Bulgarian Chemical Communications, Volume 48, Number 1(pp. 153 – 158) 2016

Physiological functions and extraction technology of Lycopene - a natural antioxidant

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Received June 26, 2015, Revised September 10, 2015

Lycopene is one kind of carotenoid. Its antioxidant is very high. It also plays the important role to prevent cancers and atherosclerosis and develop immunity from disease. Therefore, the research of lycopene is a hot point in the functional foods and new drugs as an ingredient in the world. The main physiological functions and feasible extraction technology in industry were reviewed in this paper.

Keywords: Lycopene, Physiological function, Extraction technology

INTRODUCTION

Lycopene is a kind of natural caroteniod and widely exited in the nature. It's the first isolated from tomato, therefore, called lycopene. As a potential functional natural colorant, lycopene has the active oxygen quenching, dispelling the human free radical, preventing heart disease, reducing autherosclerosis, preventing of various types of cancer, cardiovascular protection, anti-aging, protecting the skin and other physiological function. It has a “hidden in tomato gold” laudatory name. In recent years, the research of lycopene and related products have been became a hot issue in the functional foods and new drugs as an ingredient in the world.

THE PHYSIOLOGICAL FUNCTIONS OF LYCOPENE

Anti-tumors effect

For the first time since 1950, the American scientists reported that lycopene had anti-cancer effect. After a number of animal experiments, the human body cell culture and epidemiological studies in recent years showed that lycopene had the effect on cancer biology. Campbel *et al* [1]found that the content of lycopene in liver was lower in patients with hepatocellular carcinoma; Francesschi *et al* [2] doing research on more than 3000 digestive tract cancer patients for seven weeks found that the digestive tract cancer is associated with the intake of lycopene; Giovannucci *et al* [3]studied 47894 men, focused on about the relationship between the intake of carotenoids, retinol, fruits vegetable and prostate cancer, then pointed out that after eating food containing high lycopene, such as fresh tomatoes, tomato sauce had significant relationship between the reduction rate of prostate cancer. Bolieau[4]through the experimental study on rat model confirmed that licopene in rats the bladder cancer incidence was significantly lower than the control group.

The above research results indicate that rich lycopene in tomatoes and tomato products diet can reduce some of tumor closely related, and have done a lot of research on the mechanism of lycopene. Now, it is widely recognized that the main mechanism of action of lycopene in the following areas: (1) antioxidant and free radical scavenging effects. Because there are 11 conjugated double bonds of lycopene molecule, compared with other carotenoids, lycopene quenching singlet oxygen and free radical scavenging ability was the strongest, its ability to quench singlet oxygen is 100 times the vitamin E, carotene 2 times[5]; (2) inducing cell gap junction intercellular communication. Lycopene by inducing intercellular connections, enhanced cell gap junction communication between normal cells, controlling cell growth and induction of cell differentiation to inhibit tumor growth, but also promote the interaction between the phagocytes cell and lymphocytes, the activation of cells by secreting cell activating factor finally can promote phagocytic capacity and lymphocyte transformation, enhance immune function[6];(3) Regulation of tumor cell proliferation. Lycopene can affect breast cancer, lung cancer and uterine

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cancer cell cycle transition from G1 to S, to influence the growth of tumor cells, lycopene can inhibit insulin like growth factor induced proliferation of cancer cells[7];(4)genetic expression of inhibiting cancer cell proliferation and metastasis of a-TGF factor. Lycopene can reduce the expression of a-TCF in the genetic process to prevent the formation of female breast cancer in the female rats[8].

Enhance immunity

Lycopene has the activation of immune cells, protective the phagocytic cells from oxidative damage to their own, while it can promote the protection of T, B lymphocyte proliferation and stimulate T cell function then enhance the ability of macrophages, T cells to kill tumor cells. It can promote the interaction of phagocytic cells and lymphocytes the activation of cells by secreting cell activating factor finally which can promote phagocytic capacity and lymphocyte transformation, enhance immune function. The animal experiment showed that adding lycopene group mice can increase cell subsets; variation of abnormal T cells can recover to normal mice, and also reduce the oxidative damage of lymphocyte DNA, and promote the produce interleukin and bring immune regulation mechanism into play.

Medical researchers believe that tomatoes can enhance children's immunity and reducing child mortality caused by severe diarrhea. Researchers at the national Taiwan university school of medicine conducted a survey found that the immune function of human body decreased significantly for two consecutive weeks of low content of carotenoid intake of food, but after ingesting tomato juice for 2 weeks lycopene can be increased obviously in body, while at the same time the immune function of T lymphocytes was enhanced.

Anti-atherosclerosis and inhibit cholesterol synthesis

Lycopene is fat soluble substances, mostly existed in the cell membrane and lipoprotein components, more concentrated in the low density lipoprotein (LDL) and very low density lipoprotein, but not existed in high density lipoprotein. Lycopene can significantly inhibit the serum lipids and the oxidation of LDL so as to reduce the risk of coronary heart disease. The concentration of lycopene in the body and atherosclerosis, myocardial infarction is negatively correlated. Fat content of lycopene top 20% of the population has much lower risk of myocardial infarction than the minimum content of 20% of people. Lycopene can also reduce cholesterol synthesis, degradation of LDL in cells increased, thereby reducing the probability of occurrence of myocardial infarction[9]. Lycopene can inhibit macrophage cholesterol synthesis from acetate pathway; inhibition rate reached 73%, but cannot inhibit the synthesis of formic acid from cholesterol valerate pathway. It may increase LDL receptor activity, inhibit cholesterol synthesis rate-limiting enzyme methyl-glutaryl CoA reductase activity, reduce cholesterol synthesis. Meanwhile, it can accelerate the transfer of triglyceride to macrophages, reduce the ormation of triglyceride synthesis key enzyme diacylglycerol acyltransferase mRNA, generate in the blood triglyceride reduction[10].

Rissanen *et al*[11]reported that total of 725 middle-aged men epidemiological investigation showed that the lower the plasma levels of lycopene, the greater risk of suffering from acute coronary heart disease and carotid artery wall intima or media thickness ratio are. Kirsten et al[12]used the case-control method, eliminated the gender, age and other factors, analyzed the serum concentration of 108 subjects in a variety of carotenoids. The results showed that the concentration of lycopene was negatively correlation with atherosclerosis.

Skin protection

The sun and ultraviolet radiation cause skin damaged in different degree, accelerated the formation of wrinkles, stains, and even lead to skin cancer. The reason for this is the generation of ultraviolet and singlet oxygen and free radicals. Clinton[13]proved that through the usual intake of lycopene rich foods can defend against UV, and avoid UV irradiation erythema. Recent studies have confirmed that ultraviolet irradiation, first destroy the skin of lycopene by sunlight, the lycopene content of skin exposed to sunlight is 31%-46% lower than of the skin without sunlight[14]. By inference, the skin of lycopene has a clear UV produced ROS, reducing dietary lycopene content can cause skin cancer rates increased.

Other aspects of the role

Lycopene wide variety of sources and safe non-toxic, added to various foods, can improve the nutritional value, the nutrition is better than vitamin E and β- carotene. With antioxidant and photoprotective effect, it can prevent oxygen free radicals, which caused by a variety of retinal macular degeneration, and retinal pigmentation caused by degeneration of vision loss and blindness and other symptoms. In addition, lycopene from tomato has been widely used in food additives,

functional food, pharmaceutical raw materials and advanced cosmetics industries, in order to make full use of lycopene health, disease prevention, treatment and beauty features[15].

THE EXTRACTION PROCESS OF LYCOPENE

Organic solvent extraction

Depending on the properties of insoluble in water, soluble in methanol, ethanol, soluble in petroleum ether, hexane, acetone and benzene, the lipophilic organic solvents are commonly used as the extraction agent for extraction of lycopene. At present, saponification is usually used. The principle is through the saponification of tomato processing raw materials to destroy tomato tissue cells, so that lycopene can completely release.The specific method of saponification methods: (1) the fresh tomato peeled, beating, centrifugal out the water; weigh a certain amount of tomato pulp, adding the appropriate lye, heating and stirring, the reaction is completed when tomato pulp washing to neutral, then dried and crushed tomato pulp; (2) the extraction of lycopene. Adding proper extracts such as: petroleum ether into the saponification and dried tomoto powder to extract, after the extract was filtered, then vacuum concentration, obtained lycopene oleoresin[16].

Enzymatic extraction

Enzymatic extraction is a popular method for extracting lycopene by pectinase and cellulase reaction with tomato skin itself. The extraction process is:(1) tomato (or tomato processing byproducts) after beating smash, adding alkali to adjust the pHvalue; (2)45 ~ 60 ℃ heating constant temperature preservation; (3) the skin was removed by filtration, the residue seed and fiber, to obtain extract; (4) adding acid to adjust to be a weak acid to precipitate the carotenoid cohesion, by removing the upper turbid liquid siphon obtain containing carotenoid precipitate; (5) adjusting to the pH value, vacuum concentration, then adding acid or salt preserved. In addition, it can also be applied to 0.1% pectinase or cellulase, controlled by enzymatic hydrolysis and extraction time as to achieve the purpose[17]. Ranveer et al[18] optimized extraction process of lycopene by using solvents and examine the effect of enzyme treatment on the recovery if any. The results revealed that the tomato peel (417.97 μg/g) contains highest amount of lycopene followed by industry waste (195.74 μg/g), whole tomato (83.85 μg/g) and pulp (47.6 μg/g).

Supercritical fluid extraction

The supercritical fluid phase is a kind of special material, has good solvent properties, widely used in organic extraction. The principle of supercritical fluid extraction technology is the use of the relationship between solubility of supercritical fluid and its density, namely the use of pressure and temperature affect the ability of dissolved supercritical fluid carried out[19]. CO_2 is the most common extraction solvent, while supercritical fluid CO_2 is at the critical fluid temperature and pressure (called the critical temperature critical point CO_2 as 31.1℃, the critical pressure as 7.38 MPa above CO_2, which has a liquid between gas and liquid in a heavy nature, so that it has good permeability[20]. Singh et al reported that at the conditions of the 40MPa and 2.5 mL/min CO_2 flow rate, supercritical carbon dioxide technology can obtain the maximum yield of 1.18 mg lycopene per gram of samples[21].

Microwave extraction

Lycopene is a fat-soluble pigment with the characteristic of long time extraction. Because organic solvent is difficult to penetrate through the material of cell wall and membrane, so that it is not a good dissolution of the extract from organelles. Microwave-assisted extraction (microwave-assisted extraction, referred to as MAE) can improve the extraction efficiency. Microwave is an electromagnetic wave frequency between 300 MHz and 300 GHz, with volatility, high frequency, thermal properties and non thermal characteristics of four basic features. The thermal effect of microwave is based on different charge polarization internal material dielectric properties and material does not have the ability to keep up with the alternating electric field to achieve[22].

For the purpose of optimization MAE of lycopene from tomato peels and evaluation the effect of treatment on all-*trans* and isomer yields, Ho *et al*[23] used response surface methodology (RSM) to optimize lycopene extraction with solvent ratio solid-liquid ratios, microwave power, and delivered energy equivalents as factors. The results showed that the optimum MAE condition was determined as: 0:10 solvent ratio at 400 W with a yield of 13.592 mg/100 g of extracted all-*trans*-lycopene.

Ultrasonic extraction

Ultrasound can accelerate the process of dissolution of lycopene in solvents, reduce the lycopene in the air and sunlight exposure time. However, it was not very clear that whether

lycopene itself is affected or whether lycopene oxidative degradation accelerates to its cis-trans isomerization reaction[24]. Eh *et al*[25]reported that the optimisation of the lycopene extraction had been performed, giving the average relative lycopene yield of 99% at 45.6 min, 47.6 °C and ratio of solvent to freeze-dried tomato sample (v/w) of 74.4:1 via the ultrasonic assisted extraction (UAE). From the optimised model, the average yield of all-trans lycopene obtained was 5.11±0.27 mg/g dry weight. Zhang and Liu [26] reported that the extracting technology of lycopene from tomato paste by ultrasonic and microwave assisted extraction (UMAE) and ultrasonic assisted extraction (UAE). The results showed that the optimal conditions for UMAE were 98 W microwave power together with 40 KHz ultrasonic processing, the ratio of solvents to tomato paste was 10.6:1 (V/W) and the extracting time should be 367 s; as for UAE, the extracting temperature was 86.4 degrees C, the ratio of the solvents to tomato paste was 8.0:1 (V/W) and the extracting time should be 29.1 min, while the percentage of lycopene yield was 97.4% and 89.4% for UMAE and UAE, respectively. In their study, the results implied that UMAE was far more efficient extracting method than UAE for extraction (UAE) of lycopene from tomatoes.

Microbial fermentation

In addition to extract from containing lycopene substances, it can also use algae and fungi and yeast fermentation to produce the lycopene[27]. Now, the producing lycopene microorganisms are including gram negative bacteria, blakeslea trspora, golden Mycobacterium and gene engineering bacterium[28]. With the development of genetic engineering techniques, the use of genetic engineering bacteria producing lycopene has become a research hot topic. Hal *et al*[29] reported a foreign gene inserted by transgenic technology in *E. coli* cultures produce lycopene, and can obtain 11,000 ppm (μg of lycopene/g dry cell weight). Gavrilov *et al*[30] found that adding tomato industrial wastewater into the growth medium of the Blakeslea trspora can inhibit the production of carotenoids, but stimulate the synthesis of lycopene. In addition, in the breeding of high-yield β- carotene Blakeslea trispora strains, people found that the strain had a unique metabolic process. Adding vegetable oil, surface active agents, antioxidants and a variety of structural analogues can improve β-carotene yield; the other fermentations can improve the yield of other carotenoids[31,32].

CONCLUSIONS

Among the production methods of lycopene above, the method of organic solvent extraction has some characteristics, such as simple process, low energy consumption and the solvent recycled easily. However, the water-insoluble components in extraction contain a large of fatty acid glycerol vinegar and varieties of free fatty acids, which not only influence the purity of the product, but also make it difficult to release the lycopene inside; The saponification method makes the mount of extracting is almost four times higher than the normal method and organic solvent extraction. At the same time, it can eliminate the influence of carotene to the determination of lycopene. Compared to the enzyme reaction method and organic solvent extraction method, it can shorten the time with the extraction yield improved significantly. Among them, the amount of extracting of miccrowave enzymatic is higher compared with simple enzyme reaction method and microwave method. For the ultrasonic extraction lycopene, in addition to shorten extracting time and improve the high extracting amount outside, meanwhile it avoids the oxidative loss of lycopene because of long extracting time. It is suitable for industrial production with low cost and less investment.

With the superior physiological function, the lycopene can be used as health care products, cosmetics, medicine and food additives. At present, lycopene has been allowed to use as an edible natural pigment by the EC and the British. However, because of unstable characters, it is necessary to eat mix antioxidants, like vitamin E and so on, or grease in the application. With the development of technologies, the physiological function of lycopene will be proved with the scientific research in deep and system. It will open up a broad prospect for the development and utilization of lycopene.

China is the third tomato producer after America and Italy. The tomato production is about 20% of the world. It has a unique advantage to develop the tomato processing industry. However, it’s still in the initial stage on domestic research. So the gap is large compared with foreign counterparts. In our country, the size of tomato products industry is expanding quickly. However, there is a large of waste from tomato peels’ residues in factories. If each manufacturer adopts reasonable extracting methods according to their own condition, extraction of lycopene improves with high value-added from the tomato peels’ residues. It is a

potential way to raise the economic benefit and industrial development.

Acknowledgments: *This work was supported by grants from the Hubei Provincial Education of Department Scientific Research Program (Q20151508) and Graduate Innovative Fund of Wuhan Institute of Technology.*

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ФИЗИОЛОГИЧНИ ФУНКЦИИ И ТЕХНОЛОГИЯ НА ИЗВЛИЧАНЕ НА ЛИКОПЕН – ЕДИН ЕСТЕСТВЕН АНТИОКСИДАНТ

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Получена на 26 юни, 2015 г., ревизирана на 10 септември 2015 г.

(Резюме)

Ликопенът е вид каротеноид. Неговата антиоксидантна активност е много висока. Той също така играе важна роля за предотвратяване на ракови заболявания и атеросклероза и спомага да се развие имунитет срещу болестта. Поради това, изследването на ликопена е гореща точка в функционалните храни и като съставка в нови лекарства, по света. В тази статия бяха разгледани основните физиологични функции и осъществима технология за екстракция в индустрията.