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Review

Beneficial effects and potential risks of tomato consumption for human health: An overview

Bahare Salehi Ph.D. [a], Razieh Sharifi-Rad Ph.D. [b], Farukh Sharopov Ph.D. [c], Jacek Namiesnik Ph.D. [d], Amir Roointan Ph.D. [e], Madhu Kamle Ph.D. [f], Pradeep Kumar Ph.D. [f,*], Natália Martins Ph.D. [g,h,*], Javad Sharifi-Rad Ph.D. [i,h,*]

[a] Student Research Committee, School of Medicine, Bam University of Medical Sciences, Bam, Iran
[b] Zabol Medicinal Plants Research Center, Zabol University of Medical Sciences, Zabol, Iran
[c] Department of Pharmaceutical Technology, Avicenna Tajik State Medical University, Dushanbe, Tajikistan
[d] Department of Analytical Chemistry, Faculty of Chemistry, Gdańsk University of Technology, Gdańsk, Poland
[e] Department of Medical Biotechnology, School of Advanced Medical Sciences and Technologies, Shiraz University of Medical Science, Shiraz, Iran
[f] Department of Forestry, North Eastern Regional Institute of Science and Technology, Arunachal Pradesh, India
[g] Faculty of Medicine, University of Porto, Alameda Prof. Hernâni Monteiro, Porto, Portugal
[h] Institute for Research and Innovation in Health (i3S), University of Porto, Porto, Portugal
[i] Food Safety Research Center (salt), Semnan University of Medical Sciences, Semnan, Iran

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ABSTRACT

Tomato and its derived products have a very interesting nutritional value in addition to prominent antioxidant, anti-inflammatory, and anticancer activities. Tomatoes are generally quite safe to eat. However, overall consumption varies from individual to individual. Indeed, either beneficial or harmful effects of plants or their derived products are closely related to quality, including the presence of biologically active compounds. On the other hand, the synthesis and accumulation of these bioactive molecules depends on many other factors, such as environmental conditions. In this sense, this review briefly highlights the relationship between the chemistry of tomato and its derived products and their beneficial or harmful effects on human health, such as gastroesophageal reflux disease or heartburn, allergies, kidney and cardiovascular disorders, prostate cancer, irritable bowel syndrome, lycopenodermia, body aches, arthritis, and urinary problems.

Introduction

Tomato, a member of an important plant family called Solanaceae, is one of the most-produced vegetables around the world and also is considered a favorite vegetable in many different nations [1]. Potato, pepper, aubergine (eggplant), belladonna, tobacco, and even velvet tongue, are other favorable and widely popular members of this plant family with distinct food, pharmaceutical, and ornamental applications [2–4]. Potatoes are a good sources of iron, phosphorous, calcium, magnesium, and zinc, which help in the body to build and maintain bone structure and strength. The fiber content in potatoes helps lower the total amount of cholesterol in the blood, thereby decreasing the risk of heart disease. Choline is an important nutrient that helps with muscle movement, mood, learning, and memory. Potatoes also contain folate, which plays a role in DNA synthesis and repair, and so it prevents many types of cancer cells from forming as a result of mutations in the DNA. Vitamin C and quercetin also function as antioxidants, protecting cells against damage from free radicals [5]. Aubergines are an excellent source of dietary fiber and vitamins B1 and B6 and potassium. They are also high in the minerals copper, magnesium, and manganese. Aubergines are rich in antioxidants, specifically nasunin, found in aubergine skin, which gives it its purple color [6]. Tomatoes' availability, good taste, low price, and distinct health benefits are unique features that make it a popular and in-demand vegetable among adults and children [7]. In terms of nutritional composition, tomatoes contain interesting amounts of moisture (95%), carbohydrates (3%), protein (1.2%), total lipids (1%), minerals (calcium [Ca], magnesium [Mg], phosphorus [P], potassium [K], sodium [Na], zinc [Zn], manganese [Mn] and others), and vitamins (vitamins A and C, thiamin, riboflavin, niacin, pantothenic acid, and pyridoxine) [8–11]. In addition, they are a good

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* Corresponding author. Tel.: +351-225-512-100; +982188200124; +917628841479.
E-mail addresses: pkbiotech@gmail.com (P. Kumar), ncmartins@med.up.pt (N. Martins), javad.sharifirad@gmail.com (J. Sharifi-Rad).

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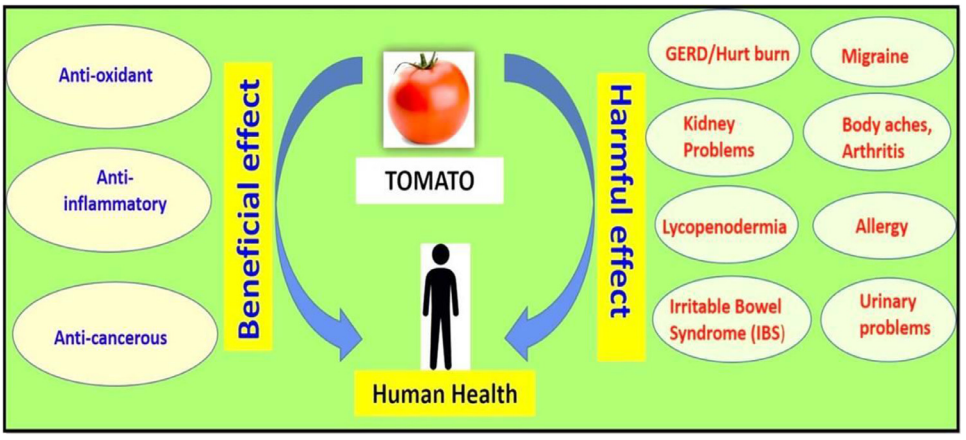

Fig. 1. Beneficial and harmful effects of tomato on human health.

source of phenolic compounds (phenolic acids and flavonoids), carotenoids (lycopene, β-carotene) and glycoalkaloids (tomatine) [12].

Phenolic compounds and carotenoids are the main biologically active compounds present in ripened tomatoes. In fact, the red color of a ripe tomato is because of a significant amount of lycopene [11,13]. Tomatine, a mildly toxic glycoalkaloid or glycospirosolane (steroidal alkaloids whose structure contains a spirosolane skeleton), is also found in both tomato stems and leaves and in the fruit of unripe (green) tomatoes (up to 500 mg/kg). Red, ripe tomatoes have somewhat reduced amounts of tomatine, although strong physiological effects on both humans and animals have been reported. The tomatine toxicity of tomato leaves consumption as tea has also been stated. Raw tomato consumption can lead to allergies and may even cause extremely severe anaphylaxis, especially in children and individuals susceptible to allergies [14]. The main symptoms characterizing tomatine acute toxicity in laboratory animal studies include vomiting, diarrhea, abdominal pain, drowsiness, confusion, weakness and depression, similar to the symptoms of solanine (potato glycoalkaloid) poisoning [15]. In fact, alkaloids are toxic compounds present in tomato and their structure is similar to nicotine. Most alkaloids are crystalline compounds and can be found freely in plants. Also, tomatoes contain citric acid, which can display some negative effects on cellular metabolism, naturally causing cellular metabolic activity and energy production (Fig. 1).

In this sense, and based on these highlighted data, this review aims to give an eye-opening look at the relationship between the chemistry of tomato and its derived products and their beneficial or harmful effects on human health, briefly specifying its effects on gastroesophageal reflux disease (GERD), allergies, kidney and cardiovascular disorders, prostate cancer, irritable bowel syndrome, lycopenodermia, body aches, arthritis, and urinary problems.

Health benefits of tomato

Among the wide variety of chemical constituents present in tomato and its derived products, isoprenoids constitute a very representative group, which includes lycopene, β-carotene, γ-carotene, ζ-carotene, phytoene, phytofluene, lutein, neoxanthin, violaxanthin, α-cryptoxanthin, zeaxanthin, β-cryptoxanthin, cyclolycopene, neurosporene, and β-carotene-5,6-epoxide. The chemical structures of the main carotenoids present in tomato and its derived products are shown in Figure 2.

Some studies have found a direct relationship between plasma or serum lycopene levels and tomato consumption [9,12,13]. Based on other data, lower lycopene levels in serum or plasma have been found to increase the likelihood of developing cancer [14–16]. Also, other experiments have found a direct association between body lycopene levels and specific markers triggering different disorders, such as osteoporosis [17,18], cardiovascular diseases [19], and cognitive function [20]. In addition, researchers have found a

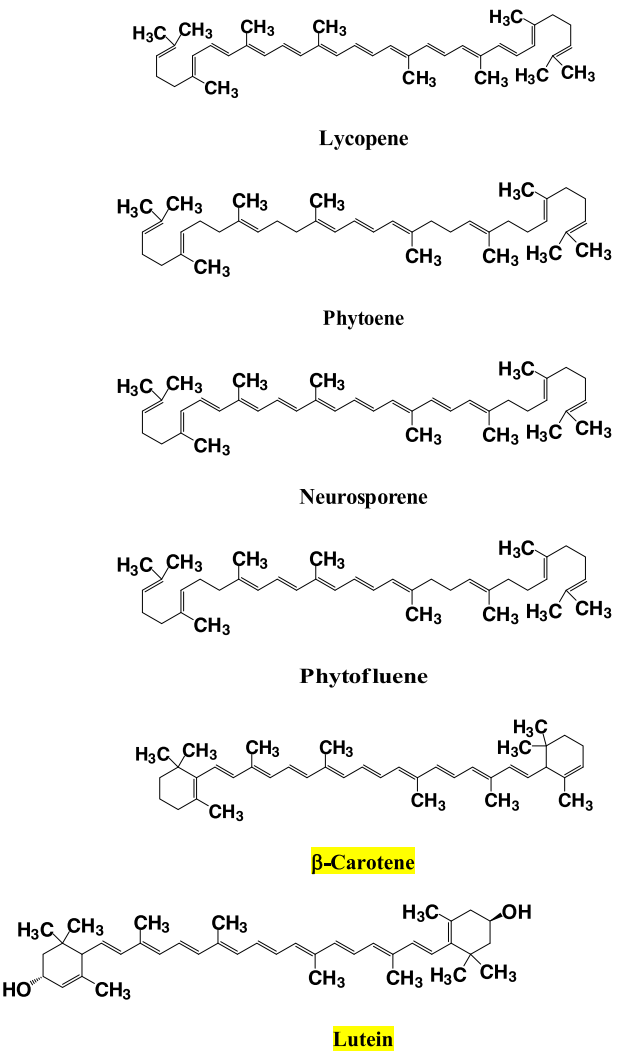

Fig. 2. Chemical structures of main carotenoids in tomatoes and tomato products.

Table 1
Concentration of carotenoids in different tomato and its derived products (mg/100 g) [9]

Carotenoids	Raw tomato	Tomato paste	Tomato sauce	Tomato juice
Lycopene	9.2	55.4	18.0	10.8
Phytoene	1.9	8.4	3.0	2.8
Neurosporene	1.2	7.0	2.5	2.0
Phytofluene	0.8	3.6	1.3	0.8
β-Carotene	0.4	1.3	0.5	0.4
Lutein	0.1	0.3	traces	0.1

direct relationship between tomato consumption and the risk of several cancers and cardiovascular diseases [21–24].

According to these experiments, tomato antioxidant effects are the most prominent beneficial feature of this vegetable, mainly attributed to the presence of lycopene and other antioxidant vitamins (e.g., A and C) on its composition. Concentrations of some carotenoids in tomatoes and tomato-based food products are briefly summarized in Table 1.

Lycopene is the most studied tomato constituent with confirmed antioxidant and anticancer activities. In fact, tomato and tomato-based foods, such as tomato sauce, tomato paste, and so on, are known as the major sources of carotenoid intake in most countries. In addition, this water-insoluble pigment is one of the main carotenoids present in tomato, being also responsible for its red color [25]. Same as all carotenoids, lycopene has a long-chain structure with dienes. However, the higher number of conjugated double bonds in its structure renders it as a potent singlet oxygen quencher and, based on some reports, the lycopene effectiveness and antioxidant activity are 10 times higher than vitamin E [26,27]. As a result, almost all scientists recognized the lycopene as the most beneficial tomato compound with distinct health-promoting effects, particularly its antioxidant activity, which is well documented by different studies. Moreover, apart from its antioxidant activity, recent findings have suggested the lycopene tuning ability in intercellular communications and metabolic and immune system pathways [28–30].

Various investigations have been performed on tomatoes' anticancer potential. Most of them have found a protective relationship between tomato intake and cancer risk [7]. For instance, prostate cancer is the most widely investigated type of cancer, and it has been proven to be highly affected by tomato intake and body lycopene levels. The increase in prostate cancer cells' apoptosis rate and an improvement in prostate-specific antigen concentration were the most remarkable positive results found using tomato products [31–35].

Although a lot of experiments have been done to check tomato anticancer effects, it is important to highlight that most of them were observational studies and measured cancer markers instead of other cancer aspects. Recent studies have reported a close relationship between tomato consumption and prostate cancer risk, where tomato intake seems to be associated with a reduced risk of prostate cancer. A meta-analysis considering a geographic region subgroup indicated that there are significant protective effects of tomato consumption in Asian and Oceanic populations, but not in other geographic populations [36]. Therefore, to achieve a real cause-effect association between tomato consumption and cancer risk, more interventional experiments on larger samples are required.

The impact of tomato consumption on cardiovascular disease (CVD) incidence is another beneficial health effect that has been confirmed by different studies [37-39]. In one experiment, women consuming higher amounts of tomato products (>7 servings/wk) had a lower risk of CVD [37]. Other studies also revealed the positive impact of daily tomato intake on serum levels of lipid peroxides and low-density lipoprotein (LDL) oxidation [40–42]. Given that LDL oxidation levels are important in atherosclerosis progression, daily tomato product intake as a source of antioxidant molecules may reduce the risk of CVD. On the other hand, tomato and its derivatives have also found to be beneficial in reducing inflammation and thrombosis incidence. In fact, some experiments have revealed the effects of tomato juice consumption, constituted of definite amounts of lycopene and vitamin C, on decreasing the inflammatory marker C-reactive protein and total cholesterol levels in the studied individuals [43,44]. Moreover, tomato extracts were found to have some antithrombotic activities that affect platelet functions and platelet aggregation. Such findings were obtained by both in vitro and ex vivo experiments, where the tomato extract evidenced a remarkable performance in altering platelet behavior [45,46].

Apart from the inhibitory effects of tomato on cancer and CVD incidence, which seems to be closely related to its antioxidant activity, some promising results have indicated the beneficial impact of this vegetable in promoting healthy skin, bones, and brain. In a recent experiment, tomato and rosemary effects were checked on skin erythema, triggered by ultraviolet (UV) radiation exposure. Given together, tomato and rosemary extracts provided great synergistic effects on interleukin-6 (IL-6) secretion and erythema intensity in UV-exposed skin. Furthermore, the phytonutrients present in tomato extract have been found to have a regulatory effect on some UV-inducible genes, which are considered skin health biomarkers [47]. Other experiments also reported the skin protection potential of tomatoes. According to these experiments, a regular intake of tomato paste for about 8 weeks can decrease UV-induced skin erythema and skin carcinoma in humans [48–50].

Based on some epidemiologic data, it is possible to affirm the existence of a positive relationship between serum lycopene concentration and healthy bone and brain states. In fact, in one survey, osteoporotic women had lower lycopene concentration in their serum samples compared with healthy controls. Similarly, serum lycopene concentration was extremely low in individuals with impaired brain function [51–53]. In addition, tomato consumption also provided remarkable benefits in reducing lead toxicity, decreasing the risk of stroke, inducing faster wound repair, reducing heart diseases, and facilitating the process of glucose and insulin uptake in diabetic individuals, as a result of its high amounts of vitamin C, pyridoxine, and folate [54].

Nonetheless, it is important to highlight that all these accumulating data on tomato's health benefits are mostly associated with its famous antioxidant component lycopene. Such information encourages high tomato consumption as a low-energy food and as a source rich in antioxidants. However, further studies are still needed to confirm and solidify the current data on tomato's beneficial effects, especially in new areas such as skin, bone, and brain health.

Harmful effects of tomato

Along with the previously cited tomato health benefits, several undesired side effects have been related to consumption of tomato and tomato-based products. Given the presence of various beneficial components in tomatoes, the results of most experiments should encourage people to include more tomato products as part of their daily and weekly diets. However, both the excessive and sometimes regular consumption of this vegetable can cause distinct side effects in the human body. The most common adverse effects of tomato intake and their main causes are summarized in Table 2 [55-113].

Table 2
Adverse effects of tomato intake

Disease	Reasons	Reference
Gastroesophageal reflux disease (heartburn)	Organic acids (citric and malic acids) are the most potent triggers of acid reflux in prone individuals and higher tomato consumers	[55–63]
Allergies	β–fructofuranosidase, Lyc e 2, Lyc e 3, profilin, superoxide dismutase, pectinesterase, polygalacturonase, lipid transfer protein cyclophilin	[56–60, 64–70]
Kidney problems	High potassium and oxalate concentrations; oxalate can react with calcium, increasing risk of kidney stones (calcium oxalate)	[71–80]
Irritable bowel syndrome	High amount consumption of skin and seeds of tomato	[81–83]
Lycopenodermia	Extra amounts of lycopene in blood	[83,84]
Urinary problems	Organic acids	[85–94]
Body aches, arthritis	Glycoalkaloids (tomatine and solanine), tomato and its derived products	[95–107]
Migraine	Tomato and its derived products	[108–113]

GERD (heartburn)

Consumption of tomato or its products is one of the main causes of GERD (also known as heartburn). In this condition, individuals experience a state in which a high amount of acid washes back into the gullet. The sensation of chest pain, the sour taste of sore throat and burning are some of the unfavorable symptoms [61]. Based on various experiments, dietary habits are considered the main cause of GERD. In one survey, tomato and tomato juice consumption were higher in GERD patients compared with healthy controls [62]. Also, both the frequency and amount of consumption of tomato and its derived products in GERD-suffering patients were higher than in healthy individuals [63,114,115]. Indeed, it is assumed that the two prominent organic acids present in tomato, citric and malic acids, are the most potent triggers of acid reflux in at-risk individuals and higher tomato consumers [55]. In this sense, limiting consumption of tomato and its derivatives and all foods containing tomato (parsley, tomato sauce, tomato juice, etc.) are some of the dietary recommendations highly recommended by many experts [116].

Allergies

Allergies usually occur immediately after consumption of allergy-inducing foods. Tomato is one of the known allergens causing different symptoms in at-risk individuals, such as sneezing, skin-related problems (eczema, rashes, etc.), red eyebrows/eyelids, itching throat, and swelling of mouth and face [64]. In some situations, even touching tomatoes can cause allergic reactions (dermatitis) in some individuals [65].

The occurrence of tomato allergic responses among different populations means that this vegetable has allergic compounds in its composition. Various studies have successfully purified and characterized different allergens from tomato. In one experiment, a glycosylated tomato protein (β–fructofuranosidase, Lyc e 2) was purified, characterized, and introduced as one of the main tomato allergens with a huge ability to trigger histamine release from basophils [66]. In another experiment, profilin was identified as another tomato allergen with a great ability to induce histamine release and, consequently, trigger allergic responses in 22% of individuals with tomato allergy [67]. Superoxide dismutase, pectinesterase, polygalacturonase, lipid transfer protein Lyc e 3, and cyclophilin, with different allergy-induction abilities, comprise other well-known and recognized tomato allergic compounds [56–60]. Interestingly, some reports proposed a reduction in tomato allergic responses by diminishing the allergens' expression in this vegetable. For instance, in one experiment, lipid transfer protein Lyc e 3, a potent tomato allergic compound, was reduced by a specific RNA interference construct [59]. The authors proposed that the reduction of this protein expression allows a marked decrease in histamine release from sensitized human basophils. Moreover, according to the European Food Safety Authority, heavy metal accumulation in the body can cause serious effects. For example, nickel, one of the heavy metals commonly found in tomato, can cause allergic reactions on short-term exposure, and long-term exposure has been linked to developmental and reproductive effects in animal studies [114].

Kidney problems

According to some reports, regular tomato consumption may provide considerable protection against several kidney disorders [68]. However, according to the US Department of Health and Human Services, individuals with kidney problems should reduce their intake of potassium, a chemical element that is found in tomatoes at high concentration [69]. In fact, the potassium concentration present in tomato is reported to be five times greater than sodium [11]. Thus patients with chronic renal dysfunction and damaged renal potassium excretion are at high risk for a life-threatening disorder called hyperkalemia [70]. In this condition, serum potassium levels are greater than the normal limits (5–5.5 mEq/L) [117]. Therefore limiting potassium-rich foods and vegetables, such as blueberries, tomato, potato, beet greens, milk, yogurt, among others, is a crucial recommendation for prevention and control of hyperkalemia [71–73].

Oxalate is the other risky compound in tomato and its derivatives, especially in tomato sauce. This chemical compound, together with calcium, has been found to be influential in both formation and recurrence of related kidney stones [74,75]. Therefore avoiding tomato sauce, a rich source of oxalate, is highly recommended by many experts to reduce the risk of kidney stones [76,77].

Irritable bowel syndrome

Irritable bowel syndrome (IBS) is a common gastrointestinal disorder characterized by various symptoms, such as altered bowel movements, bloating, abdominal pain, and frequent episodes of constipation or diarrhea [78]. It is estimated that this condition affects 15% of people worldwide [79]. Although there is no specific treatment for IBS, foods and eating habits are the most influential factors in triggering or preventing this condition [80]. Because of the allergenic nature of tomato, consuming this vegetable and its products can possibly cause some intestinal problems [118]. On the other hand, tomato skin and seeds may be irritating to some people and cause bloating and diarrhea, which is commonly found in IBS patients [119,120]. Other case reports have also found a

direct association between high tomato consumption and some gastrointestinal disorders [121].

Lycopenodermia

As previously mentioned, the tomato is a rich source of lycopene, a potent antioxidant with distinct health benefits. Regular lycopene intake via tomato consumption is highly recommended by experts. However, consuming high amounts of tomato can lead to extra amounts of lycopene in blood and plasma of individuals, which consequently leads to a skin discoloration condition called lycopenodermia [81]. Although this condition is reversible and does not constitute a real health threat, people with lycopenodermia may feel uncomfortable and suffer from other outcomes caused by high lycopene levels in their blood [80].

Urinary problems

Acidic foods, fruits, vegetables, and beverages such as coffee and tea are usually considered possible bladder irritants that may enhance the chance of urinary incontinence (uncontrolled urine leakage) [82,83]. Accordingly, consuming tomato as one of the acidic vegetable sources can irritate the bladder and cause urinary incontinence.

Cystitis is another bladder-related condition, in which patients feel bladder pressure and burning [84]. According to some specialists, excessive consumption of some foods, including chocolate, caffeine, different artificial sweeteners, and tomatoes, can cause cystitis and exacerbate undesired bladder symptoms [84,85]. In a cross-sectional study using a web-based questionnaire, the impact of 344 different foods, ingredients, beverages, and supplements on undesired bladder symptoms were evaluated [86]. Almost all of the 600 individuals who participated in this research scored several items, such as tomatoes, spicy foods, vitamin C, citrus fruits, tea, and coffee, as leading to worsening of undesired bladder symptoms. The effects of tomato and tomato-based foods on painful bladder syndrome exacerbation were also reported in other studies [87–91]. As a result, patients with bladder problems are recommended to avoid tomato and tomato-based foods.

Body aches

Solanine, tomatine, and solasonine are some of the well-known toxic glycoalkaloids in almost all nightshades (e.g., eggplant, potato, tomato, tobacco). The likely responsibility of these bitter-tasting compounds is plant protection against insects, fungi, and bacteria [92]. Solanine, α-tomatine, and dehydrotomatin are well-known toxic glycoalkaloids mostly found in green tomato [92,93]. The chemical structure of tomatine and solanine is depicted in Figure 3.

Based on a report, even small amounts of this glycoalkaloids can cause gastrointestinal tract disorders and pain [94]. α-Tomatine embryotoxicity [95] is another pharmacologic and toxicologic feature, given its high affinity to cholesterol [96] and cell membrane disruption ability [97].

Arteritis is an inflammatory condition in which blood vessel walls are compromised. Such a condition eventually leads to swollen and painful joints as a result of a decrease in the bloodstream in the organs. Some researchers believe that eating habits and some specific foods are the main factors influencing arteritis onset or progression [98–101]. In a case-control experiment, the consumption of several foods, including tomatoes and cantaloupe, was found to be higher in individuals with arteritis when compared with healthy controls [102]. Likewise, in another survey involving about 1000 patients with arthritis, tomatoes and other nightshade plants, such as potato and eggplant, were recognized as foods that may exacerbate inflammation and pain conditions [103]. Based on these studies, and according to some experts, dietary restriction and avoidance of some foods, including tomatoes and other nightshade plants, are highly recommended for patients with arthritis and pain conditions [104].

Migraine

Migraine is a well-known, common headache condition in which a patient feels pulsating pain in one half of the head [105]. About 15% of people worldwide suffer from this chronic condition [106]. Based on some experiments, nutrition has been considered as one of the predisposing factors that can affect the onset, duration, and severity of migraine [107,108]. In a case-control study in 170 women with migraine, consumption of different vegetables, including tomatoes, was significantly higher in the case group [109]. This finding, together with another similar experiment that introduced tomato and its products as one of the vegetables leading to migraine onset [110], suggested the apparent effects of tomato consumption on this headache.

Pollutant accumulation and xenobiotics detoxification in tomato plant

Pollutants pose a greater threat to tomato than other vegetables. Heavy metals, soil herbicides, pesticides, atmospheric gaseous pollutants, and ethylene gas (greenhouse gas) are the main

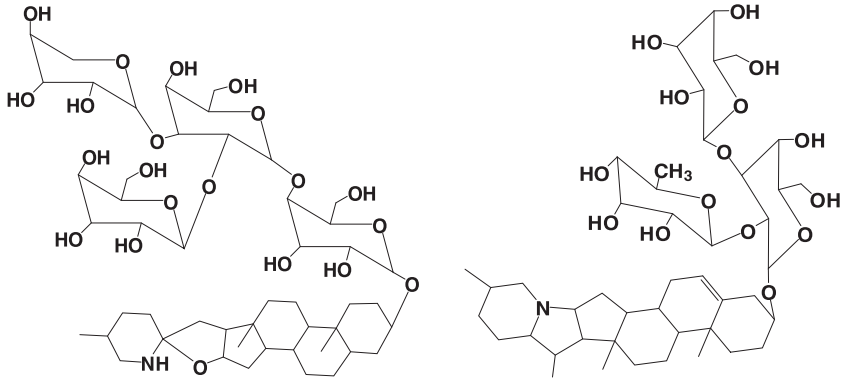

Fig. 3. Chemical structure of the tomato glycoalkaloids tomatine and solanine.

pollutants that threaten tomato crops. Anderson and Mansfield [111] reported that, in glasshouses, nitric oxide is the predominant air pollutant that can increase or reduce tomato growth. Azariz et al. [125] studied heavy metal uptake by *Lycopersicon esculentum* and other plants near a metal-scrap dumpsite in Zaria, Nigeria, and found that metal accumulation levels were higher than those at the control site. Shilev and Babrikov [112] studied the heavy metal accumulation in Solanaceae plants and concluded that tomato is not a suitable crop to be grown in industrially polluted areas because it accumulates significant amounts of heavy metals that can be dangerous for consumption. Haque et al. [113] investigated the pattern of heavy metal uptake and assessed the health risk of adult men and women through the consumption of tomato grown in industrially contaminated soils. The levels of iron (Fe), manganese (Mn), copper (Cu), zinc, chromium (Cr), and lead (Pb) were determined in tomato dried fruits, leaves, shoots, and roots using an atomic absorption spectrophotometer. The pattern of heavy metal uptake was in the sequence of Cr > Fe > Mn > Cu > Zn = Pb in fruits; Fe > Cr > Mn > Cu > Zn > Pb in leaves; Fe > Cr > Mn > Zn > Cu > Pb in roots; and Cr > Fe > Mn > Zn > Cu > Pb in shoots of tomato, respectively [113]. In addition, the authors reported that the consumption of Cr through the food chain via tomato consumption was unsafe [113]. Phenanthrene and cadmium pollutant treatment resulted in decreased tomato growth and photosynthetic capacity [122]. Opeolu et al. [123] found that plant performance significantly reduced as the concentration of Pb contamination increased. The authors also detected Pb residue in the tomato root and shoot but not in fruits. In addition, they found that the vitamin C content of tomato was not affected by various concentrations of Pb contaminants. Indeed, Pb contamination has adverse effects on tomato production but not on vitamin C content [123]. On the other hand, a study carried out on soil contaminated with heavy metals found that the concentration of cadmium, Cu, Cr, Pb, and Zn at 90% of the sites in vegetables and tomatoes was greater than the Food and Agriculture Organization/World Health Organization limit and therefore poses a health risk for consumers [124]. The experiments of phytoavailability in bioponics of lead and chromium found higher lead accumulation rates in roots, stem, and leaves, reaching very small amounts in fruit. However, chromium decreases in roots and increases in the fruit [125]. A comparative study on physical and biochemical properties of tomato grown under normal soil and heavy metal–contaminated soil found that heavy metal–contaminated soil had an adverse effect on tomatoes' lycopene, vitamin C, carbohydrate, microelement, and total soluble solids levels, in addition to the expected and very dangerous higher heavy metal levels [114].

There is a more in-depth study on lead concentration, which is one of the most worrying contaminants because of its high toxicity, even at low concentrations. According to the US Food and Drug Administration, a lead that enters into tomatoes and other plants through the soil as they grow cannot be completely washed away. No lead levels are considered safe, and chronic exposure leads to nervous system and brain damage, developmental delays, and hearing, speech, learning, and behavioral problems [114].

Similarly, cadmium accumulation from contaminated soil may cause kidney toxicity, leading to renal failure and bone demineralization and has been classified as a human carcinogen. In addition, cadmium has been linked with an increased risk of lung, bladder, breast, and endometrial cancer, making avoiding this heavy metal as much as possible absolutely essential [114].

Inherently, plants have the ability to detoxify xenobiotics for their survival. Bhuvaneswari et al. [126] reported the combinatorial antigenotoxic and anticarcinogenic effects of tomato through modulation of xenobiotic-metabolizing enzymes during hamster buccal pouch carcinogenesis. In fact, the application of brassinosteroids in tomato plants clearly attenuated the negative effects of both phenanthrene and cadmium pollutants, which involves antioxidant enzymes activity, xenobiotic detoxification capacity, and secondary metabolism stimulation [122].

Conclusions

The beneficial or harmful effects of tomato and tomato-based products are closely related to the presence and abundance of various biologically active compounds, such as carotenoids (lycopene, β-carotene), potassium, some proteins (Lyc e 2, Lyc e 3, profilin), and organic acids (citric, malic, and oxalic acids) and the presence of glycoalkaloids (tomatine and solanine). Therefore the detrimental effects of these compounds vary according to individual consumption. Several studies have stated a contradictory linkage between tomato and tomato product intake and the incidence of diseases. Therefore there is a need to explore the different doses of tomato phytochemical constituents, through in vitro and in vivo experiments, toward a precise assessment of beneficial and harmful effects on human health.

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