in carotenoid group (Stah and Sies, 1996). According to Rodriguez (2001) at least seven conjugated double bonds are needed for exhibiting attractive visible colors and higher wavelength values for maximum absorption is noticed as the number of conjugated double bonds is more. In addition, chain structure of lycopene with extensive conjugated polyene system makes it susceptible to oxidative degradation (Shi *et al.,* 2002). Naturally lycopene occurs as all *trans* form and its chain containing seven double bonds that can be isomerized to mono-*cis* and poly-*cis* due to the exposure to high temperatures, light, oxygen, acids, catalyst and metal ions (Shi *et al.,* 2002). Although trans isomers of lycopene are generally stable in the plant matrix, once liberated they are susceptible to heat-induced isomerization to cis isomers (Nguyen and Schwartz. 1998), which may be more readily absorbed (Stahl and Sies. 1992; Boileau *et al.,* 1999).The bioavailability of lycopene was found to be increased with heat and/ or homogenization, processes that break down plant cells walls, allowing release of carotenoids (Van het Hof *et al.,* 2000).

Lycopene is a lipophilic compound with hydrophobic characters pertaining to its acyclic structure and 11 linear conjugated double bonds that makes it more soluble in organic solvents such as chloroform, hexane, benzene, methylene chloride, acetone and petroleum ether (Roldán and Dolores,

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2007). Physical properties and molecular structure of lycopene are given in Table 1 and Figure 1, respectively.

Table 1. Physical Properties of Lycopene

Chemical Formula	$C_{40}H_{56}$
Molecular Weight	536.88 Da
Colour	Dark reddish- brown
Physical State	Solid
Appearance	Long crystalline needles separate from a mixture of carbon disulfide and ethanol
Odour	Neutral
Solubility in water	Practically insoluble
Solubility in Organic Solvents	Soluble in chloroform, hexane, benzene, carbon disulfide, acetone, petroleum ether and oil.
Melting Point	171-175^{0}C
Stability	Sensitive to light, oxygen, high temperature, acids, catalyst and metal ions.

Source: Shi *et al.,* (2002)

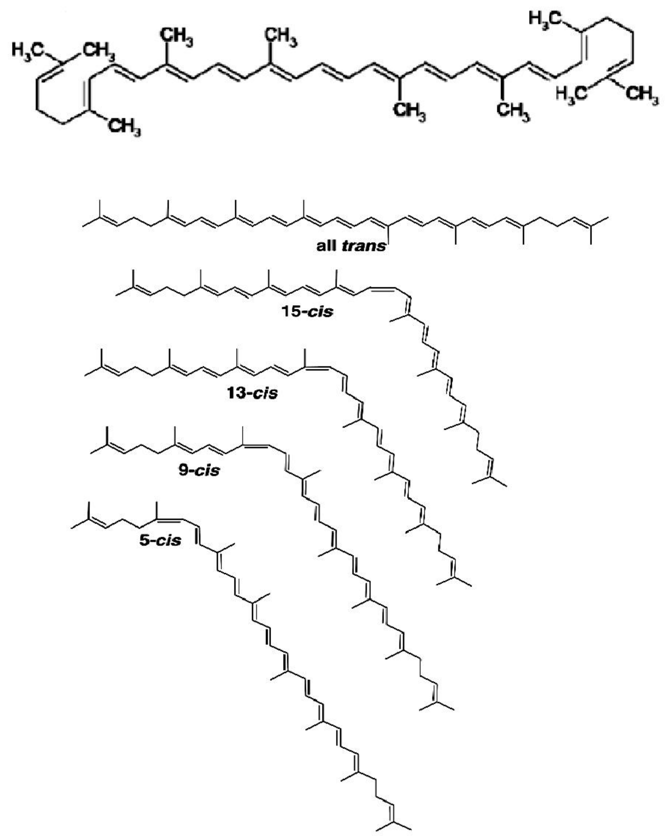

Figure 1. Molecular structures of lycopene isomers. [Source: Agarwal and Rao (1998)]

Sources

Lycopene is most abundant carotenoid present in tomatoes and one of the main carotenoids present in human diet (Maiani *et al.,* 2009). Lycopene bioavailability is majorly focused on tomato products (Stahl and Sies. 1992; Brown *et al.,* 1989; Micozzi *et al.,* 1992; Sakamoto *et al.,* 1994; Yeum *et al.,* 1996; Gartner *et al.,* 1997; Van het Hof *et al.,* 2000; Porrini *et al.,* 1990; Paetau *et al.,* 1998), while other sources of lycopene include watermelon, guava, pink grapefruit, apricots, persimmons and red-fleshed papaya, although the contribution of these foods to dietary lycopene is limited (Chug-Ahuja *et al.,* 1993; Clinton 998; Holden *et al.,* 1999; Edwards *et al.,* 2013) (Table 2) Carotenoid absorption from plants is generally poor relative to carotenoid supplements (Micozzi *et al.,* 1992) and varies with several factors, including accessibility from plant matrix (De Pee and West. 1996).

Table 2. Lycopene contents of common fruits and vegetables

Fruits/ Vegetables	Lycopene (μg/g wet weight)
Tomatoes	8.8 - 42.0
Watermelon	23.0 – 72.0
Pink Guava	54.0
Pink Grapefruit	33.6
Papaya	20.0 – 53.0
Apricot	< 0.1

The crystalline nature of lycopene in tomato may also account in part for its apparently low absorption efficiency from the tomato plant matrix (Van het Hof *et al.,* 2000 and Garrett *et al.,* 2000). Even in case of tomatoes the lycopene content differs with its varieties and ripening stages (Scott and Hart, 1995). The processed tomato products such as pasteurized tomato juice, soup, sauce, and ketchup contain the higher concentrations of bio-available lycopene than fresh tomatoes (Gross, 1987; Gross, 1991; Mangels *et al.,* 1993, Ong and Tee, 1992; Scott and Hart, 1995; Tonucci *et al.,* 1995; Schierle *et al.,* 1996) (Table 3). The reason behind this being lycopene insoluble in water and tends to tightly bind to vegetable fiber while processing.

Table 3. Lycopene contents processed products of tomato

Tomato products	Lycopene (μg/g weight)
Fresh Tomatoes	8.8-42.0
Cooked Tomatoes	37.0
Tomato Sauce	62.0
Tomato Paste	54.0-1500.0
Tomato Soup (condensed)	79.9
Tomato Powder	1126.3-1264.9
Tomato Juice	50.0- 116.0
Pizza Sauce	127.1
Ketchup	99.0- 134.4

The study of role of lycopene in human nutrition is a complicated one as the occurrence of all- *trans* isomer predominates in the tomatoes, which is main dietary source of lycopene. But blood, plasma and tissues contain relatively greater concentrations of *cis*- isomers (Campbell *et al.,* 2007). The processing and storage of tomatoes by heating converts the all- *trans* lycopene in to various *cis* isomers (Tonucci *et al.,* 1995). Unlike many pigments and few carotenoids the loss of lycopene contents appears to be minimal during cooking or food processing (Mangels *et al.,* 1993, Ong and Tee, 1992; Scott and Hart, 1995; Tonucci *et al.,* 1995). These *cis*-lycopene isomers are regarded as being more bio-available because they are more soluble and efficiently absorbed from the intestinal lumen than other forms (Boileau *et al.,* 2002). This isomerization may also occur in some sites in vivo such as gastrointestinal lumen (Moraru and Lee, 2005), liver (Teodero *et al.,* 2009), and enterocytes (Richelle *et al.,* 2010).

Few other non-plant sources include *Streptomyces chrestomyceticus*, *Candida utilis* (Yutaka *et al.,* 1998), *Blakeslea trispora* (Lampila *et al.,* 1985; Mehta *et al.,* 2003), *Phycomyces blakesleeanus* (Murillo *et al.,* 1978) and an engineered *Flavobacterium* sp. (Hohmann *et al.,* 2000).

Functions

Lycopene play a very important role in a number of biological processes, which are essential for different life processes, such as reduction of oxidative stress. Like other carotenoids, lycopene also have a strong antioxidant capacity. The defensive role towards ischemic heart disease and some types of cancer is attributed to the carotenoid constituents, particularly lycopene and β-carotene that accumulate in plasma and tissues in relation to lycopene rich tomato intake (Oshima *et al.,* 1996). Reactive Oxygen Species (ROS) are endogenously produced byproducts of routine metabolic processes, life style activity and diet. These free radicals play an important role in a number of biological processes, some of which are necessary for life, such as the intracellular killing of bacteria. Nevertheless, an excess of free radicals, constitute a serious danger for the human body, in fact, they may initiate deleterious side-chain reactions resulting in cell damage. Oxidative stress induced by ROS is associated with the incidence of several chronic diseases such as cancer, coronary heart diseases and osteoporosis. Many types of cancers are probably the result of reactions between free radicals and DNA, resulting in mutations that can adversely affect the cell cycle and potentially lead to malignancy.

Free radicals may also be involved in Parkinson's and Alzheimer's diseases, arthritis, *diabetes mellitus*, dermatitis. Some of the symptoms of aging such as atherosclerosis are also attributed to free-radical induced oxidation of many of the chemicals making up the body. (Ames *et al.,* 1995; Stadman, 1992; Witztum, 1994; Halliwell, 1995; Rao and Agarwal, 1999). In chemistry, free radicals are atoms, molecules or ions with unpaired electrons on an otherwise open shell configuration. The most important free radicals are: superoxide (O^{2-}), hydroxyl radical (OH^-), nitrous oxide (NO^{2-}), nitric oxide (NO^-), hydrogen (H^+), ossigen (O^+) and singlet oxygen (O^{2+}). These unpaired electrons are usually highly reactive, so radicals are likely to take part in chemical reactions, in a sort of chain reaction mechanism. The targets of the destructive action of free radicals are the cellular components such as membrane lipids, nucleic acids and proteins in humans. Since free radicals are necessary for life, the body has a number of mechanisms to reduce free radical action and to repair damage which does occur, such as the enzymes superoxide dismutase, catalase, glutathione peroxidase *and* glutathione reductase. These endogenous systems need to be supported by antioxidants introduced by diet, as they play a key role in these defence mechanisms. The antioxidants components, such as lycopene and other carotenes are also able to contrast the destructive action of free radicals in the human body and scavenge them to carry out a basic protective and preventive function against various diseases (Levy *et al.,* 1995, Miller *et al.,* 1996, Mortensen and Skibsted, 1997, DiMascio *et al.,* 1989, Stacewicz- Sapuntzakis and Bowen, 2005). Lycopene because of its high number of conjugated dienes, is the most potent singlet oxygen quencher among other carotenoids (DiMascio *et al.,* 1989). Mortensen *et al.,* (1997) reported that ability of carotenoids to scavenge nitrogen dioxide (NO_2^*), thiyl (RS^*) and sulphonyl (RSO_2^*) radicals. Bohm *et al.,* (1995) found that lycopene was almost twice active when compared to β-carotene in protecting lymphocytes from damage influenced by NO_2^* radicals. It is also been detected that the lycopene possess ability to improve cell to cell communication, though comparatively less pronounced than β-carotene or canthaxanthin (Zhang *et al.,* 1991).

Future Thrust

Increasing consumers' demand for healthy food products provides an opportunity to develop lycopene-rich products as new functional foods, as well as food-grade and pharmaceutical-grade lycopene as new nutraceutical products. An industrial-scale, environment friendly lycopene extraction and purification procedure with minimal loss of bioactivity is highly desirable for the food, feed, cosmetic, and pharmaceutical industries.

Conclusion

Lycopene is a powerful antioxidant with numerous useful functions to the experimental research which supports that an awareness of food stuffs containing lycopene is important for our future and health. Lycopene is particularly important because it has dual influence on production and quality as a natural colour and nutrient for the food and pharmaceutical industries. However, the evidence thus far is mainly suggestive, and the underlying mechanisms are not clearly understood. Further research is critical to elucidate the role of lycopene and to formulate guidelines for healthy eating and disease prevention. More information on lycopene bioavailability, however, is needed.

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