International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 05-08-2022, Accepted: 21-08-2022, Published: 07-09-2022
Volume 7, Issue 3, 2022, Page No. 153-157

A short review on tomato: Lycopene and It's health benefits

Moumita Barik[1], Pradnya Bhujangrao Dhutmal[2*], K Sumana Mounya[3], Madhurima Kar[4]
[1] Assistant Professor, Department of Nutrition, Haldia Institute of Health Sciences, West Bengal, India
[2] Assistant Professor, Department of Home Science, KRM Mahila College, Vazirabad, Nanded, Maharashtra, India
[3] PhD Scholar, Department of Food Science and Technology, GITAM University, Visakhapatnam, Andhra Pradesh, India
[4] Clinical Dietitian, Wellthy Therapeutics Pvt Ltd, Mumbai, Maharashtra, India

Abstract
Tomato is major source of many established phytochemicals and nutrients that may have health benefits. Lycopene is the red-coloured carotenoid found in fruits and vegetables, such as watermelon, carrots but the richest source of lycopene is tomato. The salutary effects of lycopene in human health and specifically in chronic diseases are mainly analogous with it's antioxidant properties. Lycopene is leading carotenoid found in tomatoes, manifest the elevated antioxidant activity and single oxygen extinguish ability of all dietary carotenoid. Processing of tomatoes will increase their bioavailabilty of the lycopene. It has been studied that consumption of tomatoes containing lycopene will decrease the risk of some chronic diseases like cancer and cardiovascular diseases. Tomato is actually fruit not an vegetable and it have lot's of nutrients in it which is helpful for a human body. Tomato contains vitamin A, D, B-6, calcium, iron and potassium. Tomato not only prevent cancer and cardiovascular diseases but also high cholesterol level and lowering blood pressure. The redder the colour of tomato you eat, the more beta-carotene you get. Tomato will help to detoxify the toxicity from the body. The red-coloured pigment in tomato called as lycopene.

Keywords: tomato, lycopene, antioxidant, cardiovascular diseases, cancer, health benlycope

Introduction
Tomato (*Solanum lycopersicum L.*) is a vegetable crop, largely cultivated and consumed all over the world. The overall production of tomato across the world in 2014 was 170.75 Mt from 50,238.1 km² land under cultivation as compared to that of in 2010 where it was 151.89 Mt from 44,955.8 km² land under cultivation (FAOSTAT, 2014) [14]. Tomato is popularly recognized for its uncommon flavour, nutrient content with reference to its phytochemicals and antioxidants (Kong *et al*., 2010) [23]. People can consume the fruit in different ways, can be taken as raw, included in salad, sauce, curry, and in drinks. The fruit is typically rich in lycopene and belongs to solanaceae family. The plant has weak stem, grows on a vine and often sprawls over other plants. The plant grows upto 1-3 meters. Tomato is a perennial crop in its native habitat and sometimes also grow in temperate climates as an annual crop (Ganesan *et al*., 2012**)** [16]. Tomatoes are good in taste, easily available, low in price and have distinctive health benefits, all of these makes it popular and in-demand fruit among the population (Burton-Freeman and Reimers, 2011) [8].
Tomatoes have good range of nutrients and contain moisture (95%), carbohydrates (3%), protein (1.2%), total fats (1%), and large amounts of vitamins, and minerals. (Melfi *et al*., 2018 and Riso *et al*., 2004). It is also a good source a phytochemicals such as flavanoids, phenolic acid, β-carotene, glycoalkaloids and phenolic compounds. The phenolic acids, flavanoids, lycopene and β-carotene are the major biologically actives compounds present in riped tomatoes. The significant amount of lycopene gives red colour of lycopene tomato (Perveen *et al*., 2015 and Ganji *et al*., 2005) [34].
Kopec in his studies suggested that, Lycopene is predominatly found in tomatoes and is responsible for its bright red colour (Kopec *et al*., 2010). Lycopene in tomatoes has the highest antioxidant activity and singlet oxygen quenching ability. Lycopene prevents cellular damage by destroying free radicals (Ganesh *et al*., 2016). As studied by Gross, the total lycopene content in tomatoes is found to be in between 90 to 190µg/g of fresh tomato weight (Gross, 1987) [18].
Lycopene from tomatoes provides of about 85% of totallycopene in human diet. The content may vary with varities and its amount increases as the fruit ripe.

Lycopene Chemistry and Bioavailability
Lycopene is a red-coloured carotenoid pigment with symmetrical tetraterpene structure composed of eight isoprene units. It is non-provitamin a carotenoid and has massive antioxidant activity because of its capability to

fight against singlet oxygen species (Mascio *et al*., 1989) and chlorine hydroxide (Pennathur *et al*., 2010) [32]. It is a lipophilic compound where each isoprene unit is attached by usual head to tail bindings, with the exception of at the centre of molecule where tail to tail binding is present, giving it a symmetrical appearance. Accorging to studies by Chauhan *et al*, it is soluble in organic solvent such as chloroform, benzene and insoluble in water, almost methanol and ethanol (Chauhan *et al*., 2011) [10]. Lycopene is an acyclic hydrocarbon carotenoid having molecular formula C40H56 consisting of 13 double bonds which are subjected to the formation of various isomers (Canene-Adams, *et al*., 2005) [9]. The all-trans isomer is the thermodynamically most stable structure. (Rao and Agrawal, 2000) [35] Lycopene naturally occurs as all-trans form (Schierle, *et al*., 1997) [39], wherein cis forms are present in plasma and tissues (Allen *et al*. 2003 and Walfisch *et al*., 2003) [3, 42].

Lycopene bioavalability is mainly get affected by various processing methods. Its bioavailability is more with cooked and processed tomato products. Several studies have shown that lycopene from raw tomatoes is less bioavailable than it is in thermally processed products. The absorption mechanism of lipid soluble compounds and lycopene is similar, the absorption takes place in the gastro intestinal (GI) tract by chylomicron mediated mechanism and it is then released into the lymphatic system and further get transported to liver. Through circulatory system, it is then distributed throughout the body. J.W. Erdman Jr, reported the distribution of lycopene in the human body were 10 times higher concentration in the adrenal, reproductive tissues and liver than any other tissues (Erdman, 2005) [13].

Lycopene benefits in chronic diseases

Chronic diseases including cancers and cardiovascular diseases, are the major causes of death worldwide. The important risk factors in consideration with the genetic factors include the lifestyle, age and diet.

1. Cardiovascular disease

Gajendragadkar *et al*., (2014) [15], Naz *et al*., (2014) [31], Müller *et al*., 2016) [29], Cheng *et al*., (2017) [11], Milani *et al*., 2017) [28]; Kong *et al*., 2010) [23], Riccioni *et al*., 2010) [36], Ried and Fakler, 2011 [37]; Böhm, 2012) [6], Wolak and Paran (2013); Lycopene has been shown to have numerous heart-healthy benefits, including blood pressure regulation, endothelial function (through increasing nitric oxide bioavailability and blood flow), antioxidative, anti-inflammatory, anti-atherogenic, cardioprotective, and antiplatelet properties. Lycopene is considered as one of the best oxygen quencher 10 times more potent antioxidant as compared to alpha tocophorol and twice potent than beta carotene. (Kong *et al*., 2010; Viuda-Martos *et al*., 2014, Kim *et al*., 2010) [23]. Lycopene plays an important role in the synthesis of antioxidant enzymes such as super oxide dismutase and catalase (Böhm, 2012; Pereira *et al*., 2017) [6, 33].

Oxidative reactions in the body causes inflammatory changes which lead to dysregulation of nitrogen oxide synthase and endothelial cell injury by preventing the oxidation. Lycopene promotes endothelium-dependent vasodilation, increases the bioavailability of nitric oxide (NO), and lowers protein, lipid, DNA, and mitochondrial damage (Hollman *et al*., 2011; Naz *et al*., 2014; Nakamura *et al*., 2017; Abdel-Daim *et al*., 2018) [21, 31, 1]. Lycopene is considered as one of the best oxygen quencher 10 times more potent antioxidant as compared to alpha tocophorol and twice potent than beta carotene (Kong *et al*., 2010; Viuda-Martos *et al*., 2014, Kim *et al*., 2010) [23]. Lycopene plays an important role in the synthesis of antioxidant enzymes such as super oxide dismutase and catalase (Böhm, 2012; Pereira *et al*., 2017) [6, 33].

Lycopene helps in lowering the levels of blood cholesterol by inhibiting the enzyme HMG CoA reductase and hence useful in patients who are intolerant to statins (Sultan *et al*., 2017). Lycopene is helpful in improving the LDL/HDL ratio despite improving the HDL value hence it is useful in initial stage of atherosclerosis (Lorenz *et al*., 2012; Thies *et al*., 2017) [26, 41]. Lycopene has Lipid lowering properties, reducing total cholesterol level, LDL level and dysfunctional HDL level. Lycopene has antithrombotic effect by interaction with thrombotic factors such as thromboxane, collagen, van willebrand factor and inflammatory mediators (Sawardekar *et al*., 2016; Krasinska *et al*., 2017) [38, 24]. Thus, lycopene helps in preventing myocardial infarction and stroke.

Antihypertensive effect of lycopene is mainly due to its direct inhibitory action on Angiotensin converting enzyme II and production of Nitric oxide NO by endothelial cells (Li and Xu, 2013; Belovic *et al*., 2016; Khan *et al*., 2016; Han and Liu, 2017). In a meta-analysis it has been concluded that there is reduction in systolic blood pressure in patients with Hypertension or prehypertensive blood pressure range. But does not reduce the Diastolic blood pressure (Li and Xu, 2013). Besides improving the metabolic profile (reducing LDL level, total cholesterol level), antithrombotic effect, antioxidant effect, antihypertensive effect Lycopene reduces the risk of atherosclerosis by inhibiting vascular smooth muscle cells proliferation and foam cell formation (Napolitano *et al*., 2007; Wang *et al*., 2014) [30, 43].

Lycopene helps in improving the electrical activity of heart by improving the QT interval, RR interval, ST elevation on electrocardiogram (Aman *et al*., 2012) [4]. Lycopene in daily diet improves diastolic dysfunction after myocardial infarction in rats (Pereira *et al*., 2017) [33]. Lycopene also protects heart from various cardiotoxicity caused by drugs such as Non steroidal anti-inflammatory drugs, macrolides, Doxorubicin (Abdel-Daim *et al*., 2018, Karimi *et al*., 2005; Anjos Ferreira *et al*., 2007; Abushouk *et al*., 2017) [1, 2]. Lycopene supplement in diet is helpful by reducing myocardial infarction size, hemodynamic measure, electrocardiographic changes in early as well as late myocardial infarction (Aman *et al*., 2012) [4].

2. Cancer

Tomatos constitute a major antioxidant carotenoid, having beneficial cancer preventing activity mainly for lung, breast, and prostate cancer. Lycopene helps to reduce the growth of cancer cells, considered as natural miracle antioxidant (Etminan *et al*, 2004). In a prospective study done by, 42 cancer deaths among 1271 elderly individuals, the person with top half of tomato consumption showed lower risk of total cancer compared with bottom half.

Lung cancer is leading cancer type and is one of the cancers for which a consumption of fruits and vegetable sites beneficial effect (Steinmetz and Potter, 1991) [40]. The major cause of lung cancer includes cigarette smoking. Cigarette smoke contains high percentage of nitric oxide (NO) that forms free radical NO2 by reacting with oxygen. These free radicals remain in the smoke and go to the lung tissues causing damage, causes lung cancer after long term exposure. (Halliwell and Gutteridge, 1989). Lycopene stores are also present in lung tissues (Steinmetz and Potter, 1991) [40]. The singlet oxygen quenching ability of Lycopene twice as that of β-carotene and helps to protect lymphocytes from damage caused by NO2 (Bohm *et al*, 1955). Several human observation case-control studies shown the preventive effect of lycopene against the lung cancer or pleural cancer (Li *et al*, 1997, Agudo *et al*, 1997; Comstock *et al*., 1997) [12]. Prostate cancer is most prevalent among men and leading cause of death. The important risk factors are the age and genetic factors although environmental factors and diet are also associated with disease (Chauhan *et al*., 2011) [10]. The World Cancer Research Fund showed the positive effect of lycopene in prevention of prostate cancer including, role of fruit and vegetable consumption in decreasing risk of cancer (Wiseman, 2008). The studies performed on plasma levels of lycopene in humans showed the relationship between preventions of prostate cancer and lycopene men who went on development of prostate cancer are observed with significantly lower levels of antioxidant lycopene (Gann *et al*., 1999) [17]. Recent studies have shown the close link between the tomato consumption and prostate cancer risk, where tomato consumptions is related with a lowered risk of prostate cancer. Meta-analysis in view of geographical region subgroup showed that Asian and Oceanic populations have makeable protective effect of tomato intake, but not observered on other populations (Xu *et al*., 2016). Additional studies suggested incidence on benefits of tomato and lycopene with androgen axis to lower the blood levels of prostate-specific antigen (PSA) (Paur *et al*., 2017) and also reduce the risk of advance-stage prostate cancer which can be lethal (Wang *et al*., 2016) [44].

Breast cancer is prevalent among the women across the world (Simmonds, 2003). Epidemiological studies have suggested, the decrease risk of breast cancer may be associated with the consumption of lycopene containing food (Sesso *et al*., 2005). Lycopene has anti-proliferative effect on cancer cells and decreases the expression of cell regulatory protein in the breast cancer models (Hwang and Bowen, 2004; Karas *et al*., 2000). Study results by Aune *et al*. suggested that blood concentration of carotenoid is strongly linked with reduced risk of breast cancer (Aune *et al*., 2012) [5].

Conclusion

The review concludes, the consumption of tomatoes has several beneficial health effects. Tomato is fairly rich in vitamin C. vitamin E, and minerals like calcium and phosphorus, it also contains a predominant carotenoid pigment Lycopene. Lycopene is a antioxidant principally accounts for red colour appearance of tomatoes. The importance of tomato in maintaining and sustaining human health are mainly attributed to lycopene. Lycopene is an important nutrient with various health benefits includes lowering the risk of oxidative damage, and certain chronic diseases such as cancer, cardiovascular, etc.

References

1. Abdel-Daim MM, Eltaysh R, Hassan A, Mousa SA. Lycopene attenuates tulathromycin and diclofenac sodium-induced cardiotoxicity in mice. Int. J. Mol. Sci.,2018:19:e344. 10.3390/ijms19020344 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
2. Abushouk AI, Ismail A, Salem AMA, Afifi AM, Abdel-Daim MM. Cardioprotective mechanisms of phytochemicals against doxorubicin-induced cardiotoxicity. Biomed. Pharmacother.,2017:90:935-946. 10.1016/j.biopha.2017.04.033 [PubMed] [CrossRef] [Google Scholar]
3. Allen CM, Schwartz SJ, Craft NE, *et al*. Changes in plasma and oral mucosal lycopene isomer concentrations in healthy adults consuming standard servings of processed tomato products. Nutr Cancer,2003:47:48-56.
4. Aman U, Vaibhav P, Balaraman R. Tomato lycopene attenuates myocardial infarction induced by isoproterenol: electrocardiographic, biochemical and anti-apoptotic study. Asian Pac. J. Trop. Biomed.,2012:2:345-351. 10.1016/S2221-1691(12)60054-9 [PMC free article] [PubMed] [(CrossRef] [(Google Scholar]
5. Aune D, Chan DS, Vieira AR, Navarro Rosenblatt DA, Vieira R, Greenwood DC, *et al*. Dietary compared with blood concentrations of carotenoids and breast cancer risk: a systematic review and meta-analysis of prospective studies. The American journal of clinical nutrition,2012:96(2):356-373.
6. Böhm V. Lycopene and heart health. Mol. Nutr. Food Res.,2012:56:296-303. 10.1002/mnfr.201100281 [PubMed] [CrossRef] [Google Scholar]
7. Böhm F, Tinkler JH, Truscott TG. Carotenoids protect against cell membrane damage by the nitrogen dioxide radical. Nature Medicine,1995:1(2):98-99.

8. Burton-Freeman B, Reimers K. Tomato consumption and health: emerging benefits. American Journal of Lifestyle Medicine,2011:5(2):182-191.
9. Canene-Adams K, Campbell JK, Zaripheh S, Jeffery EH, Erdman Jr JW. The tomato as a functional food. The Journal of nutrition,2005:135(5):1226-1230.
10. Chauhan K, Sharma S, Agarwal N, Chauhan B. Lycopene of tomato fame: its role in health and disease. International Journal of Pharmaceutical Sciences Review and Research,2011:10(1):99-115.
11. Cheng HM, Koutsidis G, Lodge JK, Ashor AW, Siervo M, Lara J. Lycopene and tomato and risk of cardiovascular diseases: a systematic review and meta-analysis of epiedemiological evidence. Crit. Rev. Food Sci. Nutr.,2017:11:1-18. 10.1080/10408398.2017.1362630 [PubMed] [CrossRef] [Google Scholar]
12. Comstock GW, Alberg AJ, Huang HY, Wu K, Burke AE, Hoffman SC, Helzlsouer KJ. The risk of developing lung cancer associated with antioxidants in the blood: ascorbic acid, carotenoids, alpha-tocopherol, selenium, and total peroxyl radical absorbing capacity. Cancer epidemiology, biomarkers & prevention: a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology,1997:6(11):907-916.
13. Erdman Jr JW. How do nutritional and hormonal status modify the bioavailability, uptake, and distribution of different isomers of lycopene? The Journal of nutrition,2005:135(8):2046S-2047S.
14. Faostat. Global tomato production., 2014. http://faostat.fao.org/. Accessed on June–July.
15. Gajendragadkar PR, Hubsch A, Mäki-Petäjä KM, Serg M, Wilkinson IB, Cheriyan J. Effects of oral lycopene supplementation on vascular function in patients with cardiovascular disease and healthy volunteers: a randomised controlled trial. Plos One,2014:9:e99070. 10.1371/journal.pone.0099070 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
16. Ganesan M, Rajesh M, Solairaj P, Senthilkumar T. Tomato as a pioneer in health management. Int. J. Pharm. Chem. Biol. Sci,2012:2(3):210-217.
17. Gann PH, Ma J, Giovannucci E, Willett W, Sacks FM, Hennekens CH, *et al*. Lower prostate cancer risk in men with elevated plasma lycopene levels: results of a prospective analysis. Cancer research,1999:59(6):1225-1230.
18. Gross J. Pigments in fruits. London, UK: Academic Press., 1987.
19. Halliwell B, Gutteridge JM. Free radicals in biology and medicine. Oxford university press, USA., 2015.
20. Han GM, Liu P. Higher serum lycopene is associated with reduced prevalence of hypertension in overweight or obese adults. Eur. J. Integr. Med.,2017:13:34-40. 10.1016/j.eujim.2017.07.002 [CrossRef] [Google Scholar]
21. Hollman PC, Cassidy A, Comte B, Heinonen M, Richelle M, Richling E, Vidry S. The biological relevance of direct antioxidant effects of polyphenols for cardiovascular health in humans is not established. The Journal of nutrition,2011:141(5):989S-1009S.
22. Kim JY, Paik JK, Kim OY, Park HW, Lee JH, *et al*. Effects of lycopene supplementation on oxidative stress and markers of endothelial function in healthy men. Atherosclerosis,2011:215:189-195. 10.1016/j.atherosclerosis.2010.11.036 [PubMed] [CrossRef] [Google Scholar]
23. Kong KW, Khoo HE, Prasad KN, Ismail A, Tan CP, Rajab NF. Revealing the power of the natural red pigment lycopene. Molecules,2010:15:959-987. 10.3390/molecules15020959 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
24. Krasinska B, Osinaka A, Osinski M, Krasinska A, Rzymski P, Tykarshi A, *et al*. Standardised tomato extract as an alternative to acetylsalicylic acid in patients with primary hypertension and high cardiovascular risk – a randomized, controlled trial. Arch. Med. Sci., 2017. 10.5114/aoms.2017.69864 [CrossRef] [Google Scholar]
25. Li X, Xu J. Lycopene supplement and blood pressure: an updated meta-analysis of intervention trials. Nutrients,2013:5:3696-3712. 10.3390/nu5093696 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
26. Lorenz M, Fechner M, Kalkowski J, Fröhlich K, Trautmann A, Böhm V, *et al*. Effects of lycopene on the initial state of atherosclerosis in New Zeeland White (NZW) rabbits. Plos One,2012:7:e30808. 10.1371/journal.pone.0030808 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
27. Männistö S, Smith-Warner SA, Spiegelman D, Albanes D, Anderson K, Van Den Brandt PA, *et al*. Dietary carotenoids and risk of lung, 2004.
28. Milani A, Basirnejad M, Shahbazi S, Bolhassani A. Carotenoids: biochemistry, pharmacology and treatment. Br. J. Pharmacol.,2017:174:1290-1324. 10.1111/bph.13625 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
29. Müller L, Caris-Veyrat C, Lowe G, Böhm V. Lycopene and its antioxidant role in the prevention of cardiovascular diseases – A critical review. Crit. Rev. Sci. Nutr.,2016:56:1868-1879. 10.1080/10408398.2013.801827 [PubMed] [CrossRef] [Google Scholar]
30. Napolitano M, De Pascale C, Wheeler-Jones C, Botham KM, Bravo E. Effects of lycopene on the induction of foam cell formation by modified LDL. Am. J. Physiol. Endocrinol. Metab.,2007:293:E1820–E1827. 10.1152/ajpendo.00315.2007 [PubMed] [CrossRef] [Google Scholar]
31. Naz A, Butt MS, Sultan MT, Qayyum MM, Niaz RS. Watermelon lycopene and allied health claims. EXCLI J.,2014:13:650-660. [PMC free article] [PubMed] [Google Scholar]

32. Pennathur S, Maitra D, Byun J, *et al*. Antioxidativeactivity of lycopene: a potential role in scavenging hypochlorous acid. Free RadicBiol Med,2010:49:205-213.
33. Pereira BLB, Reis PP, Severino FE, Felix TF, Braz MG, Nogueira FR, *et al*. Tomato (Lycopersiconesculentum) or lycopene supplementation attenuates ventricular remodeling after myocardial infarction through different mechanistic pathways. J. Nutr. Biochem.,2017:46:117-124. 10.1016/j.jnutbio.2017.05.010 [PubMed] [CrossRef] [Google Scholar]
34. Perveen R, Suleria HAR, Anjum FM, Butt MS, Pasha I, Ahmad S. Tomato (Solanum lycopersicum) carotenoids and lycopenes chemistry; metabolism, absorption, nutrition, and allied health claims—A comprehensive review. Critical reviews in food science and nutrition,2015:55(7):919-929.
35. Rao AV, Agarwal S. Role of antioxidant lycopene in cancer and heart disease. Journal of the American College of Nutrition,2000:19(5):563-569.
36. Riccioni G, Scotti L, Di Ilio E, Bucciarelli V, Ballone E, De Girolamo M, *et al*. Lycopene and preclinical carotid atherosclerosis. J. Biol. Regul. Homeost. Agents,2011:25:435-441. [PubMed] [Google Scholar]
37. Ried K, Fakler P. Protective effect of lycopene on serum cholesterol and blood pressure: meta-analyses of intervention trials. Maturitas,2011:68:299-310. 10.1016/j.maturitas.2010.11.018 [PubMed] [CrossRef] [Google Scholar]
38. Sawardekar SB, Patel TC, Uchil D. Comparative evaluation of antiplatelet effect of lycopene with aspirin and the effect of their combination on platelet aggregation: an *in vitro* study. Indian J. Pharmacol.,2016:48:26-31. 10.4103/0253-7613.174428 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
39. Schierle J, Bretzel W, Bühler I, Faccin N, Hess D, Steiner K, *et al*. Content and isomeric ratio of lycopene in food and human blood plasma. Food Chemistry,1997:59(3):459-465.
40. Steinmetz KA, Potter JD. Vegetables, fruit, and cancer. I. Epidemiology. Cancer Causes & Control,1991:2(5):325-357.
41. Thies F, Mills LM, Moir S, Masson LF. Cardiovascular benefits of lycopene: fantasy or reality? Proc. Nutr. Soc.,2017:76:122-129. 10.1017/S0029665116000744 [PubMed] [CrossRef] [Google Scholar]
42. Walfisch Y, Walfisch S, Agbaria R, *et al*. Lycopene in serum, skin and adipose tissues after tomato-oleoresin supplementation in patients undergoing haemorrhoidectomy or peri-anal fistulotomy. Br J Nutr,2003:90:759-766.
43. Wang X, Lv H, Gu Y, Wang X, Cao H, Tang Y, *et al*. Protective effect of lycopene on cardiac function and myocardial fibrosis after acute myocardial infarction in rats via the modulation of p38 and MMP-9. J. Mol. Histol.,2014:45:113-120. 10.1007/s10735-013-9535-2 [PubMed] [CrossRef] [Google Scholar]
44. Wang Y, Jacobs EJ, Newton CC, McCullough ML. Lycopene, tomato products and prostate cancer-specific mortality among men diagnosed with nonmetastatic prostate cancer in the Cancer Prevention Study II Nutrition Cohort. International Journal of Cancer,2016:138:2846-2855.
45. Xu X R, Zou ZY, Huang YM, Xiao X, Ma L, Lin XM. Serum carotenoids in relation to risk factors for development of atherosclerosis. Clin. Biochem.,2012:45:1357-1361. 10.1016/j.clinbiochem.2012.07.101 [PubMed] [CrossRef] [Google Scholar]