

# Lycopene Extracted from Tomato - A Review

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**Abstract** Lycopene, a bioactive compound found in tomatoes, has gained significant attention in recent years due to its various nutritional and physiological properties, including its antioxidant, anti-inflammatory, and anti-cancer effects. These properties can be the subject of claims. This review explores the source of lycopene from tomato, their potential uses and benefits. Equally, we discussed the nutrition and health claims related to lycopene. The importance of tomatoes as a rich source of lycopene and their nutritional composition was highlighted and compared with other fruits and vegetables. We discussed the use of lycopene in various food, pharmaceutical, and cosmetic products as a natural colorant. Then, the nutraceutical properties of lycopene were examined with emphasizing its role as an antioxidant and its potential to prevent cardiovascular diseases and some types of cancer. Furthermore, this paper discusses the regulatory aspects and permissible limits of lycopene usage in different countries, especially Morocco, the European Union, and the United States. It also emphasizes the regulatory texts governing food supplements and claims in these countries. Upon evaluating the Moroccan regulations regarding nutritional and health claims, it can be observed that the competent authority has thoroughly outlined the requirements for using them. However, there is a legal vacuum concerning the use of health entitlements. In

contrast, the European Amalgamation and the United States adopts a rigid policy in this regard. This review provides valuable insights into the potential applications and health benefits of lycopene extracted from tomatoes, underscoring its significance for future research and development.

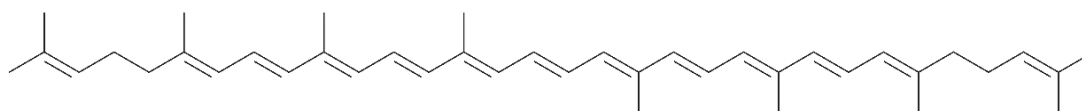
**Keywords** Lycopene, Dietary Supplement, Nutritional Claim, Health Claims

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## 1. Introduction

Numerous bioactive compounds found in natural plant matrices have received significant attention in food production [1], thanks to their different nutritive and physiological properties, such as antioxidant, anti-inflammatory, and anti-cancer properties [2], [3].

Lycopene, the major pigment in tomatoes [4], is a triterpene made up of eight isoprene molecules. Its chemical formula is  $C_{40}H_{56}$ , and its molecular weightiness is  $536,89 \text{ g mol}^{-1}$  [5]. It is a polyunsaturated acyclic carotenoid, containing 11 conjugated binary bonds in the central part of the molecule and two other unconjugated double bonds (Figure 1) [6].



LYCOPENE

**Figure 1.** Chemical structure of lycopene

Lycopene has a high antioxidant capacity due to the existence of conjugated dual bonds, which allows it to neutralize singlet oxygen and scavenge free radicals [7], which protects the body against oxidative stress that causes several cell degradations [8]. The latter is responsible for countless cardiovascular diseases and cancers.

In 1989, Di Mascio et al. [9] found lycopene to be the most effective single oxygen scavenger of over 600 naturally occurring carotenoids.

Numerous investigations have revealed that lycopene extracted from tomato by-products has a therapeutic effect [2], [10]. However, no health claims have been made for this compound, even for use as a dietary supplement. This is because food supplements should not claim prevention, treatment, or cure properties for human disease. Thus, we can legitimately ask the following question: How can we highlight the beneficial effect of lycopene extracted from tomatoes?

This paper aimed to review tomatoes as sources of lycopene. The objective of this review was subdivided as follows: i) explore the tomato as a source of lycopene; ii) identify the potential uses and benefits of lycopene extracted from tomatoes; ii) examine the nutraceutical properties of lycopene; and iii) discuss the regulatory aspects and permissible limits of lycopene usage in different countries especially in Morocco, the European

Union, and the United States. Currently, the regulation of claims is not sufficiently detailed and discussed in Morocco. Therefore, this review is suggested to be of great importance for future studies addressing lycopene.

## 2. Tomato: An Excellent Source of Lycopene

Tomatoes and tomato-based products have many nutritional and physiological benefits because they are rich in various bioactive compounds.

Tomatoes contain a variety of bioactive compounds that are extremely beneficial to one's health. It is rich in carotenoids, in particular  $\beta$ -carotene, lycopene, and lutein. Additionally, it contains potassium and vitamin C [11], [12]. Table 1 shows the chemical composition of fresh tomatoes.

The composition of the tomato depends on the cultivar, the place of cultivation, agricultural techniques, environmental factors (temperature and light), as well as post-harvest storage conditions. Carotenoids have many benefits for human health. They are crucial in the prevention and treatment of some illnesses, such as heart disease and macular degeneration [14].

**Table 1.** Proximate composition of tomato [ 13]

<b>Composite</b>	<b>Values</b>
Moisture (g x100 g <sup>-1</sup> )	91.18 (±6.83)
Energy (Kcal x 100g <sup>-1</sup> )	34.67 (±18.74)
Total protein (g x 100 g <sup>-1</sup> )	17.71 (±5.40)
Lipid (g x 100 g <sup>-1</sup> )	4.96 (±1.19)
Ash (%)	8.75 (±1.69)
Carbohydrates (g x 100 g <sup>-1</sup> )	5.96 (±1.37)
Total fiber (g/100 g <sup>-1</sup> )	11.44 (±9.31)
Total sugar (g x 100 g <sup>-1</sup> )	50.60 (±3.69)
<b>Fatty Acids</b>	
Saturated fatty acids (g/100g)	27.40 (±3.74)
Myristic acid (g/100g)	0.56 (±0.22)
Palmitic acid (g/100g)	18.07 (±2.90)
Stearic acid (g/100g)	4.81 (±1.50)
Monounsaturated fatty acids (g/100g)	13.80 (±2.42)
Palmitoleic acid (g/100g)	0.25 (±0.10)
Oleic acid (g/100g)	14.24 (±3.50)
Polyunsaturated fatty acids (g/100g)	57.55 (±23.51)
Linoleic acid (g/100g)	49.40 (±4.16)
Linolenic acid (g/100g)	10.17 (±4.46)
<b>Minerals</b>	
Calcium (mg/100g)	105.21 (±22.76)
Iron (mg/100g)	4.55 (±2.18)
Magnesium (mg/100g)	172.58 (±58.92)
Phosphorus (mg/100g)	300.99 (±32.12)
Potassium (mg/100g)	403.02 (±254.41)
Sodium (mg/100g)	70.38 (±12.20)
Zinc (mg/100g)	2.48 (±1.05)
Copper (mg/100g)	0.67 (±0.15)
<b>Vitamins</b>	
Vitamin A (IU/100 g)	614.44 (±248.18)
Vitamin E (µg/100 g)	15.08 (±1.06)
Vitamin K (µg/100 g)	98.28 (±0.00)
Vitamin C (mg/100 g)	36.16 (±29.64)
Thiamine (mg/100 g)	0.66 (±0.44)
Riboflavin (mg/100 g)	0.48 (±0.34)
Niacin (mg/100g)	9.68 (±0.00)
Pantothenic Acid (mg/100g)	4.93 (±0.41)
Vitamin B6 (mg/100g)	1.51 (±0.22)
Biotin (µg/100 g)	68.97 (±0.00)
Folates (mg/100 g)	14.00 (±1.00)
<b>Carotenoids</b>	
α-Carotene (µg)	101.00
β-Carotene (µg)	9942.16 (±264.74)
Lycopene (µg)	8002.50 (±243.54)
Lutein + Zeaxanthin (µg)	60.67 (±43.86)

**Table 2.** Lycopene content in some products ( $\mu\text{g}/100\text{g}$  of fresh material) [18]

Food	Content of lycopene ( $\mu\text{g}/100\text{g}$ )
Apricot	54
Pineapple	265-605
Bananas	n.d-247
Squash	500
Fig	320
Guava	769-1816
Mango	<10-724
Kiwi	<10
Grapefruit	750
Papaya	n.d-7564
yellow watermelon	n.d-109
red watermelon	4770-13523
Peach	11
Rhubarb	120
Tomato	850-12700
Tomato (Can)	8480-11820
Cherry tomato	800-12000
Tomato, concentrated	49300-94000
Tomato, juice	1024-11000
Tomato, Ketchup	4710-23400
Tomato, mashed	13160-26110
Tomato, instant sauce	5600-39400
Tomato, instant soup	12400- 19900

One of the main phytochemicals found in tomatoes and tomato-based products is lycopene [15]. It is found in ketchup, juices, sauces, and pastas [16]. It was Millardet who made the initial discovery of lycopene in 1876 [17] from the fruit of the tomato (*Lycopersicon esculentum* Mill.). Table 2 shows the lycopene content in some products. Lycopene is present in tomato and also in other products with different values. The Pineapple contains 265 to 605  $\mu\text{g}/100\text{g}$ , the Guava records 769 to 1816  $\mu\text{g}/100\text{g}$ , and Red watermelon demonstrates 4770 to 13523  $\mu\text{g}/100\text{g}$ . In contrast, Peach and Apricot record the lower values with 11 and 54  $\mu\text{g}/100\text{g}$ , respectively. It should be noted that the lycopene content can change with metabolic and biochemical processes. For this reason, it is essential to monitor the processing and storage conditions (temperature,

humidity, oxygen, and light) to ensure the stability of this compound [1].

### 3. Use of Lycopene

Many colors, including lycopene, are available as natural extracts or as nature-identical colors. These latter, which are non-artificial, are created by chemical synthesis to acquire molecules that are exactly the same as those found in nature [19].

Lycopene or E160d is extensively used as a natural color in many food, pharmaceutical products and cosmetics [20], [21]. It is typically added to food products at rates ranging from 10 to 50 mg/kg [22]. This addition aims to replenish the natural color that was lost during processing and storage, reduce product variation between batches, strengthen natural colors when they are weak, add color to products that are otherwise colorless, and create goods that consumers find appealing [4].

Lycopene is authorized to be incorporated in several foods, including cooked foods, dairy products, cereals of breakfast, bottled water, dairy desserts, carbonated drinks, vegetable and fruit juices, sweets, soups, drinks based on soybeans, and seasonings [23] and this is allowed in many countries, including Morocco, the European Union, Japan, the USA, and the list goes on. Lycopene is also used in food supplements for its antioxidant properties [23].

As indicated in the summary of Color Additives for Use in the United States in Foods, Drugs, Cosmetics, and Medical Devices, both tomato lycopene extract and tomato lycopene concentrate have been authorized for use only in foods since 2006. According to the Color Additive status list, these additives are released from certification and are permanently listed for food use.

In the European Union, The European Food Safety Authority (EFSA) adopted on January 30, 2008, an agreement on lycopene, endorsing an acceptable daily intake (ADI) estimated at 0.5 mg  $\text{kg}^{-1}$  of body weight/day for all sources [24]. However, this dose may be exceeded, especially in the case of children and teenagers. Thus, the usage of lycopene as a food color should therefore be limited. Consequently, Regulation (EU) No. 1129/2011 amending Annex II to Regulation (EC) No. 1333/2008 set the maximum amounts of lycopene authorized for usage in food products.

In Morocco, lycopene can be added to various food products. The maximum limits of this additive authorized for use in food products are set in Joint Order No. 1795-14.

Comparing these two texts, we found that the maximum authorized lycopene limits in Morocco and the European Union are similar (Table 3).

**Table 3.** Maximum amounts of lycopene permitted in some food products [25]

Group of products	Maximum authorized lycopene limits (in mg/l or mg/kg)
Flavored fermented dairy products, including heat-treated	30
Edible cheese rinds	30
Flavored processed cheese	5
Ice cream	40
Jams, jellies, marmalades and similar products except chestnut cream	10 (Maximum used alone or in combination with E104, E110, E120, E124, E142, E160d et E161b)
Similar spreads made from fruit or vegetables except cream of prunes	10 (Maximum used alone or in combination with E104, E110, E120, E124, E142, E160d et E161b)
Confectionery, including micro-confectionery intended for breath freshening	30
Chewing gum	300
Decorations, coatings and fillings, excluding fruit-based fillings except the red coating of chocolate-based confectionery coated with hard sugar	30
Red coating of chocolate-based confectionery coated with hard sugar	200
Batter for coating	30
Fine bakery products	25
Coatings and decorations for meat with the exception of the edible outer part pastures: preparation of beef in brine and green pepper	500
Edible meat casings	30
Salmon substitutes	10
Fish and shellfish pasta, precooked shellfish, surimi, smoked fish	30
Fish roe except sturgeon roe (caviar)	30
Seasonings and condiments	50
Soups, soups and broths	20
Sauces excluding tomato-based sauces	50
Vegetable protein based meat and fish substitutes	30
Foods on a special diet for medical reasons, with the exception of infant formula and foods on a special diet for young children	30
Items on a diet meant to replace a meal or portion of a daily diet in order to control weight	30
Flavored drinks (Excluding diluted drinks)	12
Fruit wines and made wine	10
Flavored wines, Flavored wine-based drinks, Flavored cocktails of wine products	10
Other alcoholic drinks, such as spirits with an alcohol content of less than 15% by volume and combinations of alcoholic and non-alcoholic drinks	30
Snacks made from potatoes, cereals, flour, starch or starch	30
Processed nuts	30
Desserts, excluding dairy products and substitutes, edible ices and fruit and vegetables	30
Food supplements (liquid, syrup, solid, or chewable form) other than those meant for newborns and toddlers	30

**Table 4.** Specifications established for lycopene extracted from red tomatoes [25]

<b>Substitutes</b>	Natural yellow 27
<b>Meaning</b>	Red tomatoes ( <i>Lycopersicon esculentum</i> L.) are extracted in a solvent, and the solvent is then removed to yield lycopene. You may only use the solvent listed below: methanol, carbon dioxide, ethanol, acetone, acetate, propan-2-ol, ethyl, and hexane.  Lycopene is the primary carotenoid pigment that gives tomatoes their color; other carotenoid colorings may be existing at trace levels. In addition to color pigments, the product might also include naturally occurring tomato-based flavors, oils, fats, and waxes.
<b>Composition</b>	$E_{1\text{ cm}}^{1\%} = 465\text{-}475\text{ nm}$ (in hexane for one hundred percent pure all-trans-lycopene) is estimated at 3 450. At least 5% of the overall coloring matters are content.
<b>Explanation</b>	Dark red viscous fluid
<b>Documentation</b>	
<b>Spectrophotometry</b>	Supreme in hexane (at 472 nm)
<b>Purity</b>	
Residual solvents	Propan-2ol, Acetone, Hexane, Methanol, Ethanol, and Ethylacetate. 50 mg/kg maximum, either alone or in combination
Sulphated ash	Not to exceed 1%
Cadmium	Not to exceed 1 mg/kg
Mercury	Not to exceed 1 mg/kg
Arsenic	Not to exceed 3 mg/kg
Lead	Not superior to 2 mg/kg

In the European Union, the regulatory text of the European Commission (EU) No. 231/2012 established specifications for food additives listed in Annexes II and III to Regulation (EC) No. 1333/2008.

In Morocco, the specifications for lycopene are set in Annex III to Joint Order No. 1795-14.

By comparing these two regulatory texts, we found that the specifications for lycopene extracted from red tomatoes in Morocco and the European Union are similar (Table 4).

#### 4. The Nutraceutical Properties of Lycopene

The reactive oxygen species (superoxide radical ( $\text{O}_2^-$ ), hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), hydroxyl radical (OH) and peroxynitrite ( $\text{ONOO}^-$ ), produced during the normal metabolism of biological systems, affect the main biological molecules such as lipids, proteins, or DNA, which eventually leads to numerous degenerative diseases [14] and is involved in the development of cancer [26]. Reactive oxygen species-induced oxidative stress must be combated in order to stop the diseases it causes. This is where the essential role of antioxidants, which scavenge free radicals to restore oxidative balance, emerges.

Indeed, carotenoids, including lycopene, can neutralize singlet oxygen and trap free radicals, particularly peroxide radicals, due to their strong antioxidant activity [27], [28] and therefore are crucial in preventing high cholesterol,

cardiovascular disease, and certain types of cancer [14], [28].

Numerous epidemiological studies have confirmed the benefits of eating foods high in carotenoids for your health, especially lycopene [29]. In fact, there is a correlation between the increase in the consumption of foods rich in carotenoids and the decrease in the risk of developing several diseases, such as cardiovascular, ophthalmological, gastrointestinal, and some cancers [14], [28].

Lycopene-rich diets are linked to a reduced risk of a variety of malignancies, including those of the prostate, lung, breast, colon, pancreas, stomach, rectum, esophagus, oral cavity, and cervix [7].

Similarly, *in vitro* studies have demonstrated the inhibition of leukemia and prostate cancer cell proliferation by lycopene with 1,25-dihydroxyvitamin D3 and lycopene with tocopherol, respectively [14]. Additionally, endometrial, breast, and lung cancer cell proliferation is suppressed by lycopene [27].

Other research has emphasized the protective effects of carotenoids in preventing age-linked macular degeneration, the world's leading cause of blindness [30]. These molecules protect ocular tissues against photosynthetic degradation, either acting as a filter of light and degrading blue rays or as an antioxidant, making it possible to neutralize singlet oxygen and trap reactive species of oxygen [14].

Carotenoids also protect against UV-induced erythema. In fact, ingestion of tomato paste rich in lycopene (40 g =

16 mg of lycopene) for 10 days conducts to an intensification of the lycopene level in the serum and carotenoids in the skin. After 10 weeks of treatment, the erythema significantly decreases [14].

Although lycopene is one of the most studied nutraceuticals, no health claims have been authorized for this compound by the European Commission as the claimed effects have not yet been approved [31]. This is in contradiction with new recorded results about the positive interference between lycopene and other compounds. For example, Chen et al. [32] revealed the interaction between lycopene and both flavonoids and carotenoids, which ameliorate cellular uptake and oxidative stress in different cells. Equally, lycopene recompenses hypertriglyceridemia and LPS-induced oxidative stress via Apo-CIII-mediated lipoprotein lipase activity and modulating PCSK-9 expression [33]. However, more clinical investigations are needed to demonstrate the direct effect of lycopene in sustaining good well-being and/or lowering the risk of some illnesses.

## 5. Lycopene: A Dietary Supplement and a Nutraceutical Ingredient

It is worth mentioning that nutraceuticals are a neologism created at the end of the 1980s from the prefix "nutri" of "nutrition" and the suffix "ceutical" of "pharmaceutical" by an American doctor, Stephen L. De Felice. This term characterizes food items or their components that have medicinal properties used in therapy [34] such as food supplements.

In the European Union, food supplements are regulated by the EFSA as food [35]. Directive 2002/46/EC on food supplements is the main legislation governing dietary supplements [36]. The vitamins, minerals, as well as vitamin and mineral compounds, that can be utilized to make dietary supplements, are fixed in the appendix to this directive [37].

The Decree 2006-352 of March 20, 2006 relating to food supplements, incorporated the aforementioned directive into French legislation [38]. The latter categorized food supplements as foods that are marketed in dosage form, including presentation forms like capsules, lozenges, tablets, and pills, as well as sachets of powder, ampoules of liquid, bottles with a dropper, and other similar forms, whose purpose is to complement the usual diet and which serve as a source concentrate of nutriment or other constituents having a physiological or nutritional effect, unaccompanied or in mixture.

The aforementioned decree outlines the rules relating to the composition of food supplements, their labeling, declarations and requests for usage authorization. The declaration of therapeutic effects for food supplements is forbidden by Article 8 of this decree [39]. Their packaging, labeling, and advertising cannot imply that these products

may entirely cure, prevent, or even treat human diseases.

The list of plants (other than mushrooms) that are permitted as food supplements and their usage recommendations was defined by the French Decree of June 24, 2014 [40]. The nutrients that can be utilized in food supplements are specified in the French Decree of May 9, 2006. The latter claims that one of the items permitted for use in dietary supplements is the tomato [41]. Moreover, lycopene is used as a dietary supplement or one of the key component of these supplements [42]. The labeling of food supplements must adhere to Regulation (EU) No. 1169/2011 on the provision of food information to consumers [43]. It is prohibited to state or imply that something has the capacity to prevent, treat, or cure a human disease in accordance with Directive No. 2002/46/CE standards [44].

In United States of America, the Dietary Supplement Health and Education Act (DSHEA) of 1994 defined dietary supplements as products that contain a "dietary ingredient" intended to supplement the diet [45].

The "dietary ingredient" includes minerals and vitamins; plants and other botanicals; amino acids; "dietary substances" such as enzymes and probiotics; and concentrates, metabolites, constituents, extracts, or combinations of any dietary ingredient from the preceding categories (Dietary Supplement Health and Education Act (DSHEA) of 1994) [46].

Furthermore, dietary supplement may be found in various formulas, such as tablets, pills, capsules, liquids, powders, softgels, and gummies (Dietary Supplement Health and Education Act (DSHEA) of 1994) [47]. These supplements are not envisioned to manage, diagnose, prevent, or remedy several diseases. So supplements labelling should not make such claims.

Joint Circular No. 005 of 1997 specifies the compositional requirements for food supplements and establishes guidelines for their labeling and packaging [48]. However, this text requires revision to align with the evolving demands of this sector. According to the previous circular, the marketing of food supplements is subject to the prior obtaining of a registration certificate, based on the opinion of the technical advisory committee. Furthermore, the labelling of food supplements must include the information specified in the aforementioned circular, including the name of the product, specific qualitative and quantitative compositional components [49]. Equally, it should include specific manufacturing processes (which give the product its specific nutritional characteristics), a list of additional ingredients and authorized additives, the net weight, the name or business name, and address of the manufacturer, importer, or both [50]. It must comply with current regulations on food labelling.

In fact, the majority of dietary supplements technically lack nutritional value because they do not contain sufficient calorie values and macronutrient intakes to match total energy consumption (TEC) [51]. Likewise, their

contributions to micronutrients are insignificant (with the exception of food supplements based on vitamins or minerals). However, they are valuable as a source of phytochemicals (substances with physiological effects), such as lycopene, which is one such example. The positive biological effects of dietary supplements on health, which go beyond nutrition, demonstrate the concept of a middle ground between food and drugs [52]. Thus, the idea of nutraceuticals proves to be an appropriate strategy.

## 6. Regulatory Framework: Nutrition and Health Claims Relating to Lycopene

Lycopene is a very beneficial substance from a functional and physiological point of view. Its potent antioxidant activity allows it to trap free radicals and neutralize singlet oxygen [7], which lowers the chance of developing malignancies like prostate cancer and cardiovascular illnesses in general. Therefore, a claim may be made regarding these attributes. A "claim" is any declaration that a food has certain characteristics regarding its origin, nutritional worth, nature, composition, or any other attribute [53].

In its recommendations for the usage of health claims and nutrition, "CAC/GL 23-1997" (2004), the *Codex Alimentarius*, which was established by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) in 1992, defined two groups of claims: health and nutrition claims [54].

Any depiction that suggests, implies, or indicates that a food item possesses specific nutritional qualities relating to its energy value, fat, protein, and carbohydrate compounds, as well as minerals and vitamins, is considered a nutrition claim [55]. However, a remark that affirms, implies, or posits a connection between a product or any of its ingredients and health is considered to be making a health claim [56].

Government agencies control the usage of entitlements on food goods [57]. Consequently, a number of rules controlling these claims have been adopted. In the European Union, Regulation (EC) No 1924/2006 of the

European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods is the framework text relating to claims made on foods [58]. This regulation was introduced in 2006 with the aim to offer for customers a great level of safety. This regulation refers to two main classes of claims: nutrition and health claims.

Health claims include references to disease risk reduction (function claims referring to a nutrient's role; the existence of a relationship between a component and health) [59]. The latter is not authorized in Europe because of the stringent requirements for compiling justification files. Indeed, Regulation (EU) No. 432/2012, establishing a list of permitted health claims made on foods, other than those referring to the reduction of disease risk and to children's development and health, authorizes 269 generic health claims [60]. These are functional claims of a physiological nature, intended to help maintain normal body functions. If a manufacturer wishes to use a claim that does not appear in this list, he must submit a justification file to EFSA. After evaluation, EFSA sends its opinion to the European Commission. If the opinion is positive, the European Commission then decides to add this new claim to the earlier provided list.

The EFSA Panel on Dietetic Products, Nutrition and Allergies, which evaluates claims authorization files, has issued a negative opinion on the majority of plant claim requests [61]. The main reasons for rejection were formulated: insufficient characterization of the substance or food; an unclear relationship between the nutrient and health; and, finally, insufficient or lacking evidence in healthy subjects. Studies carried out *in vitro*, *ex vivo*, or in animals are not included. Only clinical trials in healthy humans are considered, but in the case of medicinal plants, trials in humans have generally been in pathophysiological conditions.

Despite the rising number of research linking lycopene consumption to a lower risk of cancer and cardiovascular disease, all health claims made to this regard have been rejected. Notably, none of the 26 formulated requests for health claims related to lycopene has been authorized by the European Commission (Table 5). According to EFSA, there is non-compliance with the Regulation (EU Register of Nutrition and Health Claims).



**Table 5.** Statues of lycopene claims

ID	Nutrient substance	Claim	EFSA opinion reference
NA	Whey-lycopene combination	By preventing plasma lipoproteins from being oxidatively damaged, the lycopene-whey complex lowers the risk of heart disease, stroke, and other atherosclerosis-related clinical consequences as well as the accumulation of arterial plaques.	Q-2008-703 [62]
NA	Combination of vitamin C and E, fish oil, lycopene from tomato extract, and blackcurrant seed oil ( <i>Ribesnigrum</i> ).	Helps to alleviate the symptoms of dry skin.	Q-2009-00767 [63]
1948	Carotenoids	Carotenoids like beta-carotene, and lycopene and lutein are antioxidants that protect deep-layer lipids	2010;8(10):1752
1942	Lycopene from juice of tomato	-Has a significant antioxidative role and shields cells from oxidative damage; - Fortifies the body's defenses; - Boosts the immune system.	2011;9(4):2031 [64]
2374	Extract of tomato comprising lycopene	-Has the potential to support the preservation of prostate health and the prostate's ability to function normally.	
2373	Extract of tomato comprising lycopene	Helps maintain the health of the skin when exposed to the sun; Aids in keeping the skin's structural integrity;	
2372	Extract of tomato comprising lycopene	Can support the preservation of the cardiovascular system's normal functioning.	
2142	Standardized tomato extract (5% lycopene, ethyl acetate as the extraction solvent, oleoresin isolated from ripe fruits of <i>Lycopersicum esculentum</i> )	Contains naturally occurring antioxidants that help shield cells from damage caused by free radicals. Lycopene, an antioxidant, also plays a role in keeping intact cell DNA, which promotes healthy aging.	
1662	Extract of tomato comprising lycopene	Helps to keep the cardiovascular system in a healthy state. Keeps the heart healthy	
1607	Lycopene	Supports the preservation of healthy skin when exposed to sunshine. Avoids sunburns by using a sunscreen that works well. Sunscreens cannot be substituted with lycopene.	
1609	Lycopene	Helps the prostate operate normally, keeps the prostate healthy, keeps the prostate in shape, lessens oxidative damage to the prostate's cells and tissue, and keeps the prostate's DNA intact.	
1827	Lycopene	Beneficial for elderly people's ocular health.	
1610	Lycopene	Protects the arteries from narrowing and hardening, keeps the arteries healthy, and aids in maintaining regular blood flow. It also helps to maintain a healthy heart and cardiovascular system.	
1665	Tomato extract comprising lycopene	Aids in keeping the skin's structure and appearance healthy when exposed to sunlight. Aids in shielding the skin from solar radiation.	
1663	Tomato extract comprising lycopene	Aids in maintaining healthy cells.	
1664	Tomato extract comprising lycopene	Aids in keeping the prostate healthy normally. Supports the upkeep of a healthy prostate.	
2143	Standardized tomato extract (5% lycopene, ethyl acetate as the extraction solvent, oleoresin isolated from ripe fruits of <i>Lycopersicum esculentum</i> )	Reduces skin redness when exposed to the sun; Protects against UV-induced erythema; and helps shield the skin from UV-induced oxidative damage.	

Table 5 continued

2081	Lycopene (from Tomato extract)	Tomato extract contains lycopene, which has antioxidant properties. This product contains lycopene, which has antioxidant properties, guarantees the organism's protection, and helps prevent oxidation of cellular membranes.	
1608	Lycopene	This product's lycopene ensures antioxidant action; Assures the organism of a protective function; Aids in keeping the cellular membranes safe from oxidation.	
1611	Lycopene from juices of tomato	This product's lycopene ensures antioxidant action; This product's lycopene offers a preventive effect on the body; antioxidant.	
1899	Lycopene from pulp and sauces of tomato	Because tomatoes are practically unique as a source of a particular carotenoid known as lycopene, use them whenever possible due to their nutritional value.	
2082	Lycopene (from Tomato extract)	As an antioxidant, lycopene aids in the preservation of healthy bodily cells and their protection. Via its ability to preserve intact cell DNA, lycopene or a diet high in it can assist promote healthy aging.	
1859	lycopene+Soy isoflavones + zinc + vitamin D + vitamin E + selenium +vitamin C	Beneficial to the prostate gland. A thoughtfully chosen blend of vital vitamins, minerals, and isoflavones for men's health. The claim includes the name of the symbol: MenBalans®.	2011;9(6):2228 [65]
1796	Carotenoids (beta, alpha and gamma carotene, and lycopene)	Aids in shielding the skin from UV radiation's effects. Lessens the vulnerability of the skin to burns. Improves the skin's resistance to UV.	2011;9(4):2082 [66]
NA	Combination of vitamin E, lycopene, selenium, and lutein	Aids to formulate and stimulate tanning.	Q-2012-00593 [67]
NA	A combination of vitamin E, lutein, lycopene, and selenium	Improves the inside preparation of delicate skin to increase its resistance to the sun.	Q-2012-00592 [68]
NA	"L-tug lycopene"	It has been demonstrated that "L-tug lycopene" lowers or reduces blood cholesterol. One risk factor for the onset of coronary heart disease is high cholesterol.	Q-2014-00590 [69]

Some requests concerned the raw tomato extract; others were interested in lycopene alone or in combination with other compounds, including minerals (zinc, selenium, etc.) or vitamins (C, E, etc.) [70]. These claims revolve around the protective effect of lycopene against oxidative degradation, which can affect any molecule in the body, including DNA, proteins, and lipids [71]. It is therefore necessary to determine whether lycopene has the same effectiveness when it is ingested alone in a concentrated form or when it is naturally present in food [72]. Another line of research is to study the synergistic effect attributable to the association of lycopene with other substances, particularly phenolic compounds and other carotenoids, which also have antioxidant properties.

Globally, Japan has implemented a regulation for food items for specific health purposes (FOSHU) [54].

Indeed, with the appearance of many food items referring to nutritional value and health, and in order to prevent the use of claims that could mislead consumers, it seemed necessary to create a regulation that officially

authorizes them. It should be mentioned that in Japan, the Health Promotion Law regulates nutrition labeling, health claims, and the approval of food items for special nutritional uses [54].

In Morocco, the only decree specifying nutritional claims is Decree No. 281-16, which lays down the requirements and methods of indicating nutritional information on the labeling of prepackaged food products [73]. According to this decree, lycopene may be the subject of one of the following two nutrient claims: "Contains" or "Enriched." The latter can only be used if the nutrient content is increased by at least 30% compared to a similar product. Regarding health claims, according to article 26 bis of Decree No. 2-12-389 setting the conditions and modalities of labeling food products, only the claims appearing on the list fixed by the joint order of the minister in charge of agriculture and the minister in charge of health may be mentioned on food products. But, the decree in question has not yet been put into practice.

## 7. Conclusions and Perspectives

Many plant products constitute a source of interesting biomolecules that can be extracted and exploited in the food, pharmaceutical, or cosmetic industries. In this context, the researchers are talking about lycopene extracted from tomatoes or its by-products.

In fact, encouraging the use of these compounds as functional ingredients will allow the development of innovative products marked by their high added value and will limit the use of chemical and synthetic additives.

Lycopene, the major component of tomato by-products, is a promising molecule for the food industry and for food supplement manufacturers. Thanks to its remarkable health benefits, this compound is attracting more and more attention from manufacturers, who are beginning to invest more in research and innovation in order to develop new products that have several properties and can be distinguished by claims. Indeed, the use of claims on food products can be one of the most effective tools to improve a company's marketing strategy. It will boost the sale of these products, which will increase their market share. Several recent studies show the possible role of lycopene in the prevention of cardiovascular disease and cancer, in particular prostate cancer, but so far no causal relationship has been established between the consumption of this compound and improved health. Further clinical studies on the effect of lycopene consumption and the maintenance of good health are needed to demonstrate the benefits of lycopene based on the conclusions of previous studies carried out *in vitro* or on animals.

In Morocco, the use of health claims is not sufficiently controlled; this may be due to the legal vacuum in this area, and the same applies to food supplements. To do this and to ensure a high level of consumer protection against false or even false claims, the concerned authority should adopt other legal texts in order to harmonize the use of health claims. This legislation must be relevant and effective and must take account of scientific progress and technological developments in agro-industries.

Internationally, a review of the list of health claims is needed. Because of the strong antioxidant activity of lycopene, it can only have positive effects on health. Also, we must put some order into the false claims of the exposed agri-food products.

Given that the majority of the publications on the topic only discuss vitamins and minerals, which restricts the usage of other herbal substances, this study makes the case for new rules governing dietary supplements.

## Declarations

### Conflict of Interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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### Data Availability

No datasets were generated or analysed during the current study.

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