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Processing, Value Addition and Post-Harvest Technology of Tomato: A Scoping Review on Global and Indian Perspective

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

India, with its favorable climatic conditions, is a major producer of tomatoes, ranking second globally. However, the tomato processing sector in India is underdeveloped, with only 1% of the produce being processed compared to developed nations such as Italy (64.02%), Spain (39.41%) and the United States (10.34%). Of the more than 180 million tonnes of tomatoes produced annually, around 40 million tonnes are processed. India's substantial tomato output, which occurs primarily in the winter, has made it a prominent participant in the global tomato processing industry. This would help the Indian market utilize tomato-based goods throughout the off-season. Lycopene, a beneficial compound, is found to be higher in processed tomato products compared to fresh tomatoes. Prominent companies in the Indian tomato processing industry include Hindustan Unilever, Nestle India, Mother Dairy, and Dabur India. Despite the potential, the sector faces

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challenges such as inadequate processing facilities and limited varieties suitable for processing, leading to substantial post-harvest losses. The demand for tomato-processed products in India has been increasing at 30% annually in recent years, with a rising variety of products being offered. Increased support, improved supply chain management, and adoption of advanced processing techniques could reduce wastage, add value, and enable India to become a prominent player in the global tomato processing industry. With the adoption of modern technologies such as automated sorting, grading, and cold storage facilities, the efficiency of the tomato processing industry can improve. This would reduce post-harvest losses and ensure better quality control.

Keywords: Tomato; processing; production; industry.

1. INTRODUCTION

India has ideal climatic conditions for growing tomatoes year-round in different parts of the country which results in a plentiful harvest year-round mainly in winter season in northern states. The crop that is grown during the winter months has high quality overall because it has a higher total solids content. The flavor, sweetness, and nutritional value that are present in the fresh fruits are all preserved in the tomato paste. It is a good source of vitamins (A, B, C, E and K), antioxidants, lycopene, carotenoids, phenolics, minerals *viz*., sodium, potassium, folate. It also consists a few levels of cholesterol, saturated fat levels with 96% of water content (Ali, et al., 2020). Businesses that make use of state-of-the-art production facilities and cutting-edge technologies make up the tomato processing sector in India.

At global level, 90% of tomatoes are consumed in their fresh form, and the remaining 10% are used in the processing industry to create tomato paste, puree, ketchup, pickles, juices, and sauces. But, in India the situation is very pathetic *i.e.* hardly 1% tomatoes are processed (Bisht and Singh, 2024). The processing of fresh and ripened tomatoes results in the production of a smooth and thick substance known as tomato paste. Raw materials used in the production of tomato-based processed goods often include tomato paste (Geetha and Rani, 2020). The industry that uses the most tomato paste is the one that makes condiments like ketchup and sauces. In contrast to guava and mango, there are not as many industries that process tomatoes (Dhawan and Kumari 2018). The districts of Krishnagiri and Chittoor in India are home to the majority of the country's processing industry. Only a small number of the varieties that are grown in India are utilized for processing, whereas the majority of the varieties grown there are used for consumption (Tiwari et al., 2022). The southern areas of India are home to the majority of the manufacturing industries that process tomatoes. Tomato processing companies in South India are able to make tomato paste as they are located near to tomato producing areas. This proximity allows for this type of production to be profitable. According to an estimate provided by the World Processing Tomato council, 41.37 million metric tonnes of tomatoes were transformed into products with additional value all over the world. As a result, constitute 26% of the whole production of fresh tomatoes. In comparison, just around 1% of tomatoes produced are processed in any way that results in value addition to the final product.

Table 1. Tomato production in India during 2002-2018

Year	Area ('000 ha)	Production ('000 mt)
2002-03	520	7800
2003-04	560	8000
2004-05	580	8800
2005-06	600	9900
2006-07	650	10000
2007-08	620	10200
2008-09	640	11200
2009-10	700	12200
2010-11	980	17000
2011-12	1000	18800
2012-13	980	18300
2013-14	980	18800
2014-15	820	16200
2015-16	840	18800
2016-17	880	20800
2017-18	1580	22320

Source:https://data.gov.in/ministrydepartment/Department%20of%20Consumer%20Affairs

The available area for tomato cultivation across India during year 2023 is about 864 thousand hectares (Dhawan and Kumari ,2018). According to food and agriculture organization of United Nations (FAO) China ranks first (67.5 million tonnes) in production followed by India (21.1 million tonnes), Turkey (13 million tonnes), USA (10.4 million tonnes), Italy (6.6 million tonnes) (Tiwari et al., 2022). India is ranked second in the

world in 2019 with a 10.52% share in tomato output worldwide. India produced over 20,000,000 million tonnes of tomatoes in 2016-17. Tomato production in India during 2002-2018 was presented in Table 1. Tomatoes are processed by a number of food processors in India into primary processed goods like tomato paste, pulp, and juice as well as secondary products *viz*., ketchup, sauce, chutney and tomato-based culinary sauces. Tomatoes are also used to make instant soups, dehydrated curries, and powders. Hindustan Unilever, Kraft Heinz, Nestle India, Conagra Brands, Field Fresh Foods, Cremica Food Industries Ltd., Reliance retail Limited, Global Green, Mother Dairy, Godrej Beverages and Foods, NAFED, and ITC are the leading companies in the tomato processing industry. Throughout contrast to the global average of 25%, only 1% of India's tomato crop is reportedly processed into various tomato products. Production of tomato (Fresh and processed) around worldwide during 2001-2021 was presented in Table 2. On the other hand, significant losses of roughly 25-30% are incurred throughout the supply chain as a result of inadequate processing facilities at the farmer's end (Dulal, 2023).

Table 2. Fresh and processed tomato production around worldwide during 2001-2021

Year	Fresh tomatoes (mt)	Processed tomatoes (mt)
2000	82000	26000
2001	83000	24000
2002	86000	30000
2003	87000	32000
2004	90000	38000
2005	97000	32000
2006	99000	30000
2007	103000	32000
2008	104000	38000
2009	110000	44000
2010	115000	39000
2011	122000	38000
2012	130000	36000
2013	132000	36000
2014	137000	40000
2015	137000	42000
2016	140000	38000
2017	141000	38000
2018	146000	36000
2019	144000	38000
2020	146000	38000
2021	150000	39000

Source:https://www.tomatonews.com/en/worldwide-total-fresh-tomato-production-in-2021_2_1911.html

2. TOMATO PRODUCTS

Numerous tomato products have been developed since ages. Some of the commonly used products has been highlighted.

2.1 Tomato Juice Production

Tomatoes that are fully ripe and have acquired colors are chopped into pieces with a knife, steamed, cleaned, and crushed in a crusher. In the steam-jacketed kettle, the crushed bits are cooked until they are very soft. To extract juice from seeds and peel, the heated tomatoes are sent through a fine-mesh sieve in the pulping machine. A temperature of 85-90°C is reached after adding the sugar and 1% salt. After the heated juice is poured into bottles, they are promptly sealed, let to cool, and then pasteurized in boiling water for around half an hour (Giovannucci, 1999).

2.2 Tomato Puree Production

To create tomato puree, the previously obtained juice is vacuum-concentrated to a total solids content of 9-12%. The product is poured into bottles, sealed with a crown cork, heated to a boil for half an hour, then let to cool. The natural total soluble solids content of tomato pastes ranges from 22-36 °Brix, whereas that of tomato puree is between 6 and 9 °Brix (Kumari and Singh, 2018).

2.3 Tomato Paste

The juice obtained in the above manner is concentrated and contains sugar, salt, and spices. In a steam jacketed kettle, the spices cloves, cardamom, pepper, cinnamon, and other ingredients, among others are loosely knotted in a muslin cloth and dropped into boiling juice. Later on, you add the sugar, salt, vinegar, acetic acid, etc. Concentration is typically done in three steps. Tomato solids make up 12% of the concentrated 28-30% solids. The final product may be preserved by adding 750 parts per million (PPM) of sodium benzoate. After being heated to room temperature and placed in clean, dry bottles, the tomato ketchup is corked and cooked in boiling water for half an hour (Nagil and Chamroy, 2020).

3. WORLD TOMATO PROCESSING

The international non-profit World Processing Tomato Council (WPTC) is a representative body

for the tomato processing industry. More than 90% of the tomatoes processed globally are currently represented by its members, which are professional farmers and/or processors organizations representative of their production area. The organization, which has its headquarters in Avignon, France, was founded in May 1998 during the 3rd World Processing Tomato Congress in Pamplona, Spain (Rajan et al., 2022). Around 180 million tonnes of fresh tomatoes are produced annually on a global basis. Comparatively, four times more rice and two times more potatoes are farmed worldwide. Tomatoes are the most processed vegetable in the world since the processing sector grows roughly 25% of the 160 million tonnes of tomatoes that are grown. Annually, over 40 million tonnes of tomatoes are processed at facilities owned by the biggest brands in the world's food sector. Processing tomatoes are grown only in open fields they are never grown in greenhouses (Rajan et al., 2022).

Temperate zones are home to the majority of tomato production regions used for processing. But the majority of this output is concentrated in the Northern Hemisphere, where between July and December, 90% of the world's harvest is processed on average. Between January and June, the remaining 10% are processed in the Southern Hemisphere. As the only nation in the Southern Hemisphere to process over a million tonnes annually concurrently with the Northern Hemisphere. Even though there are many nations that process tomatoes, the world's annual output of tomatoes is heavily concentrated, with the top ten producing nations accounting for 83% of the total. However, the amounts processed outside of these ten nations have been rising consistently in recent years, and the Top 10's share of worldwide activity has been declining (Soytong., 2021).

4. TOMATO PROCESSING INDUSTRY IN INDIA

In India, more than 1500 different types of tomatoes are grown. Commercial cultivation of these cultivars is limited. With more than 20 million tonnes tomatoes produced annually, India ranks as the world's second-largest tomato grower. Nearly 11% of the world's total tomato production ,186.82 million tonnes come from India. However, India processes about 190000 tonnes of tomatoes annually and demand for tomato processed products has surged by 40% (Pradeepkumar et al., 2022).

4.1 Hindustan Unilever (HUL)

With a market share of 25%, the Kissan brand of ketchup produced by Hindustan Unilever (HUL) is the country's second-most popular ketchup brand. One of the first processing companies to institutionalize farm-gate procurement of tomatoes from smallholder farmers in the Nasik district in 2011 was HUL. In order to build a supply chain for the manufacturing of tomato paste locally that could be used as an input into Kissan's ketchup production process, the company Kissan partnered with smallholder farmers, a local tomato paste processor named Varun Agro, and Agri-input supply firms. In 2011, Unilever received around 60% of the tomatoes it needed for the production of ketchup from India, accounting 40,000 tonnes of tomato. Through collaboration with farmers, the organization aimed to popularize sustainable agricultural practices such as enhancing soil fertility, enhancing water management, and enhancing insect control (https://www. vigyanvarta.com/ adminpanel/upload_doc/VV_ 1123_43.pdf).

4.2 Field Fresh Foods

Field fresh foods in Krishnagiri (India) processing tomato segment in 16 districts of Tamil Nadu, which is India's 3rd largest maker of processed tomato products, produces tomato sauce, pasta and pizza sauce under the Del Monte brand name. It has created a 120 hectares area research and development farm at Ladhowal, close to Ludhiana, where it is conducting trials on tomato production. These studies include the use of specialized cultivars for the processing industry as well as the application of mechanization for the planting and harvesting of tomatoes (https://www.vigyanvarta. com/adminpanel/ upload_doc/VV_1123_43.pdf).

4.3 Nestle India

Maggi, which is manufactured by Nestle India, holds 37% of the market share for ketchup in India. Nestle is the main manufacturer of ketchup in India. Additionally, Nestle manufactures tomato soup mixes that compete with those made by Knorr and other industry leaders. While

Nestle supplier development programme encourages suppliers to work together to find local sources of raw materials, the company also uses its global supply chain to bring in raw ingredients from other countries for use in the production of ketchup in India (Ohlhorst et al., 2012).

4.4 Dabur India

Under its retail brand Homemade and for the institutional market, Dabur India is a leading producer of tomato puree, tomato juice, soups and chutneys. These products are also sold by the company. It began processing tomatoes in 2011 at its plant in Siliguri, which is located in the state of West Bengal, while its factory in Nepal is responsible for the production of tomato juices (https://www.onmanorama.com/news/india/2023/08/16/nccf-and-nafed-to-curb-tomato-prices.html).

4.5 Mother Dairy

The company's pulp and concentrate factory in Karnataka, which has a capacity of 23,000 tonnes per year, is where they make tomato paste and their own brand of tomato ketchup under the Safal name. In order to meet the requirements of its processing operations, Mother Dairy formed a partnership with Bayer Crop. Science to encourage increased tomato production among farmers in the Chickballapur and Tumkur districts of Karnataka has begun. Bayer Crop Science identified tomato varieties that are acceptable for processing and scientifically produced seedlings of the nominated varieties. Bayer Crop Science also identified tomato varieties that are not suitable for processing. These were subsequently given to approximately 361 farmers so that they could continue cultivating the land on a total area of 280 hectares while being supervised by the organization. Additionally, enhanced crop production practices, such as crop protection methods, were implemented, as well as the institutionalization of traceability procedures. As a direct consequence of this, it is reported that tomato yields among farmers have grown from 35-45 tonnes per hectare. Additionally, in February of 2016, the firm disclosed its intentions to establish a new puree production and processing center in Ranchi, which is located in Eastern India. In addition, Mother Dairy provides customers in the Delhi National Capital Region with frozen tomatoes that were prepared at the facility located in West Delhi (Ohlhorst et al., 2012).

4.6 National Agriculture Co-operative Marketing Federation

The highest authority on cooperative marketing of agricultural products in India is the National Agricultural Cooperative Marketing Federation of India Ltd. (NAFED). Under the multi-state Cooperative Societies Act, it was founded in 1958. The purpose of NAFED's founding was to develop national trade in agricultural products and forest resources. Chief executives of state level marketing/tribal/commodity federations, primary cooperative marketing/processing societies, and apex level marketing/consumer cooperative/other national level federations represent the organizations over 900 members. The majority of NAFED's members are farmers. The work that NAFED does improves both agriculture and produce postharvest. Through the cooperative infrastructure, NAFED directly purchases stocks from farmers in controlled wholesale market at open auction, giving them access to a ready market at a reasonable price and shielding them from abuse by private traders (https://www.onmanorama.com/news/india/2023/08/16/nccf-and-nafed-to-curb-tomato-prices.html). NAFED operates a tomato paste and ketchup production facility in Vellore (Tamil Nadu) (Tiwari et al., 2022).

4.7 Indira Foods

It is a tomato ketchup manufacturer that began operations in 2008 and primarily serves the southern Indian retail and institutional markets. The company's primary market is in southern India. With the ability to produce 30 tonnes per day, not only does it provide Global Green and Namdhari Group, but it also has a market share of 70 % in the sales of its products to hotels, restaurants, and airlines in Karnataka. Tomatoes are sourced for the company's operations from the Kolar area in Karnataka (Pradeepkumar et al., 2022). The rise in demand for value-added and reasonably priced tomato products has led to an increase in output of tomatoes as well as an increase in processing of tomatoes in India. In order to compete successfully with established and well-known companies, new entrants must first carve out a specific place for themselves in the market. On the worldwide market, there is room for the export of fresh tomatoes in addition to processed tomato products. This opportunity

exists. Along with flavoured tomato paste and tomato soup, there is a growing acceptance for the use of tomato pastes and purees in the preparation of tomato-based dishes in the house.

5. LYCOPENE CONTENT IN TOMATOES AND TOMATO PRODUCTS

Lycopene is a bright red colour carotenoid pigment and phytochemical found in tomatoes (Perveen et al., 2015). Lycopene content varies according to cultivars and its content increases with the fruit ripening (Kuti and Konuru, 2005). Lycopene is biosynthesized in plants mainly above 90% as the all-E-isomer. Most available sources of lycopene maintain the natural isomeric distribution ratio. It was so that during food processing, lycopene undergoes geometrical isomerization increasing the proportion of Z-isomers (Melendez-Martinez et al., 2014). Additionally, when processed foods were being stored, lycopene experienced additional geometric isomerization, mostly retro-isomerization. Thus, a tomato extract with stable Z-isomers that do not undergo retro-isomerization would be the best source of highly bioavailable lycopene. Lycopene has been isomerized by a variety of techniques, including complexation with boron trifluoride, heat, acids, active surfaces, and light with or without a photosensitizer (Xianquan et al., 2005). These isomerization processes highlight the competition between degradation and isomerization in addition to causing the creation of different Z-isomers. Degradation happens more quickly than isomerization at temperatures over 50 °C or during prolonged heating periods (Lambelet 2009).

In fruits and vegetables, nutritional content is reduced due to cooking but in case of tomato processing increases the lycopene content (Shi and Maguer, 2000). From tomato-based sources, processed tomato products such pasteurized tomato juice, soup, sauce, and ketchup have the highest quantities of bioavailable lycopene (Sandei, 2018). Compared to fresh tomatoes, tomato soup and tomato paste have higher accessible lycopene. Tomato sauce is therefore a better supply than raw tomatoes for this reason (Wu et al., 2022). Lycopene is firmly bonded to vegetable fibre and is insoluble in water, despite the fact that most green leafy vegetables and other lycopene sources are low in lipids and oils (Srivastava and Srivastava, 2015). Although it is not a necessary component for humans, lycopene is frequently consumed through food, mostly in tomato-based recipes (Shi and Maguer, 2000). Lycopene content in various tomato products were presented in Table 3. Lycopene is absorbed from the stomach and accumulates in the liver, adrenal glands, and testes before being carried by different lipoproteins through the circulation (Arballo et al., 2021). Lycopene has been considered a possible agent for the prevention of some forms of cancer, notably prostate cancer, because preliminary research has indicated an inverse link between intake of tomatoes and cancer risk (Agarwal and Rao 2000).

Table 3. Lycopene content in various tomato products (mg/100g)

Products	Lycopene (mg/100g)	
	472nm	502nm
Fresh Tomatoes	12.58	12.34
Tomato paste	15.65	15.83
Tomato boild sauce	4.32	3.92
Tomato ketchup	17.12	17.00
Spaghetti Sauce	15.92	16.15

Lycopene content (mg/100g) recorded in tomato paste, tomato ketchup and spaghetti sauce increased compared to the lycopene content of fresh tomatoes (Alda et al., 2009, Wawrzyniak et al., 2005).

6. FUTURE TRENDS IN THE TOMATO PROCESSING INDUSTRY

Due to rapid urbanization, consumers in emerging and developed countries are attracted to eat convenience foods and tomato products. To meet growing demand, processed food manufacturers and tomato paste processors are focusing on edible products. In 2021, the value of the world tomato processing market was 43.4 million tons. The CAGR of the global refining industry is expected to be 3.8% during 2022-2027. India's tomato industry experienced moderate growth between 2015 and 2020. However, the market is expected to grow at a CAGR (compound annual growth rate) of 4.2% during 2021-2026. Advances in seed research and breeding methods make tomatoes available year-round. It is one of the driving factors of the global tomato industry (https://abcfruits.com/tomato-processing-industries-in-india/). The growing output and consumption of processed tomatoes support the global market for tomato processing. Global consumption of processed tomatoes reached 82.54 million tons in 2023. It is anticipated that throughout the projected period of 2024-2032, their consumption will increase

even more, reaching 115.46 million tons in 2032 at a CAGR of 3.8% (https://www.expertmarketresearch.com/reports/tomato-processing-market).

The previous three years have seen a 30% annual growth in demand for tomato-processed goods in India (Ramappa and Manjunatha 2016). Furthermore, a growing variety of tomato-based processed meals are being offered, including some that are powder-based (Anisuzzaman et al., 2022). There are several chances to breed dual purpose possibilities with processing quality qualities, according to ICAR-IIHR Bengaluru (Archana, 2021). This would facilitate the production of more puree and paste in India by the tomato processing sector (Rajan et al., 2022). Over the past several decades, there has been a significant increase in tomato exports as consumers have grown more aware of the variety of tomato-flavored goods on the market (Gould, 2013). To suit consumer demand, tomato-based ingredients like purees and concentrates have witnessed a rise in sales (Gatahi, 2020).

7. CONCLUSION

India, with its favorable climatic conditions and year-round tomato cultivation, holds vast potential in the tomato processing industry. The majority of tomato-based products are manufactured in southern India especially in proximity to tomato-producing areas which facilitates profitable operations. Globally, tomato processing industries have capitalized on technological advancements with tomatoes being transformed into various value-added products *viz*., ketchup, paste, sauces and pickles. In contrast, India's tomato processing sector is underdeveloped, primarily due to the lack of adequate facilities and limited variety of tomatoes suitable for processing. This has resulted in substantial post-harvest losses particularly at the farmer's end underscoring the need for investment in modern processing technologies and infrastructure. By leveraging its second-ranking global position in tomato production, India has the potential to significantly expand its tomato processing sector. With increased government and private sector support, improved supply chain management and adoption of advanced processing techniques, India could reduce wastage, add value to its tomato crops and become a more prominent player in the global tomato processing industry. This transformation could enhance farmer incomes, meet rising domestic and export demands and contribute to the overall growth of the agricultural and food processing sectors.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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