International Journal of Plant & Soil Science

33(17): 165-172, 2021; Article no.IJPSS.71682
ISSN: 2320-7035

Assessment of Lycopene Derived Fresh and Processed Tomato Products on Human Diet in Eliminating Health Diseases

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2021/v33i1730561
Editor(s):
(1) Prof. Yong In Kuk, Sunchon National University, South Korea.
Reviewers:
(1) Nihad Abdul-Lateef Ali Kadhim, AL -Qasim Green University .Iraq.
(2) Gyula Oros, Hungarian Academy of Sciences, Hungary.
Complete Peer review History: https://www.sdiarticle4.com/review-history/71682

Review Article

Received 27 May 2021
Accepted 02 August 2021
Published 05 August 2021

ABSTRACT

Tomato which is scientifically known as *Lycopersicon esculentum* and basically belonging to the Solanaceae family is categorized as one of the most essential horticultural crops. The red colour in tomatoes and other fruits is primarily due to the presence of a carotenoid pigment particularly lycopene which acts as a phytochemical. Higher concentrations of lycopene pigment are particularly found in fruits like tomatoes, watermelon, pink grapefruit, pink guava, red bell pepper, sea buckhorn, wolfberry, and rosehip. Lycopene plays a fundamental role in the process of biosynthesis of several carotenoid pigments specifically available in two forms; Hydrocarbon carotenoids and Xanthophylls thereby responsible for imparting red, yellow, and orange color in addition to photosynthesis and photo-protection in terms of plants, algae and other photosynthetic organisms. It acts as a potential antioxidant among the entire carotenoid pigments because of its characteristics involving strong color and anti-toxicity properties. Vitamins enriched beta carotene provitamin A, and Ascorbic acid in the form of edible compounds have been abundantly found in tomatoes. Daily intake of lycopene through consumption of tomato and processed tomato products helps in reducing the risk of chronic diseases particularly cancer and cardiovascular diseases. Epidemiological studies have indicated the importance of lycopene in eliminating the risk of human

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diseases thereby preventing it from deterioration of health. Based on the chemical structure of lycopene, it exists in a thermodynamically stable form thereby exhibiting *trans*-configuration. In this manuscript, major emphasis highlighted in involving an intake of carotenoid enriched fruits and vegetables for further controlling and reducing the risk of occurrence of human diseases has been reviewed. In addition, significance of manufacturing of value added products and its consumption in the form of tomato oil, non-alcoholic flavored drink etc. has also been reviewed. Authentic information in terms of the addition of lycopene in a daily balanced diet either fresh or processed tomato products along with its functions involving the singlet oxygen quenching ability, as well as benefits of consuming lycopene derived fruits has been reviewed in this manuscript.

Keywords: Lycopene; carotenoids; tomatoes; cancer; cardiovascular disease.

1. INTRODUCTION

Lycopersicon esculentum which is commonly known as tomato is a major antioxidant and is rich in lycopene and hence tomatoes are popularly known as a rich source of lycopene. Tomatoes are considered to be a potent horticultural crop that plays a significant role in the human diet. Tomatoes are the second-most consumed vegetables after potatoes as per the research conducted by Rao and Agarwal [1]. Edible compounds enriched with vitamins particularly beta carotene, provitamin A and Ascorbic Acid have been abundantly found in tomatoes [2]. The red colour in some fruits such as tomatoes, watermelons and pink grapefruits are due to the presence of naturally occurring carotenoids [3]. Among the lycopene enriched sources of fruits and vegetables containing watermelon, grapefruits, guava and tomatoes, it is in conformity to consider tomatoes as the richest source of lycopene [4] because of its higher rate of utility and availability throughout the year and as in the research conducted so far, tomatoes have been typically considered to be the predominant source of carotenoids and vitamins [2] particularly beta carotene, pro-vitamin, Ascorbic acid and Vitamin C. Carotenoid pigment particularly lycopene in absence of pro-vitamin has proven to be a potential source of providing beneficial effects in the human health [5,3]. Carotenoids are considerably essential pigments in plant growth and more than 750 carotenoids have been identified and considered as biological substances which are further synthesized by photosynthetic plants, algae, fungi, and bacteria in addition to animals that consume carotenoids [6]. Carotenoids are natural compounds which are specifically responsible for performing two important functions, viz; pigments as accessories in photosynthesis in plant organs and photoprotection thereby allowing molecules to absorb light along with deactivation of single oxygen in addition to free radicals. The aroma in some plant foods is primarily due to the presence of carotenoids [7]. A number of carotenoids moreover possesses pro-vitamin A action and encompass effective antioxidant activity [8]. Carotenoids are divided into the following two categories namely (a) Hydrocarbon carotenoids and (b) Xanthophylls [8] [9]. Hydrocarbons carotenoids such as lycopene are composed entirely of hydrogen and carbon, whereas on the other hand, xanthophylls such as lutein are composed specifically of oxygen along with carbon and hydrogen. Enzymatic cleavage of hydrocarbon carotenoids such as beta carotene and alpha-carotene encourages in the formation of vitamin A. Regular intake of lycopene in varying forms of carotenoid preferably occurring naturally in fruits and vegetables along with addition of food colorants in food are routinely practiced by humans [10,11]. It has been apparently confined that more than 100% of consumption of carotenoid is primarily derived from cooked and processed tomato products rather than fresh tomatoes since the carotenoids are biosynthesized during cooking and moreover, extraction of carotenoids from cooked and processed tomato products are comparatively convenient than fresh tomatoes, which are particularly adulterated with other dietary components. Biosynthesis of carotenoids occurs due to enzyme activation which is further responsible for stimulation of isomerization in addition to oxidative degradation of carotenoids. Most predominant carotenoid present in human plasma is lycopene having the ability of quenching singlet oxygen double as equal to that of beta carotene and ten times more than alpha tocopherol [9,12]. Lycopene is also a phytonutrient and an antioxidant. Among all dietary carotenoids, essential one exhibiting highest antioxidant activity as well as having singlet oxygen quenching ability has been definitely found to be in lycopene which is further responsible for producing variant colours in

diverse group of fruits and vegetables particularly yellow, orange and red colours in squash, pumpkin and tomatoes [13,12]. Apart from containing lycopene in fresh fruits and vegetables, processed tomato products [14] have also proven to be an essential source of lycopene content. The increase in lycopene content in fruits depends on the ripening of fruits as well as species [14]. Maturity on the vine tomatoes consisted with more lycopene content than those matured after picking [15,16]. In terms of classification of lycopene, it is distributed under the category of carotenoid compounds in addition to carotenoids including terpenoids. Hence, lycopene has been also considered as terpenoids. There are several types of terpenoids in tomatoes, one of which is tetrapenoid which is further classified into carotenoids. Based on the lipophilic nature [17] of lycopene and other carotenoid compounds, it is observed to be concentrated in low density lipophilic fractions of serum [18]. Composition of tissue-specific carotenoid particularly lycopene in terms of supplying is of significant importance in functioning as an antioxidant [17]. Oxidative damage to lipids, proteins and DNA [17] by addition of fresh and processed tomato products have been reported by several researchers [19,20,13]. Bioavailability of lycopene is enhanced by the discharge of lycopene [17] commencing from food matrix as a result of processing, existence of dietary lipids in addition to heat-induced isomerisation on or after *trans* to a *cis* conformation [3]. Consumption of lycopene derived fruits and vegetables helps in absorbtion of lycopene from the stomach which is carried in the blood vessels by several types of lipoproteins and is further accumulated in the liver, testes, and adrenal glands. Factors involving mechanical churning, enzyme activation and bile acids are responsible for partial breakdown of carotenoids from the lycopene derived food matrix [21]. It is further converted into the lipid droplets and incorporated into the lipid micelles for absorbtion by enterocytes [22,23]. The bioavailability of lycopene is believed to be strongly exaggerated by the prescribed amount and existences of other carotenoids are similar to beta carotene [17]. While ingestion, bioavailability of lycopene was observed to be significantly higher while it was ingested with beta carotene relatively than ingesting alone [13,21]. In terms of its functions and benefits, it also acts as an inhibiting agent in addition to elimination of carcinogenesis where antioxidant mechanism is responsible for preventing cellular and genetic deterioration to DNA [24]. It also helps in neutralizing free radicals since damage of free radicals is the major cause of promoting heart diseases, premature ageing, cancer, cataracts in addition to prostate cancer. Hence, consumption of fresh and processed tomato products helps in further elimination and lowering the risk of occurrence of health diseases [25]. Improvement in health diseases can be approved by single nucleotide polymorphisms in addition to dietary fat which encourages in more accumulation of lycopene [26]. Keeping in view of the factors concerned and reviewed, it has become essential to get habituated in the daily consumption of lycopene at an appropriate amount either in the form of fresh fruits and vegetables or processed products for further prevention from occurrence of human health diseases.

2. CHEMICAL STRUCTURE OF LYCOPENE

Lycopene is a highly unsaturated compound having a molecular formula of C^{40} and H^{56} with its 11 conjugated double bonds and 2 non-conjugated double bonds [27]. Lycopene exists in a thermodynamically stable form and occurs from the natural plant source which is predominantly in the form of all *trans*-configuration. The chemical structure of lycopene resembles a tetraterpene [3] constructed from eight isoprene units composed entirely of carbon and hydrogen. Unsaturated polyisoprenoid 40 carbon compound of lycopene with 13 double bonds is the most abundant carotenoid consisting of more than 90% of lycopene in matured tomatoes. The colour of lycopene is entirely dependent on its isomeric forms indicating all *trans*-isomers and other isomers represent red color while tetra-*sis*-lycopene possesses an orange color [8]. Predeposition of lycopene with a specifically long chain of conjugated carbon-carbon bonds [19] in terms of isomerization and degradation is primarily because of three factors particularly exposure to light, heat, and oxygen [28] as well as successive loss of its coloring properties [29] which eventually renders tomato extract unproductive as a food color. Human plasma consisting of lycopene [17] is present in an isomeric mixture with 50% as *cis*-isomers [30]. *Cis*-isomer type lycopene is found in human blood plasma breast milk as well as human tissues [31]. Enhancement of the bioavailability of lycopene is due to the discharge of lycopene [17] from food-matrix which is principal as a result of dispensation, the existence of dietary lipids in addition to heat-

induced isomerization from *trans* to a *cis* conformation [3].

3. MANUFACTURING OF VALUE PRODUCTS

Since lycopene is considered to be an individual significant content in human dietary foods, consequently, more researches should be conducted and directed on issues of lycopene production on a commercial scale [4]. The processed foodstuffs of tomato are prepared by crushing tomatoes for producing crude tomato juice which is further separated into serum and pulp [19]. The pulp of the tomatoes is then extracted by means of ethyl acetate as a solvent. Tomato oil which is a final product consisting of lycopene collectively with a number of additional constituents that crop up naturally in tomatoes is eventually dissolved and detached [19]. These constituents include fatty acids and glycerol, unsaponifiable matter, water-soluble matter, phosphorous compounds, and phospholipids. Lycopene content from extracted tomato is utilized as a food color in milk products, non-alcoholic flavored drinks, cereal and cereal products, bread, and baked goods in addition to providing color shades from yellow to red [19]. Lycopene extract in tomatoes is moreover used in food supplements. The content of lycopene supplemented to the food varies from 2mg/l in bottled water to 130mg/kg in readymade cooked cereals [29]. Lycopene extract in tomatoes remains constant at room temperature at 4ºC for up to three years [1]. The objective of coloring pigment in tomatoes is due to the all-*trans*-lycopene whereas on the other hand, the presence of negligible amounts of *cis*-isomers in addition to supplementary carotenoids and related substances including beta-carotene, phytofluene, phytoene, and tocopherols are also present [19]. Depending on the nature of fruit from which it is extracted as well as the tomato seed oil contained in the extract, the lycopene content [19] of tomato extract varies from 5% to 15%. Lycopene that is extracted from tomatoes contains both carotenoids at the rate of 5-15% w/w and non-carotenoid components.

4. CONSUMPTION OF LYCOPENE FROM TOMATO AND TOMATO PRODUCTS

Concentration of lycopene in tomato in addition to tomato products is composed primarily of all-*trans*-lycopene preferably in the range of 30% to 97% and a lower amount of *cis*-lycopene with a concentration of 1-22% [19]. Further, products are also used as antioxidants in food supplements. In fresh tomatoes, the content of lycopene ranges from 920.4 to 141microgram/gram FW [32] and 25 to 2000 microgram/gram FW [14] which is comparatively lower than the values varied from 3110 to 6700 microgram/gram FW [33]. An experiment was conducted for the estimation of lycopene content among tomato varieties particularly Leader and Lindo and had been found that Leader consisted of the highest lycopene content (147.29) microgram/gram and Lindo consisted with the lowest lycopene content (70.25) microgram/ gram [20]. The average Canadian daily dietary intake of lycopene is about 25.2 mg [34]. It was also anticipated that 50% of the lycopene content was derived from fresh tomatoes and the remaining 50% was derived from processed tomato products [16]. Lycopene content present in processed foods is much higher as compared to fresh fruits as the process of processing involves concentration through water loss. Processed tomato products including ketchup contain 9.9 to 13.44 % mg lycopene/100 gm whereas fresh tomatoes include 0.88 to 7.74mg lycopene/100 g wet weight [16]. Depending on the nature of variety, geographic location, techniques of cultivation, climatic conditions, and degree of maturity of tomato fruits, the lycopene content of tomatoes typically varies from 70 to 130 mg/kg [1]. Variation in the redness of several cultivars is generally due to the difference in the concentrations of lycopene accumulated in their skin, and the only carotenoid constituent in the skin is lycopene [20]. Lycopene content in tomato soup [3] and tomato paste is more bioavailable than in fresh tomatoes [35]. Fraction of carotenoid obtained from tomato extract consists largely of lycopene of which 86 % is all-*trans*-lycopene, 6% is 5-*cis* lycopene, 2 % is 9 *cis* lycopene, 2% is 13 *cis* lycopene and 4% are other carotenoids [19]. Table 1 and Fig. 1 clearly shows the concentration of lycopene in diverse tomato products having the following values such as in tomato paste approximately 16 mg/100g, in tomato boiled sauce approximately 4 mg/100g, tomato ketchup 17 mg/100g and spaghetti sauce 16 mg/100g [3].

4.1 Functions of Lycopene

Because of singlet oxygen quenching ability, lycopene is enriched with antioxidant properties [36]. Lycopene has the capacity to oxidizing in both human serum and plants. The major oxidation product in human serum is lycopene 5, 6-epoxide in the reaction with chloroperbenzoic

acid. An experiment was conducted for isolating final hydrolysis products followed by re-arrangement which included epimers of 2, 6 cyclolycopene-1, 5 diol secluded by HPLC on or after human serum [30] [5]. While in flora, the pace for the singlet oxygen quenching ability by lycopene is in second-order and K= 7×10^{-9} M^{-1} S^{-1}[37]. Since lycopene is considered to be a natural coloring substance, it inhibits the occurrence of harmful effects of synthetic food colourants [4] [19]. During the process of ripening of fruits or color development in some leaves (except green) thereby coinciding with the transformation of chloroplasts into chromoplasts, esterification of carotenoids like lycopene takes place with various forms of fatty acids intended for excluding and balancing free radicals of oxygen formed during development [4]. Unsaturated hydrocarbon preferably lycopene plays a major role in the process of photosynthesis. Since chloroplasts are associated in terms of photosynthesis, most of the cell materials are correlated with it. There is a probability of damage through photo-oxidation and hence protection of these cell materials can be done by self esterification of carotenoids like lycopene [19]. The precursor of vitamin A is lycopene. It is an aliphatic hydrocarbon with 11 conjugated double carbon-carbon bonds [38]. Being acyclic in nature, lycopene possesses symmetrical planarity. When these structures undergo certain biochemical reactions [4], it forms pro-vitamin A which is further converted into vitamins. Some of the critical *in vivo* biological processes like expansion and enlargement control in terms of growth, cell to cell contact as well as modulating hormones [4] become beneficial due to the presence of lycopene [32]. Through lycopene content, treatment of cancer without the aid of chemotherapy can be done. It has been justified by conducting experiments especially on rats, rabbits and human tumor cells it has been found that due to the presence of lycopene, uncontrollable growth of cells could be inhibited. In human cells, a type of cancer such as Leukemia is difficult to cure but it can be treated at a very early stage with the help of lycopene. There are also various types of cancers such as prostate, pancreas, stomach cancers, which could be treated through the proper utilization of lycopene.

Table1. Lycopene content (mg/100 g) in tomatoes and several products of tomatoes [42]

Product	Lycopene (mg/100 g)	
	472nm	**502 nm**
Fresh tomato	1258	1234
Tomato paste	1565	1583
Tomato boiled sauce	432	392
Tomato ketchup	1712	1700
Spaghetti sauce	1592	1615

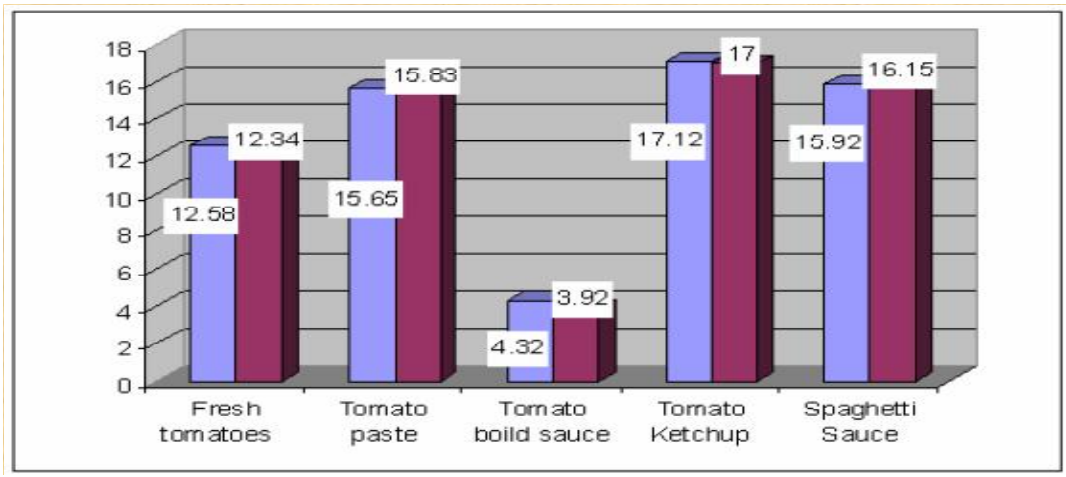

Fig. 1. Lycopene content in tomatoes and tomato products [42]

4.2 Benefits of Lycopene

Lycopene, while interacts by means of supplementary food components, provides additive or nutritious effects. The essential characteristic of lycopene study is the bioavailability of this compound as well as its metabolism toward derivative which may furthermore show signs of natural procedures contributing to its prospective cancer-preventing properties [4]. Lycopene is a phytonutrient in addition to an antioxidant which is accountable for the deep red color of matured tomatoes as well as their products [18]. It plays a major role in healthy human wellbeing, thereby dropping the threat of unceasing diseases [39]. Lycopene is a chief carotenoid lacking pro-vitamin activity [40] which is copiously present in tomatoes as well as is responsible intended for their beneficial effects [8]. The capability of lycopene to perform as an effective antioxidant is in consideration to be responsibly designed for defending cells against oxidative damage leading to diminishing the threat of persistent diseases [3]. Due to the presence of antioxidant activity in addition to potential in alleviating persistent diseases such as cancer along with heart diseases [32], the importance of adding lycopene has been increasing gradually. It is literally said that consumption of tomato and tomato products definitely helps in improving human health due to its distinct characteristics such as antioxidant and anti-carcinogenic activities at cellular levels. Therefore more emphasis should be given to gradually increasing the consumption of naturally occurring carotenoid-rich fruits and vegetables, particularly processed tomato products containing lycopene which is in direct correlation with improving human health and disease. On the basis of epidemiological studies indicating the reduction of risk of several types of cancers, increasing the content of lycopene through the dietary intake of tomato and tomato products have become beneficial to an extent [39]. High consumption of lycopene containing products such as tomato helps in encouraging protective effects such as digestive tract cancers [15] and a 50% lessening in fatality rate [17] from cancers in aged inhabitants from US citizens [39]. Higher the intake of lycopene content by the human population more would be the reduction in risk of prostate cancer. Capsules containing oleoresin which is considered as a supplement of tomato extract lowers the levels of prostate specific antigen [17] in patients with prostate cancer [20]. The utilization of tomatoes along with tomato products [28] containing lycopene reduces the possibility of cardiovascular diseases. Heart diseases and asthma in humans could be reduced by encouraging the consumption of lycopene containing foods such as tomato and tomato products [20,41]. The Mediterranean diets loaded with vegetables as well as fruits, together with tomatoes have been recommended to be dependable for the minor cancer rates in the area [17] [34].

5. CONCLUSION

Lycopene exists in a thermodynamically stable form and occurs from the natural plant source which is predominantly in the form of all-*trans*-configuration. Since tomato and tomato products have been considered as an important source of lycopene, therefore additional information is obligatory towards decisively establishing lycopene's function in wellbeing fortification in addition to identifying fundamental biochemical mechanisms. In this manuscript, using up of naturally occurring carotenoids enriched fruits and vegetables mainly processed tomato products containing lycopene has been encouraged for reducing the risk of health diseases has been reviewed. The current dietary recommendations to augment the utilization of fruits and vegetables rich in antioxidants have generated curiosity in the responsibility of lycopene in ailment hindrance. A supplementary investigation is encouraged in the direction of understanding the function of lycopene as well as composing a strategy intended for healthy consumption along with disease prevention.

ACKNOWLEDGEMENT

Authors highly acknowledge their gratitude to 'Google Search' for providing authentic information for preparation and writing of the manuscript. Authors are further thankful to the anonymous reviewer(s) and the editor of this article for their critical comments and suggestions on the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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