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EXTENSIVE RESEARCH ON HOW EXTRACTION METHOD, HEAT TREATMENT AND THE STORAGE CONDITION AFFECT THE LYCOPENE CONTENT OF VARIOUS FOODS

Joykishan Sharma Hanjabam[1*], Maharabam Anandi Devi[1], Soibam Giri Singh[2], Nidhi Brahmacharimayum[3], Khuraijam Mrinalini Devi[4], Oinam Sangita Devi[5], Lutrika Moirangthem[6]

[1*]Spice Research Association of India, Guwahati-781003, India
[1] Department of Biochemistry, Manipur University, Imphal-795003, India
[2]Principal, YK College, Wangjing, Manipur, India
[3]Department of Zoology, Lovely Professional University, Punjab, India
[4]Department of Biotechnology, Manipur University, Imphal, India
[5,6]Department of Biochemistry, Manipur University, Imphal India

***Corresponding Author:** Joykishan Sharma Hanjabam
Email: jkshnshrm@gmail.com

Abstract
Lycopene is one of the main carotenoids we eat on a daily basis. Fruit variety, environmental conditions, and fruit maturity stage are the variables affecting the lycopene content. Different processing and extraction techniques can also change the amount of lycopene in different food products, which can change the biological role of lycopene. The biological purpose of lycopene is to ward off predators by drawing them in with its red and protecting tomato tissues by conjugate bonding. Furthermore, storage conditions have an impact on the lycopene content of fruits, vegetables, and their products. Innovative and practical technological solutions are needed to stabilize the lycopene content during post-harvest procedures like refrigeration, heating, extraction, and transportation. It also emphasises how storage conditions affect lycopene content and the significance of for more investigation on the matter. Thus, investigation into a number of significant variables related to the variation in lycopene content is required.

Keywords: Lycopene, antioxidant, extraction, thermal, storage, impact

1. Introduction
Lycopene, a naturally occurring pigment, belongs to the carotenoid family. Many fruits and vegetables, such as watermelon, pink grapefruit, tomatoes, papayas, rosehips, and gac fruit, contain the red, fat-soluble pigment lycopene. On the other hand, fresh tomatoes have the highest level of lycopene (0.77–20 mg/100 g fresh weight), while apricots have the lowest level (0.01–0.05) [1-3]. The amount of lycopene in fresh fruit varies by variety, maturity level, and climate. Tomatoes, which are known for their deep red colour, contain a significant amount of lycopene (80–90%) and very little other carotenoids, such as lutein, α-carotene, β-carotene, and β-cryptoxanthin. More research has been done on tomatoes and tomato-derived products than any other commodity due to their high lycopene content [4-6]. A variety of foods' lycopene contents are displayed in Figure 1. It has been demonstrated that getting enough lycopene protects against cancer, macular degeneration, heart disease, and

cognitive decline [9]. Furthermore, studies using epidemiological data demonstrated that lycopene prevents skin, lung, breast, prostate, and cervix cancers in addition to lowering blood cholesterol and serum lipid oxidation [10, 11]. Moreover, lycopene is more effective than vitamin E as an antioxidant at scavenging reactive oxygen species (ROS), which prevents cell damage linked to a higher risk of chronic illnesses [7, 8]. Different processing methods cause lycopene to isomerize and become oxidized or degraded, which affects the nutritional value and quality of food [12]. Lycopene degradation also affects the final products' colour and sensory attributes [13]. Thus, it is imperative to investigate the effects of different food processing methods on the concentration and stability of lycopene content.

2. Effect of Postharvest Operations on Lycopene Content

The main postharvest tasks include cleaning, sorting, packing, storing, and shipping [14]. The quantity of lycopene in a variety of fruits and vegetables, such as grapefruit, citrus fruits, cucurbits, tomatoes, and their byproducts, may change as a result of these processes [15–18]. Consequently, innovative, cost-effective, and efficient postharvest methods are needed to preserve lycopene in food products.

2.1The impact of packaging and transportation circumstances

Fresh vegetables may undergo chemical changes more quickly when transported over longer distances. The temperature at which fresh goods are stored has an impact on their quality as well [15]. Tomato fruit (Miral variety) was examined for its lycopene content in relation to the following transportation parameters: temperature (10 and 20 degrees Celsius), distance travelled (100, 154, and 205 km), and time needed (75, 120, and 180 minutes). The results showed that the tomato group that travelled a significant distance (205 km) and was kept at 22° C on day 12 had the highest level of lycopene, 1.21 mg/100 g FW. [15]. In a similar vein, Huangewyi [19] found that the growth of lycopene in tomatoes is significantly influenced by the ambient storage temperature of 22–25°C. Long transportation distances have been shown to accelerate the ripening process, which raises the amount of lycopene and carotene in produce and causes it to become redder. For instance, there is evidence that the freshness, moisture content, colour, and carotenoids of fruit alter as transportation distance increases [20]. Fresh produce can be kept fresher for longer thanks to the storage technologies known as controlled atmosphere packaging (CA) and modified atmosphere packaging (MAP). In order to regulate the amounts of O2 and CO2, MAP involves modifying the gaseous environment through respiration (passive MAP) or by adding and removing gases from food packages (active MAP). By decreasing ethylene production, postponing textural softening, decreasing ripening, postponing respiration, and slowing down compositional changes linked to ripening, these packaging strategies increase the product's shelf life [21]. Lycopene accumulation was found to be inhibited in tomatoes grown in the CA atmosphere (20% CO2 and 30% O2), while tomatoes grown in ambient conditions demonstrated an increase in lycopene content [22]. After injecting 5% O2 + 5% CO2 + 90% N2, cherry tomatoes (cv. "Josefna") were sealed in a plastic bag and kept at 5°C for 25 days. The concentration of lycopene in MAP samples was found to be 39 g/L, which was lower than the concentration in the control group (53 g/L) [21]. Similarly, MAP of watermelon varieties in 10 kPa O2 for seven or ten days at 2°C showed a slight decrease in lycopene concentration [23].

2.2. Lycopene and the Effect of Storage Environment

Lycopene efficiently builds up during storage and gets stronger as it ripens [24]. The harvesting stage has a major influence on the lycopene content. Fruits with higher levels of lycopene are harvested at the breaker stage rather than the green stage [25]. Oxygen and light have comparable effects on processed food's lycopene content. Temperature is a significant factor in lycopene loss during storage. Tomato juice in cans stored for a year at 25°C and 37°C showed no lycopene loss [26]. Lavelli and Giovanelli [27] maintained commercial tomato paste, puree, and pulp at 30, 40, and 50°C for up to 90 days without observing any appreciable changes in the lycopene concentration. Preservatives that were added during manufacturing could be the cause of this. Watermelon stored between -20°C and

-80°C for a year had lycopene levels about 40% lower, per a study on frozen food storage [28]. Moreover, frozen tomato puree and diced had lower levels of lycopene degradation than the tomato ingredients in frozen pizza [29]. Nonetheless, the lycopene content of diced tomatoes remained constant after a year of storage at −20°C and −30°C [30]. Oxygen is kept out of tomato products during freezing storage, which slows down lycopene deterioration [31]. Lycopene accumulation was found to be slower in conventionally grown tomato cultivars (e.g., "Matouleibi," "Mahi," "Sanalembi," "Lingjel," "Liana," etc.) when stored at a low temperature (4°C); lycopene accumulation in hydroponically grown tomatoes increased by as much as 70%. The reason for this increase is not known [9]. In one study, for ten days, greenhouse tomatoes of the salad variety "Trader" were maintained at three different temperatures: 7, 15, and 25°C. Lycopene concentrations in tomatoes were two times higher (7.5 mg/100 g) at 15 and 25°C than they were at 7°C (3.2 mg/100 g) [3]. The lycopene content of minimally processed watermelon (fresh cut) decreased slightly when it was stored at 5°C for up to nine days, according to Gil et al. [32]. Lycopene inhibitors prevented lycopene from being synthesized, but ethylene treatment following harvest also promotes lycopene accumulation and fruit ripening [32].

Oxidation and isomerization are the primary mechanisms causing lycopene loss in dried tomato storage. Oxidation rises in response to higher storage temperatures, whereas isomerization increases with longer storage periods under lightening conditions [7]. According to Sharma and Le Maguer [33], after four months of storage at 25 to 75°C, the lycopene content of freeze-dried and oven-dried tomato pulp decreased by up to 79% and 97%, respectively. The pulp that had been freeze-dried had a fluffier texture and more volume than samples that had been oven-dried with thin crust sheets. This event demonstrated that exposure to air and light resulted in a greater loss of lycopene content in freeze-dried fibres. Tomato powder that had been foam-mat dried in the presence of oxygen was the subject of a storage study by Lovric et al. [34] so that their results could be compared with samples kept in air and N2. They found that oxygen is essential for lycopene to be retained in storage. Additionally, over the course of three months at 25°C, 30°C, and 40°C, Lavelli and Giovanelli [27] investigated tomato paste (in aluminium tubes), pulp (in cans), and puree (in glass bottles) They discovered that each sample's lycopene content stayed constant. The packaging materials might have had a major impact on the stability of the lycopene levels. Li et al. [35] studied tomato hot pot sauce for 120 days at three different storage temperatures (0, 25, and 37°C) using two different types of packaging materials. They came to the conclusion that while the lycopene content of both packaging types dropped at 25°C and 37°C, there was no discernible variation in either packaging material's lycopene content at 0°C for as long as 120 days. Similarly, after up to eight months of storage at 30°C, there was no discernible change in the lycopene content of tomato ketchup [36]. Pagane et al. [37] found that fresh-cut tomatoes' lycopene content decreased by 45%, or 100–110 mg/kg, after they were packaged and stored at 4°C for 12 days. Conversely, Odriozola-Serrano et al. [38] discovered that sliced (fresh-cut) tomatoes had a marginally higher lycopene concentration at 4°C for up to 21 days of storage as opposed to a drop in lycopene content. The effects of temperature and duration of storage for various commodities are listed in Table 1.

3. Effect of Different Processing Components on Concentration of Lycopene

Many common foods that we eat every day contain lycopene. Tomatoes and tomato-based products provide about 85% of the lycopene consumed [47, 48]. Based on data from the Food and Agriculture Organization [49], China is the world leader in tomato production (6, 75, 38,340 tonnes), followed by India (2, 11, 81,000 tonnes) and the United States (1, 04, 75,265). California accounted for 40% of global tomato production, and about 95% of tomatoes processed in the USA came from this state alone [48]. Outside of the US, the top countries for processing tomatoes are Italy, China, Spain, and Turkey [50]. Tomato paste, puree, ketchup, juice, salsa, and sauce are made from about 80% of the tomatoes that are grown. Lycopene's content is changed by processing in a home or place of business. Thermal processing (cooking, pasteurization, blanching, drying, and frying) breaks down the cell wall and releases bound molecules for better solubilization, which can increase the amount of lycopene available even though it can decrease the amount present [51–54]. Processed foods change from cis to trans form because the Trans isomer is more stable than the cis isomer [5, 55]. The impact of extra processing techniques and temperature

(3.1) Temperature effects and additional processing techniques

Usually, pulp, puree, paste, and ketchup are made from concentrated tomato juice using steam coils and vacuum evaporation. While whole or sliced tomatoes are preserved for canning, tomatoes are dried to make tomato powder and dried slices. The thermal processes used in such products may have an impact on their lycopene content. Tomato products' lycopene content is believed to be less accurate due to processing. Isomerization and oxidation are the main processing steps that cause lycopene to degrade [56]. In the processing of tomatoes, oxidation is a composite process that is impacted by several factors, such as

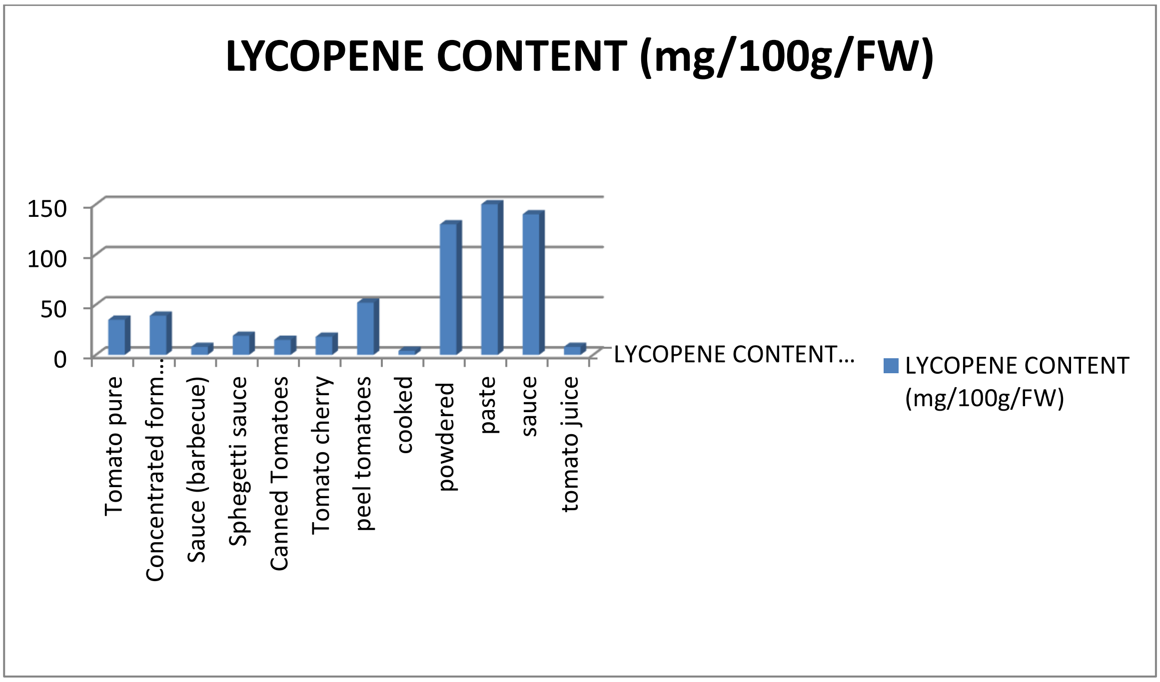

***Figure 1**. Lycopene content of various tomato products*

Table 1: Lycopene content in relation to storage time and temperature (< 0º, 0 -10˚ and > 11˚)

Storage temperature	Duration of storage	Product or Service	Effect on lycopene	References
	12 days	Tomato: homogenized (1500 g) traditionally grown "BOS 3155" variety was stored at -20°C. Pizza: pizza was stored at -18°C in low-oxygen packaging with a tomato puree prepared with oil on top.	Cut down by 9–28%	[39]
	12 days	Made with "Micro RS" tomatoes, tomato pulp is frozen and kept at -20°C.	72% less in comparison	[31]

<0°C	12 months	Diced tomatoes: 12 x 12 x 12 mm cubes were cut, 500 g plastic boxes were filled, and the boxes were frozen at -40°C.	Cut down by 48%	[30]
	12 months	Watermelon: After being cut into 3 cm3 chunks, 10 g of the "Sangria" cultivar was placed into a plastic bag and kept at -20°C.	Nothing changes.	[30]
	12 months	Mato puree: the puree was sealed, heated in oil, and kept cold—-18°C.	30–40% less	[28]
	50 days		decreased by 18.5%	[29]
	9 days	Strawberry: After cutting the fruit into four pieces, 150 g of the 3 kg of fresh fruit were kept at 5°C.	An increase of 98.5 ± 11.5 ug/100 g	[40]
	9 days	Two watermelon rings in the centre were cut into 4 cm cubes and stored at 5°C.		[40]

0–10°C	9 days	Five kiwifruit slices, each 7 mm thick, were stored at 5°C.	Reduced to 7780.4 ± 346.6 ug/100 g	[40]
	9 days	Mango: the fruit was cut into 2-by-2-by-2-cm cubes after peeling and kept in storage at 5°C.	232.7 ± 12.8 ug/100 g saw a reduction.	[40]
	10 days	Watermelon: 5 cm cubes of the "sugar shack" variety, seedless, were stored at 2°C.	Increasing to 2789.6 ± 125.6 ug/100 g.	[23]
	12 days	Tomato: "Locale di Volcano" was sliced in half lengthwise and then packed (about 100 g) into a conventional container before being kept in storage at 4°C.	Decreased by 7%	[37]
	12 days	Tomatoes are cultivated hydroponically and stored at 4°C.	Decreased by 45 percent	[9]

			Increased 70%	
	12 days	Tomato: A storehouse with 10°C and 95% relative humidity was used to maintain the "Miral" variety.		
	15 days	The bio nanocomposite films are then wrapped in LDPE films and stored at 10°C and 10% relative humidity.	Increased from 0.12 mg to 0.42 mg/100 g.	[15]
	21 days	cut into 7 mm slices, stored at 4°C in a modified environment in polypropylene trays.	A 7.4 ± 0.07 mg/100 g increase	[41]
	56 days	Carrot: Daucus carota var. Kintoki was blanched for 15 minutes at 70°C. It was then sliced and packed (250 g) to be stored at 1°C.		[38]
	120 days	At 160°C, combine spice mixture, 14% sucrose, 2.5% salt, 1% soy sauce, and 3% chicken essence; store at 0°C.	A 29.3 mg/kg fw increase	

			60% fewer	[42]
			Nothing changes.	[35]
	6 days	Medium-ripe fruit was kept in a gac at 26°C and 24% relative humidity.	An increase in FW of 50.11 ± 1.59 mg/100 g	[45]
	8 days	Cherry tomatoes: cultivar "Punjab Red Cherry" were stored at 30°C and 61.2% relative humidity after being wrapped in LDPE film and covered in pectin-based bio nanocomposite films.	The expanded value was 7.6 ± 0.42 mg/100 g.	[41]
>11°C	10 days	Tomato: "Tradiro" tomatoes that were hydroponically grown were kept in cardboard boxes at 15°C in the dark.	It tripled from 3.6 to 9.0 mg/100 g.	[3]

		Tomato powder that had been commercially spray-dried in an amount of 0.2 g was placed inside glass vials that had a 20 ml crimped cap and kept at 45°C.		
	42 days	Commercial tomato products, such as pulp (450 g), puree (700 g), and aluminium tubes containing 130 g of tomato paste, were kept in a thermostat at 40°C.	60% fewer	[44]
	90 days	Commercial tomato paste, 25% soybean oil, a mixture of spices, 14% sucrose, 2.5% salt, 1% soy sauce, and 3% chicken essence were combined at 160°C to make the tomato hot pot sauce. After that, it was stored at 37°C.	No effect	[27]
	120 days	Tomato: Fresh tomatoes (var. "Punjab Ratta") were cut into 5–8 mm pieces, blanched at 100°C for 15 seconds, dipped in a 1:1 solution of citric and ascorbic acid for 10 minutes, and then dried in a convection dryer (hot air cabinet at 60°C, 1.5 m/s velocity). This process produced flour powder. Ten, kept at 28°C in cold storage	decreased by 83 mg/kg	[35]

	180 days	Tomato pulp: One hundred grams of raw, fresh tomatoes (variety "H-9035") were chopped, ground, and heated to 100°C. The mixture was then centrifuged and dried in an oven. After that, the fibre portion was kept in a light- and air-filled environment at 50°C.	The value of db rose to 131.11 ± 0.04 mg/100 g.	[46]
	4 months	Tomato pulp: We chopped, ground, and heated one hundred grams of fresh, raw tomatoes (variety "H-9035") to a temperature of one hundred degrees Celsius. The fibre portion of the pulp was then freeze-dried and stored in an airtight container at 25 degrees Celsius. After that, the tomatoes were centrifuged.	Cut down by 97%	[33]
		Tomato paste (72%, 32° brix), water (19%), sugar (5%), salt (1%), and		

	4 months	soybean fiber (3%), were the ingredients used to make tomato ketchup. Following homogenization at 20 MPa, it was sterilized for 15 minutes at 90°C, cooled (RT), and then stored at 30°C.		[33]
		Tomato juice: After being extracted using a hot break process at 91°C and quickly cooled at 20°C, 50 g of juice from CV "FG99–218" was vacuum-packed and stored at 36°C.	diminished by 73.3%–78.9%	
	8 months			[36]
			Nothing changes.	
	1 year			

			decreased by 27 percent	[43]

Temperature, moisture content, and processing conditions. Miki and Akas [57] observed a 1.1% and 1.7% decrease in lycopene content when they heated tomato juice to 90°C and 100°C, respectively. As the temperature rose to 130°C, lycopene's potency decreased by 17%. Dewanto et al. [58] found that lycopene levels increased by 1.6 times when raw tomatoes were heated to 88°C for two minutes. Jabbari et al. [13] used a 4% nanofluid heating medium to heat tomato juice for 30 seconds at 30°C, and they observed a 60% retention of lycopene. Tomato pulp heated for two hours at 100°C showed some lycopene content degradation 18%. The examination in the processing of tomatoes, oxidation is a composite process that is dependent on several factors, such as temperature, moisture content, and processing conditions. Miki and Akas [57] observed a 1.1% and 1.7% decrease in lycopene content when they heated tomato juice to 90°C and 100°C, respectively. As the temperature rose to 130°C, lycopene's potency decreased by 17%. Dewanto et al. [58] found those raw tomatoes' lycopene levels increased by 1.6 times when heated to 88°C for two minutes. Jabbari et al. [13] heated tomato juice for 30 seconds at 30°C using a 4% nanofluid heating medium and discovered that 60% of the lycopene was kept. After two hours of heating at 100°C, some of the lycopene content in tomato pulp was lost. Similarly, when the tomato was made into a paste, up to 32% of the lycopene was lost [61]. It has been demonstrated that thermal processing methods such as frying, blanching, steaming, and microwaving raise the levels of lycopene in tomato fruits [62, 63]. The concentration of lycopene in ripe tomatoes increased up to 12% during stewing and about 8 times during paste production, according to Khachik et al. [64]. The homogenization of tomato juice decreased its lycopene content [65]. In one experiment, it was discovered that lycopene decreased when tomatoes were fried but decreased when they were baked or boiled [66]. After heating tomatoes in an oil bath at 100°C for two hours, Graziani et al. [67] observed an increase in the concentration of lycopene. Furthermore, Re et al. [68] examined how processing tomato pulp to make paste at different temperatures increased the concentration of lycopene; however, when tomato puree was pasteurized at 60–85°C [69], no effect on lycopene was reported. In addition to tomatoes and their products, other food commodities have also displayed variations in their lycopene content during processing. For instance, lycopene-containing oil-in-water emulsions were incubated at 5 to 90°C without the presence of oxygen. The initial concentration of 9-cis lycopene in the emulsions increased to 150% after seven hours at 90 degrees Celsius, but only half of the 13-cis lycopene was lost [70]. Similarly, heating guava juice led to a five-fold increase in lycopene content due to trans-cis isomerization [71]. After blanching Kintoki carrots for 15 minutes at 90°C, their lycopene content rose by 15% [53]. One possible reason could be variations in the commodities and processing conditions. Tomato concentrate was processed using four different techniques: high temperature with shear (HTS), steam injection, waring blender with steam, and conventional hot break. HTS yielded the maximum lycopene increment (32.28 mg/100 g) among these techniques [72]. Additionally, watermelon juice that had been freeze-dried or sprayed with maltodextrin (3%–10%) was infused by Oberoi and Sogi [73]. In comparison to the freeze-dried powder (62.3 mg/100 g) and the spray-dried powder (54.6 mg/100 g), they discovered that the fresh juice (6.53 mg/100 g) had a lower lycopene concentration. Tey came to the conclusion that while boosting yield, maltodextrin kept the samples' sensory characteristics. After 9 minutes of ultrasonic processing, the lycopene content of guava juice dropped from 29.4 μg/g to 15.18 μg/g [74]. Similar conclusions were reached by Rawson et al. [75], who discovered that ultrasonic processing reduced the amount of lycopene in watermelon juice. However, after ultrasound treatment, the amount of lycopene in guava juice and tomato puree did not change [76, 77]. The lycopene content changed due to oxidation and heat; however, lycopene is found to be more sensitive to direct heat than ultrasound. A study by González-Casado et al. [78] found that the pulse electric field technique increased tomatoes' 150% lycopene accumulation during five days of storage at 12°C. When papaya juice was ultrafiltered using a PS 100 membrane, 1 bar of pressure, and a tangential velocity of 6 m/s, 90% lycopene retention was reported [79]. Jayathunge et al. [80] examined the combined effects of an ultrasonic, high-intensity pulse electric field and blanching process to increase the lycopene bio accessibility of tomato fruit. A greater lycopene bio accessibility of 9.6% was attained by them. Novel techniques have been found to either increase or retain the lycopene content in foods due to their tailored operation and effectiveness. Comparably, the effects of reverse osmosis, infiltration, and microfiltration combined on the quantity of lycopene in watermelon juice were investigated in Oliveira et al.'s study [81]. Tey experienced a 17-fold increase in lycopene concentration. Furthermore, compared to fruit that was not treated, the lycopene content of fresh cut papaya fruit treated highly hydrostatically (50–400 MP and 3–60 min) and stored at 4° C increased by an 11-fold [82]. The effects of various processing methods on the amount of lycopene are combined in Table 2.

3.2 Lycopene Content and the Effect of Extraction Methods.

The extraction process is one of the most important factors in obtaining more lycopene. Temperature, cell disintegration, and applied pressure levels are linked to enhanced lycopene recovery [12]. Consequently, the pretreatment phase is crucial when employing chemicals or heat to dissolve physical barriers such as membranes and cell walls [95]. It was discovered that cooking was the most efficient method for achieving a higher lycopene content when compared to milling and dehydration [42, 85]. Many extraction techniques, such as pressurized liquid extraction, supercritical fluid extraction, microwave-assisted extraction, maceration, ultrasound-assisted extraction, and enzyme-assisted extraction, can be used to extract lycopene [95, 96]. The micro emulsion method with surfactants has been reported to be an additional useful lycopene extraction technique [97]. These conventional and state-of-the-art extraction methods are used to separate lycopene from different food products. The configuration, circumstances, and functioning of these methods may have an impact on the lycopene extraction yield. It has been observed that novel techniques can enhance the recovery of lycopene from the food matrix without causing any chemical residues or adverse effects on the environment [98]. Pol et al. [99] optimized the supercritical fluid extraction (SC-CO2) method at 400 bar pressure, 90°C temperature, and 1.5 ml/min CO2 flow rate. This made it possible to recover all of the lycopene content in watermelon, rosehip paste, grapefruit, tomato, guava, and tomato paste in just 35 minutes. Furthermore, SC-CO2 was used to extract dried tomato peel byproducts at 90 °C, 40 MP pressure, and 1.05 mm particle size; this led to a 56% recovery of lycopene [100]. As stated by Parrett et al. In order to achieve maximum lycopene recovery, [101] used the SC-CO2 extraction technique on tomato pomade powder at 30 MP pressure and 15 kg/h CO2 fowl rate. Moreover, a 60.85% lycopene content was obtained by SC-CO2 treating tomato peel by-products at 80°C, 400 bar pressure, and 4 g/min CO2 fowl rate [102]. The integrated approaches improved the recovery of lycopene, according to observations. The enzyme-assisted extraction (EAE) method yielded a ten-fold higher content of lycopene from tomato waste treated with pectinase and cellulose (122.5 and 70 U/g, respectively) [103]. Furthermore, lycopene recovery was increased by adding pectinase (2%) and cellulose (3%) (w/w) enzymes to waste tomato, tomato peel, and fruit pulp [104]. Furthermore, when tomato-processing waste was extracted using cellulitis (Cellulite 50LC) and pectin lytic (PeLCV PR) enzymes at 30°C with a 1.6% (w/w) enzyme load for 3.18 h, an 8–18-fold increase in lycopene yield was reported [105]. The highest yield of lycopene was obtained from tomato processing waste treated with a tri-mixture of ethanol,

Table 2: The concentration of lycopene and the impact of processing techniques

Methods of processing	Item	Conditions	impact on lycopene	Reference
Drying	Tomato-based paste	Prayed at inlet temperatures between 110 and 140°C, with drying air flow rates between 17.50 and 22.75 m3/h (±0.18 m3/h) and atomizing agent flow rates between 500 and 8000 I/h. The feed rate is 1.75 ± 0.05 g/min, the pressure is 5 ± 0.1 bar, and the feed temperature is 32.0 ± 0.5°C	Lowering by 8.07–20.93%	[89]
	A ripe tomato	Heated for two hours to 80°C, then kept for six hours at 60°C.	Increased to 8.90 ± 0.3 mg/100 g	[62, 63]
	Juice from watermelon	Pray-drying using an air pressure of 0.25 kg/cm2, an aspiration rate of 6.5 m3/min, a feed rate of 3 g/min, a pump speed of 4 ml/min, an outlet temperature of 70°C, and an	Peaked at 100 g at 56.4 mg.	[73]

		input temperature of 25°C		
	A ripe tomato	Homogenized with 80% acetone and stirred for 4 hours at 5-7°C in a rotary mixer.	A 9.0 mg/g increase	[3]
	Aril Gac Lubricant	Drying with hot air at 50°C and 1.5 m/s	An increase in grams by 0.82	[91]
	Carrots (Nutri-red)	Hot air drying below 70°C	No effect	[90]
Heating	Paste made of tomatoes	To allow for evaporation, take a 5-to 10-minute hot break at 90°C, boil at 70–80°C, and then store under vacuum for 4 hours at 60–70°C	A rise of 47.3 µg/g	[39]
	A ripe tomato	Heating for two minutes at 75–95°C.	A 19.46 ± 0.86 mg reduction	[60]
			Five times more	

	Guava concentrates	Heat for two hours at 60°C.		[71]
	Pomelos	Heating at 100–120°C for a duration of 0–5 hours	Half as many	[56]
	Paste made of tomatoes	90°C is ideal for focus and 90°C for a heated rest.	A rise of 4.50 g/100 g	[83]
	A ripe tomato	Numerous heat-treatment techniques, including as homogenization, scalding, steam sterilization, and canning	No effect	[26]
	Melon	Cooking in boiling water for fifteen minutes	Decreased by 41%	[88]
	Poor quality tomato sauce	Boil for thirty minutes in olive oil.	A rise to 319.2 ± 13.4 µg/g	[84]
	Orange Fresh sweet potatoes	Boiling 500 milliliters of water for 15 minutes.	Decreased by 37-86%	[87]
	A ripe tomato	Boiled for 15 minutes in 500	Decrease of 35.5 ± 21	[66]

Cooking and boiling		cc of boiling water.		
	Melon	Cooking in boiling water for fifteen minutes	Decreased by 41%	[88]
	Expertly made sauce for tomatoes	Boil for thirty minutes in olive oil.	There was a 343.3 ± 27.7 µg/g rise.	[84]
	Enchilada with a side of onion	Preheating at 100 ± 1°C (using a home cooking method)	went up by 122.6 µg/g.	[85]
	Carrots (nutri-red)	Heating without oil and cooking at 100°C	A 126 ± 3 mg/kgw increase	[86]
	Tomato slurry	Cooking in water bath for 1 hour at 100°C	decreased to 78.97 µg/g from 48.41	[59]
	Tomato pulp	Tumble pulp in oven at 25°C; let cool to room temperature.	117.3 mg/100 g of total salt fell	[33]
	Juice from tomatoes	Several heat-treatment procedures, including canning, scalding, steaming, and homogenization	No effect	[26]
	Tomato pulp			[76]

Other methods: canning		Increasing in temperature by 90 to 110 degrees Celsius	5.20 ± 0.25 mg/100 g an increase	
UV-B radiation	A fully ripe tomato	For one hour, radiate at 6.08 kJ/m2 d.	increased 40% to 59.91 ± 1.47.	[94]
Blanching	Carrots (Kintoki)	Blanching at 50–90°C for 15 minutes	No effect	[42]
Pulse light	A recently sliced tomato	A maximum pulse light intensity of 8 J·cm−2 is presented.	a 57.25 mg/kg rise	[93]
Homogenization	Juice of tomatoes	62.5 kg/h homogenized feed rate at 60 bar	Reduction of 6.70 ± 0.22 mg/100 millilitre	[58, 65]
Stewing and frying	Arana, or tomato paste	Coated in vinegar	An increase of 49.8 mg/100 g +/- 2.0	[66]

Ultrasound Processing	Guava Concentrates	With a 1.26 cm2 titanium point, 1000 W of Power and 20 kHz of frequency are employed. Intensity power of 15 W/cm2 and volumetric power of 121 W/L	3.58 ± 15.18 μg/g Decreased	[74]
Microfiltration	Watermelon juice	Microfiltration is 69.6 kg/h/m−2 at permeate flux.	A rise to 229.77 ± 6.86 μg/g	[81]
High hydrostatic pressure	Raw papaya slices	Treated for 3–60 minutes at 50–400 MPa.	A 17.95 ± 0.6 mg/100 g increase	[82]
Treatment	Uncooked papaya slices	Treated at 50–400 MPa for 3–60 minutes.	An rise of 17.95 ± 0.6 mg/100 g	[82]

hexane, and acetone (1:1:2). This was reported by Ranvier et al. [6]. Pectinase (3%) was more effective than cellulose. Lycopene recovery was as high as 25–50% when tomato peel residue was treated with a pectin lytic enzyme pretreatment using a surfactant-assisted extraction method for 20 minutes at 6-7 surfactant molecules per lycopene [106]. Applying ultrasound-assisted extraction (UAE) at an amplitude of 94 μm and an external pressure of 50 kPa to dry tomato pomade resulted in the highest yield of lycopene [107]. After treating tomato pomade with cellulitis and pectin lytic enzymes, glycerol, and surfactant (saponin) using ultrasound and an enzyme-assisted extraction method, a maximum yield of lycopene (409.68 μg/g) was obtained [97]. Enzymes facilitate the diffusion of solvents into the sample, which enhances the elution of the sample's metabolites and increases the concentration of the end product. Furthermore, using ultrasound and enzyme-assisted extraction methods to treat tomato industrial waste resulted in the highest yield of lycopene (lycopene: surfactant (saponin) ratio of 1:20, particle size of 400–545 μm, and surfactant: surfactant ratio of 1:1) [108]. The solvent extraction method (SEM) was used for tomato processing waste, and different acetone to hexane ratios (1:3, 2:2, and 3:1 v/v) were used, all at temperatures between 30 and 50° C. At 30°C and a 1:3 ratio, the highest lycopene recovery (65.22–75.75%) was recorded [109]. In a different experiment, Phoney et al. [110] extracted lycopene from commercial tomato waste using three different methods: ethanol with hexane, acetone or ethanol, and acetone/hexane. According to research results, lycopene extracted in hexane showed more stability than lycopene extracted in acetone, dichloromethane, methanol, and ethanol [6, 108, 111]. Additionally, hexane can be evaporated from the extract using a vacuum drier or dried with $CaCO_3$ [108]. 13.592/100 g of all trans-lycopene were extracted by Ho et al. [112] using the microwave-assisted extraction (MAE) method on a tomato peel (1 g) for 6 seconds at 400 W of power and a 1: 20 (w/v) solid-to-liquid ratio. On the other hand, 7.325/100 g of lycopene was obtained using the traditional method, which involved heating a 1:1 mixture of ethyl acetate and hexane for 15 seconds at 45° C. The results under discussion show that the yield of lycopene extraction can vary depending on the type of commodity, duration of extraction, solvent, enzyme, and techniques employed.

4. Conclusion

Variable amounts of lycopene can be found in fruits, vegetables, and other processed foods that contain red pigment. Lycopene has a big impact on our diet. The focus of the current review was on the ways in which lycopene levels in various food products are influenced by postharvest practices and processing methods. The postharvest procedures that affect food's lycopene content include packaging, transportation, and storage. It has been found that ripening increases the amount of lycopene in stored commodities if the temperature is not maintained at 8 ± 2°C. The packaging also helps to maintain lycopene levels when stored correctly. The ideal temperature and timing are crucial for preserving lycopene and extending product shelf life. Many heat treatments, including steaming, boiling, cooking, frying, chopping, dicing, blanching, canning, and pasteurization, are used in the processing industries; it has been shown that these techniques have different effects on the amount of lycopene. It has been demonstrated that while boiling, steaming, stewing, and canning increase the content of lycopene, high-temperature heating decreases it. The amount of lycopene also depends on the extraction techniques employed. Higher yields of lycopene are obtained by combining different extraction techniques, such as solvent extraction, enzyme-assisted extraction, supercritical fluid extraction, ultrasound-assisted extraction, and so on. This review offers insights into the lycopene content of processed products as well as a comparative analysis of the variations in lycopene content in fruits and vegetables.

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Author Contributions

All the authors are equally contributed until the completion of final drafting of the manuscript. OSD, SGS, NB, and LM helped in searching the review of literature, designing the tables, collection of primary datas. MAD, JSH and KMD did the concepts designed, preparation of manuscript and final draft.

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