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TOMATO BY-PRODUCTS AS A SOURCE OF NATURAL ANTIOXIDANTS FOR PHARMACEUTICAL AND FOOD INDUSTRIES – A MINI-REVIEW

Roxana-Mădălina STOICA, Caterina TOMULESCU, Angela CĂȘĂRICĂ, Mariana-Grațiela SOARE (VLADU)

National Institute for Chemical-Pharmaceutical Research and Development - ICCF,
112 Vitan Ave, District 3, Bucharest, Romania

Corresponding author email: roxym_stoica@yahoo.com

Abstract

Antioxidants are substances that are able to prevent or inhibit oxidation processes in human body as well as in food products. The entire tissue of fruits and vegetables are rich in bioactive compounds and in most cases the waste by-products can present similar or even higher contents of antioxidant compounds. The tomato processing industry generates large quantities of tomato peel residues, usually creating environmental problems. The tomato by-products mainly constituted by tomato skins and seeds represent one of the richest sources of lycopene, a carotenoid with a noncyclic, not branched structure which has demonstrated antioxidant properties and an important role in the prevention of chronic diseases. Tomatoes skin can, in fact, contain up to 5 times more lycopene than the pulp. So, although these by-products of tomato industry represent a major disposal problem for the food industry, they are also a promising source of compounds which may be used in the food, pharmaceutical and cosmetic industries because of their antioxidant or nutritional properties.

Key words: *lycopene, peel tomatoes, properties, applications, antioxidant.*

INTRODUCTION

Lycopene is an important carotenoid in tomatoes, responsible for the red color of tomatoes. Tomatoes and tomato products are the major sources of lycopene compounds which can represent more than 85% of all the carotenoids present in the fruits (Abreu W. et al., 2011). Lycopene is an important biological compound and has received great interest in the past decade because of its important role in preventing chronic diseases, such as atherosclerosis, skin cancer and prostate cancer (Cruz B.R.M. et al., 2013). It is an antioxidant that displays higher efficiency than vitamin E and other kinds of carotenoids. Tomato skins can be a viable source of lycopene, as the per unit mass of tomato skins contain about five times more lycopene than the whole tomato pulp (Muhammad W. et al., 2017). George et al. (2004) studied 12 genotypes of tomatoes, and found that the free polyphenolic content (expressed as mg catechin/100 g fresh weight) in pulps ranged from 9.2 to 27.0 mg/100 g, compared to 10.4 to 40.0 mg/100 g in skin, and also that for each genotype, the polyphenolic content in skin was higher than in pulp. A similar observation has been made by Toor and Savage (2005), who reported that the total polyphenolic content (expressed as mg gallic acid equivalents/100 g) of skin and seeds of tomatoes were, respectively, 29.1 and 22.0, compared to 12.7 mg/100 g in the pulp. However, when tomatoes are processed into products like ketchup, sauces or juice, 3-7% of their weight become waste. Tomato waste, since it contains a significant amount of skin and seeds, is a potential source of natural antioxidants (Savatovic M.S. et al., 2010). Considering that more than one third of the tomatoes delivered to processing plants end as processing wastes, mainly constituted by seeds and skins, the recovery of this carotenoid could represent an alternative for the valorization of the by-products of the tomato industry. Commercial processing of tomato produces a large amount of waste at various stages and constitutes the major part of the waste that comes from the pulper. Because tomato skins were found to give the highest yield of lycopene, it has been reported that tomato processing residues, including skins, are ideal for extracting large amounts of lycopene (Sandei L. et al., 2006). Industrial production of

lycopene from tomatoes appears to be in high demand by food companies for the development of functional foods (Kaur D. et al., 2004).
Discarded tomato skins from the production of tomato juice have been found to be the best source for lycopene extraction. Enrichment of tomato paste with tomato peel is an interesting option for increasing lycopene and β-carotene intakes (Mortensen A., 2006). The lycopene content in tomatoes typically ranges from 70 to 130 mg/kg and depends on the variety, geographic location, cultivation technique, climatic conditions and ripeness of the tomato.
The lycopene content increases as the fruit ripens. Tomato sauce and ketchup contain lycopene at concentrations of 33 to 68 mg per 100 g, while raw tomatoes contain lycopene at concentrations of 3.1 mg per 100 g.
The lycopene concentration in the non-blanched tomato peels was 62.92 mg/100 g, whereas it was 134 mg/100 g in the blanched tomato peels (Rao A.V. et al., 2004). It is one of the pigments widely used by the food industry as a food additive due to its strong colour and non-toxicity. It has many health benefits and is in increasing demand as a red colorant and antioxidant agent (Krinsky et al., 2005; Chauhan K. et al., 2011).

LYCOPENE CHEMISTRY

Structurally, it is a tetraterpene assembled from eight isoprene units, composed entirely of carbon and hydrogen. Lycopene, a C40 polyisoprenoid compound containing 13 double bonds, is the most abundant carotenoid, accounting for approximately 80–90% of the total pigment contents in ripe tomatoes. With its 11 conjugated and two non-conjugated double bonds, it was found to be a more efficient antioxidant (singlet oxygen quencher) than β-carotene, α-carotene, and α-tocopherol (Chun Yi et al., 2009; Liana M.A et al., 2009).
The acyclic structure of lycopene makes it more soluble in organic solvents, such as chloroform, hexane, benzene, methylene chloride, acetone and petroleum ether (Shi J., 2000). Structure and physical properties of lycopene are shown in Figure 1 and Table 1 (Pratik M.K. et al., 2007; Raey M.A. et al., 2013).

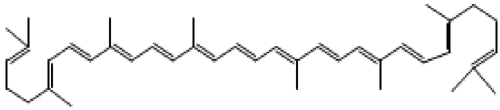

Figure 1: Structure of lycopene

Table 1: Physical properties of lycopene

Molecular formula	$C_{40}H_{56}$
Molecular weight	536.85 Da
Melting point	172-175^{0}C
Crystal form	Long red needles separate from a mixture of carbon disulfide and ethanol.
Powder form	Dark reddish brown.
Solubility	Soluble in chloroform, hexane, benzene, carbon disulfide, acetone, petroleum ether and oil; Insoluble in water, ethanol and methanol.
Stability	Sensitive to light, oxygen, high temperature, acids, catalysts and metal ions.

The main concerns in using lycopene extracted from tomatoes and waste tomatoes are solubility and stability. Carotenoids are susceptible to degradation due to high temperatures, oxidation and UV light, which further limit their application in the food industry.

EXTRACTION METHODS

Nowadays, there is an increasing trend towards utilization of food processing by-products as a source of functional components. Many studies have been carried out on the extraction of lycopene from by-products, especially tomato waste.
Several different methods have been used to extract lycopene, such as supercritical fluid extraction (SCFE) with CO_2 and solvent extraction (Rozzi N.L., 2002; Vagi E. et al., 2007). Solvents for extracting carotenoids, include ethyl acetate (100%) or different mixtures of solvents such as ethanol/hexane (1:1), acetone/ethanol/hexane (1:1:2), ethyl acetate/hexane (1:1) or acetone/hexane (1:1), ethyl acetate and ethyl lactate being non-toxic solvents. Recent studies describe a lycopene extraction process based on supercritical CO_2, which avoids using harmful solvents. Over 60% of the lycopene in tomato waste was extracted

with this process. This type of extraction is extremely efficient with non-polar carotenoids (lycopene) with a total of carotenoids recovery of 96% (Topal U. et al., 2006; Akbari et al., 2014). Successful extraction technology for lycopene recovery from tomato pomace (seeds and skin) can significantly improve the economic aspects of tomato industry besides making available one of the most potent antioxidants for formulating health supplements for human beings (Naviglio D. et al., 2008).

ANALYTICAL METHODS

Various analytical methods have been developed to measure and analysis of lycopene. These include ultraviolet-visible (UV-VIS) spectrophotometry, liquid chromatography (LC), thin layer chromatography (TLC) and high-performance liquid chromatography (HPLC). UV-VIS spectrophotometry is more convenient, faster and less expensive than HPLC analysis and large numbers of samples can be processed in a relatively short time. However, UV-VIS spectrophotometry cannot detect very small quantities of lycopene (less than 1 μg), whereas HPLC can detect quantities as small as 1 ng. Although HPLC analysis allows accurate quantification of pigments and separation of isomers, it is laborious and a high level of skill is required to produce consistent results (Knoblich M. et al., 2005).

THE MAJOR HEALTH BENEFITS OF LYCOPENE INCLUDE:

• Antioxidant activity

Lycopene is one of the most potent antioxidants. Its singlet-oxygen-quenching ability is twice that of β-carotene and ten times higher than that of α-tocopherol. As an antioxidant, it traps reactive oxygen species, increasing the overall antioxidant potential and reducing the oxidative damage to lipids (lipoproteins, membrane lipids), proteins (important enzymes) and DNA (genetic material), thereby lowering oxidative stress. This reduced oxidative stress leads to reduced risk of cancer and cardiovascular heart disease. As lycopene levels in the blood increase, the levels of oxidized lipoproteins, proteins and DNA compounds decrease (Rao A.V. et al., 2002; Erdman J.W. et al., 2009).

• Reducing prostate cancer

Studies show that taking high doses of lycopene can slow the progression of prostate cancer. The estimated intake of lycopene from various tomato products was inversely proportional to the risk of prostate cancer, a result not observed for any other carotenoid. Consuming ten or more servings of tomato products per week reduced the risk by almost 35%. The protective effects were highest for more advanced or aggressive prostate cancer (Basu A. et al., 2007; Zhang J. et al., 2007).

• Inhibiting cancer cells

Lycopene has a protective effect against stomach, colon, lung and skin cancers. Free radicals in the body can damage DNA and proteins in the cells and tissues, resulting in inflammation which may lead to cancer. Hence, the antioxidant properties of lycopene in eliminating free radicals may reduce the risk of cancer (Giovannucci E. et al., 2002). Research in breast, lung and endometrial cancers has shown that lycopene is even more effective than the other bright vegetable carotenoids α- and β-carotene in delaying the cell cycle progression from one growth phase to the next, thus inhibiting growth of tumor cells. Lycopene also plays a role in modulating intercellular communication by regulating irregular pathways that may be associated with cancer. Multiple studies have investigated whether intake of tomatoes or tomato-based products helps prevent digestive tract cancers, including oral, pharyngeal, oesophageal, gastric, colon, and rectal cancer. People with a higher intake of lycopene have been shown to have a reduced risk of developing cervical and breast cancer (Keleman L.E. et al., 2006; Rao A.V., 2006).

• Reducing blindness

Age-related macular degeneration (ARMD) is the most common form of blindness in elderly people in the Western world. Lycopene is the only micro-nutrient whose serum level is shown to be inversely related to the risk of ARMD. Lycopene also helps reduce the incidence of cancers and cardiovascular diseases which play a role in eye health (Mendelova A. et al., 2013).

• Reducing atherosclerosis and heart disease

Lycopene may be helpful in people with high cholesterol, atherosclerosis or coronary heart disease, possibly due to its antioxidant properties. Lycopene prevents oxidation of low density lipoprotein (LDL) cholesterol and reduces the risk of arteries becoming thickened and blocked (Rao A.V. et al., 2000). Most published studies in this area used tomato juice as a treatment (Kritchevsky S.B., 1999; Arab L. et al., 2000; Ito Y. et al., 2006).

• Reducing osteoporosis

Epidemiological data indicates, lycopene prevents osteoporosis in post-menopausal women. This is a new and exciting finding and could stimulate serious dietary considerations for all people seeking to protect against this disease (Rao L.G. et al., 2007).

• Preventing skin damage

Lycopene can reduce inflammation and help to protect the skin from damage resulting from UV sun exposure. It is a common ingredient in anti-aging creams and lotions but because it degrades easily, containers must be properly sealed between uses (Stahl W. et al., 2006).

FUNCTIONAL USES OF LYCOPENE IN FOOD

Because of lycopene benefits, there is a growing interest in using lycopene as a value-added or functional ingredient in food products. Lycopene extract from peel tomatoes can be used as a nutritional supplement in several food categories such as baked goods, breakfast cereals, dairy products including frozen dairy desserts, dairy product analogues, spreads, bottled water, carbonated beverages, fruit and vegetable juices, soybean beverages, candy, soups, salad dressings, and other foods and beverages. Lycopene is a natural food colouring, thus eliminating the adverse effects of artificial food colorants. It provides colour shades ranging from yellow to red.

There are initiatives by food scientists to recycle lycopene-rich by-products as food ingredients. Fortifying dry fermented sausage with lycopene can be achieved by adding dried tomato peel to the meat mixture during sausage production. Extrusion processing allows barley-tomato pomace blends to be formulated into snacks.

Research shows that heat processing converts lycopene in tomatoes to a form the body can absorb more easily. One study showed that lycopene is absorbed 2.5 times better from tomato paste than from fresh tomatoes (D'Evoli et al., 2013).

CONCLUSIONS

By-products derived from food processing are considered highly advantageous for their development as nutraceuticals and food ingredients, additives, functional fruits, and are also used in the pharmaceutical industry due to the various bioactive components and colour pigments present in them.

Tomato peels, usually eliminated during tomato processing as by-product, are a valuable source of carotenoids. Wastes from processing tomato products contain the carotenoid rich skins and the seeds, and are available in large quantities. Extracting lycopene from tomato processing wastes is economical and these by-products could become a cheap source or lycopene, carotenoids and/or natural oils for formulating new nutraceuticals, pharmaceuticals, and cosmetic products. Lycopene is particularly important because it has a dual influence on production and quality as a natural color and nutrient for the food and pharmaceutical industries. Color also serves as a measure of total quality for tomato and tomato products. Lycopene can play an important role in human health and provide protection against a broad range of epithelial cancers.

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