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# Lycopene: antioxidant properties and medical applications. A review of the literature

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## ABSTRACT

In recent years, lycopene and its effects on the body have become a popular topic for research due to the distinctive anti-inflammatory properties of this compound. This study presents a review of the literature related to the biological role of lycopene and its possible application in healthcare. Carotenoids are potent antioxidants. Among them is lycopene, which has the highest concentration in the human body. Antioxidants have a positive impact on health and play a protective role in many non-communicable diseases. Lycopene has remarkable antioxidant properties, which result in its potential protective use in numerous chronic diseases. It contributes to the prevention and supportive treatment of cancers and cardiovascular diseases. It influences the regulation of metabolic processes related to carbohydrate metabolism. Examples of them are type II diabetes and insulin resistance. It shows beneficial effects in depressive disorders. It also positively affects skin health, which is especially evident in the areas of photoprotection, anti-aging, and acne treatment.

**Keywords:** lycopene, antioxidant, carotenoids, tomato products.

## 1. INTRODUCTION

Lycopene is a red pigment from the carotenoid group. It is known for its antioxidant properties and ability to neutralize free radicals. Carotenoids are lipophilic compounds. They contain forty carbon atoms in their molecules. They occur naturally in a variety of edible plants, where they contribute to pigmentation ranging from yellow and orange to red and pink tones (Krinsky and Johnson, 2005). The chemical formula of lycopene is C40H56. The sequence of connected double bonds enables extensive isomerization, with up to 1,056 theoretical cis-trans isomer forms. Multiple isomers are found in nature, among which the all-trans configuration is the most prevalent. According to Zechmeister (1944), the 5-cis lycopene isomer is considered the most stable.

The bioavailability and content of lycopene depend on several factors. The main ones are food processing and diet composition. Improper storage (contact with light and air) of food containing lycopene can lead to the complete breakdown of this carotenoid (Xianquan et al., 2005).

Consuming lycopene together with fatty substances leads to a notable improvement in its absorption. That is because this carotenoid is fat-soluble and insoluble in water. Lycopene absorption is greater when individuals consume it with a fat-rich meal (Brown et al., 2004).

Among all carotenoids, lycopene occurs in the highest concentration in blood serum and various body tissues. It is considered the most effective carotenoid in neutralizing singlet oxygen and scavenging superoxide radicals. Researchers have suggested this function as one of the possible explanations for the health-promoting properties attributed to lycopene (Story et al., 2010).

The imbalance between the production of free radicals and reactive metabolites (oxidants) or reactive oxygen species, and the protective mechanisms that eliminate these harmful molecules, leads to oxidative stress. This imbalance leads to damage at the molecular and cellular levels, thus resulting in a negative impact on the entire human body (Reuter et al., 2010). Free radicals and oxidative stress are involved in the development of numerous long-term, lifestyle-related illnesses, and neurodegenerative diseases (Chaudhary et al., 2023). They also damage the vascular endothelium and promote inflammation. They are considered one of the causes of atherosclerosis and hypertension (Lakshmi et al., 2009). Free radicals promote tumor initiation, proliferation, and progression (Dreher and Junod, 1996). They can also be responsible for the occurrence of acne (Chernyshova et al., 2019).

Lycopene and other antioxidants contribute to both the prevention and management of cardiovascular disease, cancer, and metabolic disorders in which free radicals play a harmful role, as outlined in this review.

## 2. REVIEW METHODS

This work is based on an analysis of materials obtained from the PubMed scientific database. We selected relevant publications using keywords such as: lycopene, lycopene in medicine, lycopene in diseases. This review includes clinical studies, meta-analyses, and systematic reviews of the antioxidative properties of lycopene. We selected studies that specifically refer to the clinical use of lycopene, particularly concerning its antioxidative effects. The article screening process adhered to the PRISMA guidelines (Figure 1).

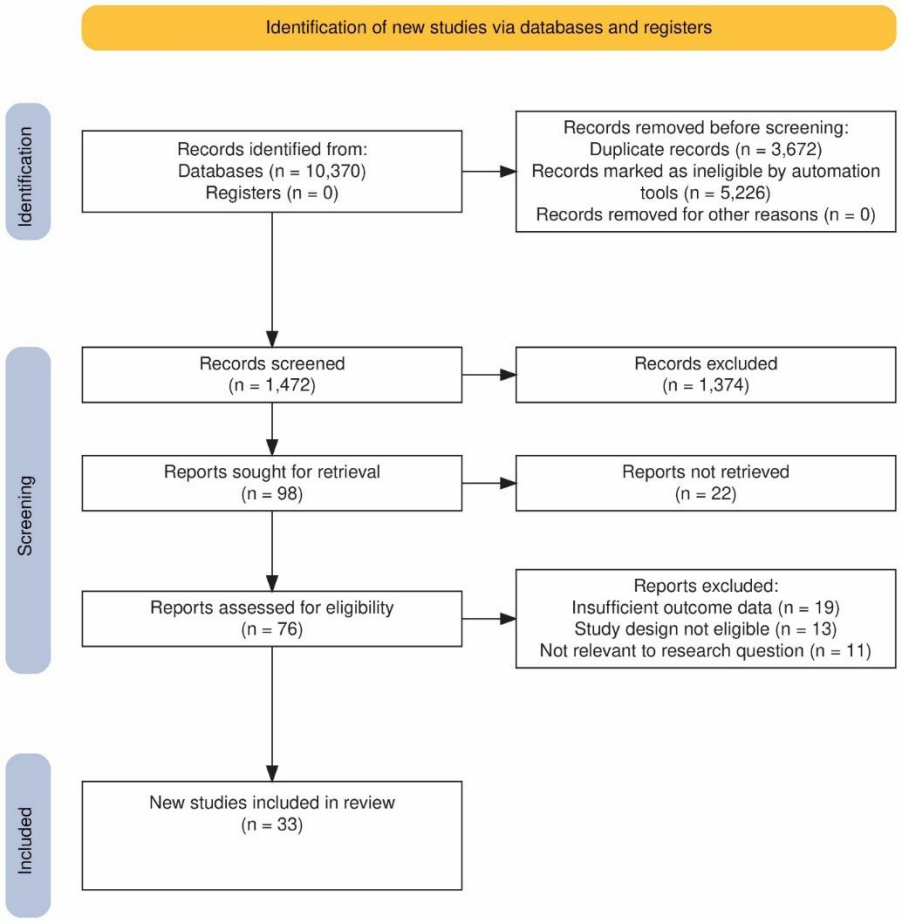


**Figure 1**: PRISMA flow diagram.

## 3. RESULTS AND DISCUSSION

Lycopene is notably effective in eradicating free radicals and has a wide range of health benefits. Current research supports further investigation into its clinical applications.

**Lycopene and cardiovascular diseases**

Dysfunction of the vascular endothelium leads to the development of cardiovascular diseases. It can lead to atherosclerosis. When the number of produced reactive oxygen species exceeds the amount of antioxidants in the organism, the bioavailability of nitric oxide in epithelial cells decreases. Nitric oxide is a vasodilator. Its reduced concentration leads to vasoconstriction and endothelial dysfunction. Oxidative stress is one of the most significant causes that leads to the development of vascular endothelial dysfunction. This dysfunction can ultimately lead to atherosclerosis (Lakshmi et al., 2009; Incalza et al., 2018). A study involving overweight women demonstrated that drinking tomato juice (which contains lycopene) lowers oxidative stress levels, which will therefore reduce the risk of cardiovascular diseases (Ghavipour et al., 2015).

The level of individual lipoproteins also has a crucial impact on the progression of atherosclerosis. Numerous studies have documented the positive effects of high-density lipoproteins (HDL) on the vascular endothelium. They are protecting vessels against the development of atherosclerotic plaque. HDL transports cholesterol to the liver via reverse cholesterol transport, where it serves as the primary substrate for the production of bile salts. This mechanism prevents excessive cholesterol accumulation, which could lead to harmful effects (Bandeali and Farmer, 2012). Researchers conducted a study to examine the relationship between tomato consumption (one of the richest dietary sources of lycopene) and serum HDL levels. The study group consumed two tomatoes daily. A significant increase in serum HDL concentration was recorded in the group consuming tomatoes, while the group without tomato intake showed no such improvement during the same period. Intake of tomatoes high in lycopene had a beneficial effect on HDL levels in the study group. This phenomenon is associated with anti-atherosclerotic benefits, contributing to the protection of vascular health (Cuevas-Ramos et al., 2013).

Lycopene plays a protective role in the development of cardiovascular diseases. In two ways: through directly reducing oxidative stress levels and indirectly by increasing HDL levels (Ghavipour et al., 2015; Cuevas-Ramos et al., 2013).

**Lycopene and Cancer**

Free radicals contribute to the initiation of cancer due to their high chemical reactivity. Cancer develops when DNA damage and mutations cause uncontrolled cell division. Chronic inflammation in tissues causes inflammatory cells to release large amounts of reactive oxygen molecules. These include macrophages and neutrophils. As a result, these molecules accumulate, leading to DNA damage. Thus, evidence suggests a link between chronic inflammation and an increased risk of cancer development (Reuter et al., 2010).

**Prostate cancer**

Lycopene consumption has demonstrated a lowering effect on the likelihood of prostate cancer. The results of the meta-analysis showed that higher consumption of products with high lycopene content correlates with a lower risk of prostate cancer, with a statistically significant reduction in risk when consuming at least 27 milligrams of lycopene per day. Additionally, elevated serum lycopene levels were associated with reduced prostate cancer risk. Studies with follow-up periods exceeding ten years particularly demonstrate the protective effect of lycopene mentioned above. The authors underline that both a lycopene-rich diet and long-term supplementation may significantly help to reduce the likelihood of prostate cancer formation (Chen et al., 2015).

**Breast cancer**

Lycopene exerts anticancer effects against breast cancer, especially triple-negative breast cancer. It inhibits the growth of cancer cells and their spread to other parts of the body. Lycopene also induces the apoptosis of cancer cells. This mechanism involves, among others, inhibition of the pathway (PI3K/Akt/mTOR), activation of ERK1/2, and reduction of cyclin D1 levels. It increases the expression of proapoptotic proteins such as Bax. A diet rich in lycopene may, therefore, have a protective effect against breast cancer formation (Prabhu et al., 2024). In studies on MCF-7 cells, lycopene reduced cell viability in a dose- and exposure-time-dependent manner. It reduces the expression of estrogen receptors (ERα). They may be valid in hormonally dependent breast cancers. The findings mentioned above suggest the potential usage of lycopene as an adjuvant agent in breast cancer treatment (Takeshima et al., 2014).

**Lycopene and depression**

Studies show that patients with depression often have a disrupted balance between oxidative processes and antioxidant defenses. The action of antioxidative enzymes decreases, resulting in increased oxidative stress.

Literature shows that more frequent intake of tomatoes and tomato-based products (which are rich in lycopene) is strongly related to a reduced risk of depressive symptoms in older adults. The analysis showed that people who ate tomatoes at least once a day were significantly less likely to develop depression than those who ate them less than once a week. As a potent antioxidant, lycopene can have a positive effect on mental health by reducing oxidative stress. Low lycopene intake can potentially contribute to an increased risk of the development of depression. This association was independent of additional variables, such as age, gender, health status, and lifestyle (Niu et al., 2013).

**Lycopene and metabolic diseases**

Cellular imbalance and immune-related reactions may contribute to both the onset and progression of metabolic diseases. Long-term inflammation may be a promoting factor in many metabolic disturbances. This finding makes the intake of lycopene a significant target for interventions that aim to prevent and treat these conditions. The impact of a diet rich in antioxidant compounds is an essential target of research on the prevention of metabolic disease development (Shi et al., 2011). Oxidative stress present in metabolic diseases is linked, among other factors, to obesity. Adiposity can both contribute to and result from it (Manna et al., 2015).

Within the group of patients suffering from metabolic syndrome, those with elevated serum lycopene levels showed longer median survival times. This finding suggests that higher serum lycopene concentrations may reduce mortality risk among patients with metabolic syndrome (Han et al., 2016). In a study involving twenty-seven participants, twelve had metabolic syndrome. Fifteen participants consumed tomato juice four times a week for two months. Before and after this time, they took measurements of inflammation markers, insulin resistance, and endothelial dysfunction.

Researchers observed significant improvements in inflammation markers and endothelial function in the intervention group. The control group did not exhibit the changes mentioned above. What is more, insulin resistance improved, accompanied by a marked decrease in low-density lipoproteins (LDL) cholesterol levels and a minor increase in HDL cholesterol levels. These results indicate a favorable shift in the tested lipid profiles (Tsitsimpikou et al., 2014).

Research involving mice with type II diabetes showed that lycopene significantly decreased inflammation and cell death in pancreatic islets. Lycopene restored the balance between pro-inflammatory M1 macrophages and anti-inflammatory M2 macrophages, which led to the observed effect.

**Lycopene and skin health**

Covering the entire body, the skin is the most extensive organ. It creates a barrier between the internal and external environment, continuously defending us from oxidizing agents, both endogenous and exogenous. Chronic exposure of the skin to damaging factors, including ultraviolet (UV) radiation, contributes to the development of skin diseases, such as melanomas. It also significantly accelerates the appearance of premature aging signs (Briganti and Picardo, 2003).

Lycopene functions in the skin as a potent antioxidant. It protects the skin from free radicals generated by UV radiation as well as other external factors. This activity helps maintain healthy skin structure, slows down the aging process, and reduces oxidative stress (Franco et al., 2021).

A randomized crossover trial evaluated the impact of food enriched with lycopene on antioxidant activity and morphological features of facial skin in healthy volunteers. Daily portions of lycopene-enriched ice cream, containing 7 milligrams of lycopene per day, were used in the intervention group. After the intervention period, both the lycopene-treated group and the placebo group underwent serum analyses.

The results showed a significant increase in lycopene levels in the serum and the skin of participants consuming the lycopene-enriched ice cream, accompanied by a decrease in serum oxidative stress markers and no changes in the stratum corneum of facial skin. Table 1 summarizes selected medical applications, mechanisms of action, and health benefits of lycopene.

**Table 1**. Medical applications and health benefits of lycopene.

| Area of Application | Mechanism of Action | Health Benefit |
|---|---|---|
| Cardiovascular diseases | Reduction of oxidative stress; Increase in HDL cholesterol levels | Improvement of endothelial function; Anti-atherosclerotic effects |
| Cancer - Prostate | Antioxidant activity; Decrease in DNA damage | Lower risk of prostate cancer; Protective effect with long-term intake |
| Cancer – Breast | Inhibition of cell proliferation and invasion; Modulation of hormone receptor expression | Potential protective role against breast cancer; Supportive effect in hormone-related types |
| Depression | Reduction of oxidative stress | Lower prevalence of depressive symptoms in older adults |
| Metabolic diseases | Anti-inflammatory activity; Improvement of endothelial function; Macrophage polarization | Improved lipid profile; Decreased insulin resistance |
| Type 2 diabetes | Inhibition of TLR4/MyD88/NF-κB signaling pathway; Protection of pancreatic islets | Enhanced insulin secretion; Lower fasting glucose levels |
| Skin health | Neutralization of free radicals; Protection against UV-induced oxidative damage | Anti-aging effects; Anti-acne properties |

## 4. CONCLUSION

Lycopene ranks as the most potent antioxidant among carotenoids. It demonstrates a broad spectrum of potential medical applications. Its strong ability to neutralize free radicals makes it a key protective agent in diseases where oxidative stress has a crucial pathophysiological function. An analysis of the existing scientific literature suggests that lycopene plays an essential part in the prevention and supportive treatment of various lifestyle-related diseases. Among them are cardiovascular diseases, cancers, type II diabetes, depressive disorders, and skin conditions.

Regular consumption of lycopene-rich foods is associated with beneficial effects on metabolic parameters. Particularly important are products based on tomatoes. Researchers also observed improvements in lipid profiles, reductions in inflammatory markers, and enhanced endothelial function. Lycopene protects the skin from UV radiation damage and slows down the aging process. Current results of studies on lycopene are promising. Further well-designed clinical trials are required to confirm the effectiveness of long-term lycopene supplementation, both as a part of a conscious diet and in supplement form. Lycopene comes from natural sources. It is well absorbed by the body and has low toxicity. For these reasons, it can help prevent and treat many medical conditions.

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**Author's Contribution**

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**Conflict of interest**
The authors declare that there is no conflict of interest.

**Data and materials availability**
All data associated with this work are present in the paper.

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