Wydawnictwo UR 2021
ISSN 2544-1361 (online); ISSN 2544-2406
doi: 10.15584/ejcem.2021.2.8

http://www.ejcem.ur.edu.pl/en/
European Journal of Clinical and Experimental Medicine
Eur J Clin Exp Med 2021; 19 (2): 170–173

REVIEW PAPER

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Natural properties of lycopene and its application in medicine

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ABSTRACT

Introduction. The subject of the article is a chemical compound belonging to the carotenoid family, i.e. lycopene.

Aim. The aim of this study was to describe interest among scientists regarding lycopene due to its unique properties, general availability and potential for wide application in medicine.

Material and methods. This article is a review in which the properties of lycopene, its chemical structure and sources (especially in the form of tomato fruits and its products), as well as its important role and importance in medicine, is presented.

Analysis of the literature. Lycopene is an interesting compound with interesting properties. It may prove to be an important and readily available means of preventing and fighting cancer (especially prostate cancer, uterine cancer and breast cancer). Additionally, lycopene can counteract cardiovascular diseases that are common nowadays.

Conclusion. The data indicates increased number of papers regarding applications of lycopene in medicine.

Keywords. carotenoid, lycopene, medicine

Introduction

Lycopene is a chemical compound from the carotene group, belonging to the carotenoid family. Due to its belonging to this family and its characteristic intense red color, it is often used as a dye in food products under the name E160d. It is not synthesized by the human body, therefore it must be taken with food.

Due to the fact that lycopene is a natural dye found in plants, it is found in fruits and vegetables that are available and eagerly eaten every day, especially those with a red color. We can find it in vegetables and fruits such as pepper, watermelon, pink grapefruit, peach, papaya tree, guava, strawberry, papaya, or rosehip.[1,2] However, tomatoes are a particularly rich source of lycopene. Its content changes during the ripening of tomato fruits and depends on the growing conditions and the microclimate (mainly temperature and sunlight). In addition, sun-ripened tomatoes are the richest in lycopene, not greenhouse tomatoes or tomatoes.[1-3] According to Clinton, the content of lycopene, depending on the variety and ripeness of tomatoes, ranges from 0.9 to 4.2 mg/100g.[4] On the other hand, McClain and Baush report that in yellow tomatoes lycopene is about 0.5 mg/100g, and in intensely red tomatoes it can be even ten times more - 5 mg/100g.[3-5]

In addition to the (total) absolute lycopene content of the raw or processed raw material, its bioavailability

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Participation of co-authors: A – Author of the concept and objectives of paper; B – collection of data; C – implementation of research; D – elaborate, analysis and interpretation of data; E – statistical analysis; F – preparation of a manuscript; G – working out the literature; H – obtaining funds

Received: 27.03.2021 | Accepted: 30.04.2021
Publication date: June 2021

Sowińska M. *Natural properties of lycopene and its application in medicine*. Eur J Clin Exp Med. 2021;19(2):170–173. doi: 10.15584/ejcem.2021.2.8.

is also important. Lycopene is found mainly under the skin of tomatoes, and the process of grinding and cooking them causes the release of lycopene. Moreover, under the influence of temperature, lycopene in tomatoes or its products is transformed into the form of trans-lycopene, where it is more efficiently absorbed from the gastrointestinal tract, which is related to its better solubility in fats in this form.[6]

Aim

The aim of this study was to presents the natural properties of lycopene and its application in medicine

Material and methods

Literature search was done to identify appropriate methodology and design of the study. The search of literature was helpful to mark the map of interest.

Analysis of the literature

The processing of tomatoes generates large amounts of by-products (mainly seeds and skins), which until recently were only additives for livestock feed. The by-products of tomato processing, however, turned out to be an important source of lycopene. Lycopene obtained from the remains of tomatoes is used as a supplement in the production of functional food.[7]

Synthetic lycopene is also available. It is a mixture of geometric isomers of lycopene (double bonds of trans configuration) and is obtained by condensation of synthetic intermediates, commonly used in the production of other carotenoids used in food. Due to the inability to obtain crystalline lycopene in an aqueous solution and its high susceptibility to the negative effects of light and oxygen, it is not suitable for industrial purposes. Only properly transformed material is placed on the market and intended for consumption. Additionally, attempts are still being made to produce lycopene with the participation of Mycobacterium aurum bacteria, which are classified as non-pathogenic microorganisms *Blakeslea trispora*.[8]

Lycopene is an unsaturated hydrocarbon containing forty carbon atoms in the molecule of the formula C40H56. It owes its intense red color to the chromophore system, which strongly absorbs radiation in the visible light range with a wavelength of $\lambda = 444$, 470 and 502 nm.[9]

This compound, as an unsaturated polyene hydrocarbon, is composed of eight isoprene residues (having five carbon atoms). In total, the isprene residues form a carbon chain of forty carbon atoms containing two unconjugated and eleven conjugated double bonds. This makes seventy-two geometric isomers of lycopene possible. Both lycopene ion rings are open, so this compound does not have the properties of β-carotene (provitamin A).

Lycopene is the main carotenoid, which (unlike β-carotene), when absorbed in the intestine, is not converted to retinol, nor is it (unlike other carotenoids) a substrate for cyclin-dependent dioxygenase.[10]

The double bonds in lycopene can be isomerized from the all-trans position to the mono- or poly-cis isomers by exposure to light, heating, or chemical reactions. The presence of many conjugated double bonds makes lycopene distinguishable among carotenoids with the strongest antioxidant properties and participates in the creation of an antioxidant barrier in living organisms. It neutralizes free radicals more effectively than β-carotene, α-tocopherol or lutein. Additionally, it has been shown that lycopene not only neutralizes free radicals, but also has the ability to regenerate other antioxidants.[11]

Lycopene tends to accumulate in cell membranes, which increases their fluidity and permeability, which indirectly modifies the antioxidant response pathways in the cell. Moreover, lycopene, being an effective scavenger of free radicals, protects lipids of cell membranes against their oxidation and degradation (i.e. lipid peroxidation).

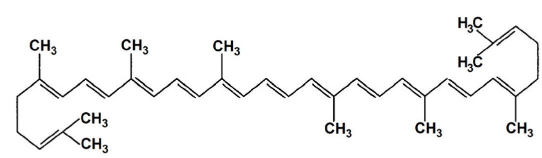

Fig. 1. Lycopene structure

The structure of lycopene carries properties that are used in many areas, including in cosmetics (cosmetics for skin and hair care), food production (improving the color of dishes), or in medicine (where the properties and applications will be described in more detail). Scientists emphasize the antioxidant properties of lycopene in particular. Antioxidation consists in neutralizing the action of harmful compounds formed during all metabolic processes in the body. These compounds are called free radicals.[12]

Free radicals are groups of atoms or molecules containing one or more unpaired electrons on the last shell, which makes them unstable and very reactive.[13] In addition, they are dangerous for the body because they cause an avalanche of new radicals which, striving for a stable electronic system, react with various cells and damage their structures, thus disrupting their functions. As a consequence, it leads to changes in the genetic material and the occurrence of pathological conditions.

Lycopene belongs to the group of carotenoids, which are characterized by strong antioxidant properties, however, the antioxidant activity of lycopene is three times higher compared to other carotenoids. Due to the presence of conjugated double bonds, lycopene reacts extremely efficiently with atomic oxygen and reactive oxygen species. The active forms of oxygen include both free radicals, e.g. superoxide anion ($O_2^{\bullet -}$), hydroperoxide radical ($HO_2^{\bullet}$), hydroxyl radical ($OH^{\bullet}$) and singlet oxygen ($^1O_2$), ozone (O_3), and hydrogen peroxide (H_2O_2). Many conjugated double bonds in the lycopene molecule make it participate in the creation of the antioxidant barrier of the human body and show a protective effect against the genetic material.[16]

Lycopene, as an exceptionally effective free radical scavenger, also plays a particularly important role in the prevention and prevention of civilization diseases, including reducing the risk of cardiovascular diseases. The etiology of most cardiovascular diseases is primarily associated with the process of atherosclerotic changes. Its essence is the deposition of atherosclerotic plaque on the walls of arteries, which leads to narrowing of blood vessels and many diseases. Plaque formation is a complex and lengthy process in which low-density lipoproteins (LDL) play an important role. They penetrate into the arterial endothelium and undergo gradual oxidation Frequent consumption of lycopene, and thus a higher concentration of this compound in the blood, prevents the oxidation of the LDL cholesterol fraction and lowers its overall level, thus reducing the risk of developing cardiovascular diseases.

The antioxidant properties of lycopene also contribute to reducing the risk of senile cataracts, autoimmune and neurodegenerative diseases, infertility, rheumatoid arthritis and carcinogenesis, which is associated with the anti-cancer and anti-inflammatory properties of lycopene.[18-20]

Reducing the frequency of carcinogenesis by using the addition of lycopene (scavenger of free radicals, reactive oxygen species) results from the reduction of the size of the formation efficiency of cancer-causing substances and the inhibition of unnatural cell division in the body of humans and animals.[21]

In developed countries, cancer is now becoming the leading cause of premature death. Therefore, methods of preventive disease prevention are still being sought. Based on epidemiological studies, food producers are increasingly using raw materials of plant origin containing substances that prevent the formation of cancer. One of the substances of plant origin with this effect is lycopene.[22]

Prostate cancer is the second most common cancer diagnosed in men worldwide and is the sixth most common cause of cancer death. Risk factors that influence the development of prostate cancer include age, race, genetics, obesity, and diet. Perhaps an additional factor leading to the development of this disease is a mutation in the genes that control cell differentiation and growth. Moreover, the chronic inflammatory process in bacterial prostatitis can lead to the formation of oxygen free radicals, which results in DNA damage and mutation formation, as is the case with exogenous mutagenic factors. Studies conducted on men indicate a relationship between the content of lycopene in the serum and the incidence of prostate cancer. Those of the respondents whose consumption of lycopene was at the level of about 33 mg/day showed half the risk of developing prostate cancer compared to the group that consumed much less of it, within 13 mg/day. The results of clinical trials also suggest that supplementation with lycopene 15-30 mg/day reduces the incidence of benign prostatic hyperplasia and prostate cancer.[23] Lycopene may inhibit the growth of lung and kidney cancer cells.[24]

A similar relationship can be observed in studies on the incidence of breast cancer, ovarian cancer and endometrial cancer in women. Women with the highest serum lycopene levels (0.59-1.58 g/dL) had an 85% reduced risk of developing endometrial cancer compared with patients with serum lycopene levels 0.36-0.51 g/dL. In addition, lycopene used during radiotherapy of women with breast cancer has a protective effect and reduces the side effects of irradiation within the irradiated skin.

Lycopene, being an effective scavenger of free radicals, also inhibits the aging process of the skin, increases resistance to solar radiation, which is manifested by less reddening of the skin during sunbathing. Lycopene added to the diet protects human skin against UVA and UVB rays (i.e. rays that generate free radicals). Therefore, it reduces the frequency of skin melanoma.[25]

The health-promoting properties of lycopene can be used both in the prevention and treatment of cardiovascular diseases.[26] The blood LDL-lowering properties of lycopene have been shown to inhibit the atherosclerotic process in the arteries.

Supplementation with 60 mg of lycopene daily for 3 months leads to a reduction in LDL levels by 14% In addition, lycopene helps maintain normal blood pressure values, and its effect is greater in the group of subjects with systolic blood pressure values above 140 mm Hg Additionally, consuming lycopene above 12 mg/day lowers systolic blood pressure by an average of 4.95 mm Hg which partially prevents the progression of arterial hypertension.[27,28]

Conclusion

Lycopene is an interesting compound with interesting properties. It may prove to be an important and readily available means of preventing and fighting cancer (especially prostate cancer, uterine cancer and breast cancer). Additionally, lycopene can counteract cardiovascular diseases that are common nowadays. Increased interest in lycopene and its properties in use may contribute to the improvement of the quality of life of people in society in the field of civilization diseases, and further exploration of knowledge and research on it may be beneficial for the field of medicine.

References

1. Qu Y, Su A, Li Y, Meng Y, Chen Z. Manipulation of the Regulatory Genes Rhodobacter sphaeroides Enhances Lycopene Production. *J Agric Food Chem.* 2021;69(14):4134-4143.
2. McTiernan A. Dietary prevention of breast cancer in high-risk women: role of carotenoids. *Am J Clin Nutr.* 2021;113(3):499-500.
3. Xie Z, Yang F. The effects of lycopene supplementation on serum insulin-like growth factor 1 (IGF-1) levels and cardiovascular disease: A dose-response meta-analysis of clinical trials. *Complement Ther Med.* 202156:102632.
4. Gopinath H, Karthikeyan K, Meghana V. For the love of color: Plant colors and the dermatologist. *Indian J Dermatol Venereol Leprol.* 202086(6):622-629.
5. Dumont D, Danielato G, Chastellier A, et al. Multi-Targeted Metabolic Profiling of Carotenoids, Phenolic Compounds and Primary Metabolites in Goji Lycium.) Berry and Tomato Solanum lycopersicum Reveals Inter and Intra Genus Biomarkers. *Metabolites.* 2020;10(10):422.
6. Wise LA, Wesselink AK, Bethea TN, et al. Intake of Lycopene and other Carotenoids and Incidence of Uterine Leiomyomata: A Prospective Ultrasound Study. *J Acad Nutr Diet.* 2021 121(1):92-104.
7. Vats S, Bansal R, Rana N, et al. Unexplored nutritive potential of tomato to combat global malnutrition. *Crit Rev Food Sci Nutr.* 2020:1-32.
8. Zhu K, Zheng X, Ye J, et al. Building the Synthetic Biology Toolbox with Enzyme Variants to Expand Opportunities for Biofortification of Provitamin A and Other Health-Promoting Carotenoids. *J Agric Food Chem.* 2020;68(43):12048-12057.
9. Li N, Wu X, Zhuang W, et al. Tomato and lycopene and multiple health outcomes: Umbrella review. *Food Chem.* 2021;343:128396.
10. Sakemi Y, Sato K, Hara K, Honda M, Shindo K. Biological Activities of Z-Lycopenes Contained in Food. *J Oleo Sci.* 2020;69(11):1509-1516.
11. Wang J, Huang C, Guo K, et al. Converting Escherichia coli MG1655 into a chemical overproducer through inactivating defense system against exogenous DNA. *Synth Syst Biotechnol.* 2020;5(4):333-342.
12. Kumari GUWUP, Gunathilake KDPP. In vitro bioaccessibility and antioxidant activity of black plum (Syzygium caryophyllatum). *J Food Biochem.* 2020;44(12):e13499.
13. Zhao Y, Ma DX, Wang HG, et al. Lycopene Prevents DEHP-Induced Liver Lipid Metabolism Disorder by Inhibiting the HIF-1α-Induced PPARα/PPARγ/FXR/LXR System. *J Agric Food Chem.* 2020;68(41):11468-11479.
14. Loayza FE, Brecht JK, Simonne AH, et al. A brief hot-water treatment alleviates chilling injury symptoms in fresh tomatoes. *J Sci Food Agric.* 2021;101(1):54-64.
15. Ali A, Saliem S, Abdulkareem A, Radhi H, Gul S. Evaluation of the efficacy of lycopene gel compared with minocycline hydrochloride microspheres as an adjunct to nonsurgical periodontal treatment: A randomised clinical trial. *J Dent Sci.* 2021;16(2):691-699.
16. van Steenwijk HP, Bast A, de Boer A. The Role of Circulating Lycopene in Low-Grade Chronic Inflammation: A Systematic Review of the Literature. *Molecules.* 2020;25(19):4378.
17. Gupta N, Kalaskar A, Kalaskar R. Efficacy of lycopene in management of Oral Submucous Fibrosis- A systematic review and meta-analysis. *J Oral Biol Craniofac Res.* 2020;10(4):690-697.
18. Grabowska M, Wawrzyniak D, Rolle K, Chomczyński P, Oziewicz S, Jurga S, Barciszewski J. Let food be your medicine: nutraceutical properties of lycopene. *Food Funct.* 2019;10(6):3090-3102.
19. Bacanli M, Başaran N, Başaran AA. Lycopene: Is it Beneficial to Human Health as an Antioxidant? *Turk J Pharm Sci.* 2017;14(3):311-318.
20. Kelkel M, Schumacher M, Dicato M, Diederich M. Antioxidant and anti-proliferative properties of lycopene. *Free Radic Res.* 2011;45(8):925-40.
21. Zhai LL, Tang ZG. Lycopene improves sperm motility and morphology: a promising agent for treating male infertility. *Eur J Nutr.* 2020;59(2):835-836.
22. Williams EA, Pacey A. Reply to the letter: Lycopene improves sperm motility and morphology: a promising agent for treating male infertility. *Eur J Nutr.* 2020;59(2):837.
23. Saini RK, Rengasamy KRR, Mahomoodally FM, Keum YS. Protective effects of lycopene in cancer, cardiovascular, and neurodegenerative diseases: An update on epidemiological and mechanistic perspectives. *Pharmacol Res.* 2020 May;155:104730.
24. Pogoda K, Pucka M, Tabarkiewicz J, et al. Lycopene activity on lung and kidney cancer cells by T2 relaxation time ^{1}H Magnetic Resonance Imaging in vitro. *Eur J Clin Exp Med.* 2020;18 (1):5–9.
25. Steiner AZ, Hansen KR, Barnhart KT, et al. Reproductive Medicine Network. The effect of antioxidants on male factor infertility: the Males, Antioxidants, and Infertility (MOXI) randomized clinical trial. *Fertil Steril.* 2020;113(3):552-560.e3.
26. Cheng HM, Koutsidis G, Lodge JK, Ashor A, Siervo M, Lara J. Tomato and lycopene supplementation and cardiovascular risk factors: A systematic review and meta-analysis. *Atherosclerosis.* 2017;257:100-108.
27. Palozza P, Catalano A, Simone RE, Mele MC, Cittadini A. Effect of lycopene and tomato products on cholesterol metabolism. *Ann Nutr Metab.* 2012;61(2):126-34.
28. Cuevas-Ramos D, Almeda-Valdés P, Chávez-Manzanera E, et al. Effect of tomato consumption on high-density lipoprotein cholesterol level: a randomized, single-blinded, controlled clinical trial. *Diabetes Metab Syndr Obes.* 2013;6:263-73.