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ECO-FRIENDLY PEST CONTROL AND PROCESSING OF TOMATO PRODUCTS: A REVIEW

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ABSTRACT

Tomato (*Lycopersicon esculentum* L.) cultivation is increasingly adopting biological pest control strategies to manage key insect pests while reducing reliance on synthetic pesticides. This review focuses exclusively on biological control methods, including the use of predatory and parasitoid insects, microbial biocontrol agents and bio-pesticides derived from natural sources, highlighting their effectiveness in pest suppression and residue reduction in harvested tomatoes. The review further examines the chemical processing of tomatoes, emphasizing unit operations such as enzymatic treatment, chemical preservation and the use of additives that influence stability, color, flavor and shelf life. Major chemically processed tomato products including paste, puree, ketchupand juices are discussed in relation to their chemical composition and quality attributes. The link between biologically managed tomato production and chemical processing outcomes is addressed, particularly regarding raw material chemistry and its impact on processed product quality. This review provides a focused overview of biological pest control and chemical processing practices that support the production of safe, stable and value-added tomato products.

Key words: Biological pest control, biocontrol agents, tomato processing, tomato products, Ketchup. Paste and puree

Introduction

Tomato (*Lycopersicon esculentum* L) is a globally significant crop in terms of quality and quantity. Tomatoes originated in South America's Andes (Dam *et al.*, 2005; Jy *et al.,* 2004). The cultivated Spanish conquistadors introduced tomatoes to Europe in the 16th century and thereafter introduced from Europe to southern East Asia, Africa and the Middle East. Most recently, wild tomatoes have been spread to other parts of South America and Mexico. Common names for the tomato include tomate (Spain and France), tomat (Indonesia), faanke'e (China), tomati (West Africa), and tomatl (Nahuatl). Jitomate (Mexico), Pomodoro (Italy) and Nyanya (Swahili)(Dam *et al.*, 2005).

It is a warm-season fruit vegetable, which needs day temperatures of 25-30 °C and night temperatures of 16-20 °C for optimal growth and development, with fruit set best achieved at 18-24 °C, where night temperature is crucial (Garg and Cheema, 2011). The tomato fruit is categorized as a berry, with significant diversity in size, shape and internal structure (locules), ranging from little cherry varieties to giant fresh-market cultivars with 4-6 locules (Jones, 2007). Tomato plants have three types of growth habits: determinate (bush), indeterminate (vining), and semi-determinate. They are fast-growing, herbaceous plants that often require supporting or caging to control their sprawling, vine-like growth and increase fruit yield (Vicente *et al.,* 2015). Tomato plants normally rise to a height of 1-3 meters and are perennial in their natural habitat, but are planted as annuals in temperate countries. There are numerous varieties with varying fruit size, shape, color and water content; processing types such plum and Roma tomatoes have long stems with lower moisture, which makes them appropriate for canning and sauce preparation (Allen, 2008).

They help to maintain a healthy and balanced diet. They are high in minerals, vitamins, amino acids, carbohydrates and dietary fiber. Tomatoes have high levels of vitamins B and C as well as iron and phosphorus. Yellow tomatoes contain more vitamin A than red tomatoes, but red tomatoes include lycopene, an antioxidant that may provide protection against carcinogens (Dam *et al.,* 2005). Tomatoes have several health benefits, including a lower risk of cardiovascular disease, cancer, osteoporosis and liver issues. They have detoxifying effects due to the presence of chlorine and sulfur, which help the liver operate and eliminate physiological toxins. Due to high in lycopene, vitamin C and vitamin E making them powerful antioxidants that limit LDL oxidation, minimize artery hardening and help lower blood pressure. Consumption of tomatoes and tomato-based items has been related to better cardiovascular health, increased energy and antioxidant protection. Tomato juice also promotes skin cell renewal, treats sunburn and is thought to be good for people who are undergoing dialysis (Lal, 2021).

Insect pests, including the fruit worm *Helicoverp aarmigera* Hübner (Collingwood and Bourdouxhe, 1980), leafminer flies (*Liriomyzatrifolii* Burgess) (Neuenschwander *et al.,* 1987), and whitefly *Bemisiatabaci* Gennadius (which can transmit Tomato yellow leaf curl virus (TYLCV)) (D'Hondt and Russo, 1985; Camara *et al.,* 2013). The invasive South American tomato leafminer was recently introduced. A recent problem for farmers is *Tutaabsoluta* Meyrick (Pfeiffer *et al.,* 2013). The South American tomato pin worm can infect tomato plants at any stage of growth. Fruit quality and crop productivity are adversely affected by *Tutaabsoluta* larvae, which mine leaves and bore holes in stems and fruits (Diatte, 2018).

Utilizing food by-products/waste as a secondary source for innovative product development is a growing research topic. Food sector waste, both solid and liquid, may offer health benefits. Recent research has focused on utilizing food waste for nutraceuticals and pharmaceuticals as well as generating energy through biogas, hydrogen and bio-ethanol production. Food waste must be processed before it may be used in food items. Converting food waste into valuable goods comes with significant research and development costs. As a result, obtaining vital and high value added products is critical for justifying the expenditure (Karthika *et al.,* 2016). Tomato being has a low shelf life. Therefore storage and preservation of the tomatoes is one of the most important factors after harvesting. Without proper storage and preservation, they lose their quality. Tomatoes are commonly processed into pulp, juice, paste, puree, dehydrated tomato, tomato flakes and powder, soup, ketchup, sauce, pickles and canned tomatoes (Motamedzadegan and Tabarestani, 2018).

This review focuses on biological control strategies for the management of major tomato pests, emphasizing the use of natural enemies, microbial agents and biologically derived pesticides as sustainable alternatives to chemical pest control. In parallel, it examines the chemical processing of tomatoes, highlighting key operations such as enzymatic treatments, preservation, and formulation practices that influence product stability and quality. Major chemically processed tomato products, including paste, puree, ketchup and juices, are discussed in relation to their chemical composition. By integrating biological pest control at the production stage with chemical processing approaches, this review aims to provide a focused perspective on the development of safe, stable and value added tomato products.

Biological control of tomato pests

1. Tomato Pinworm

- *Trichogramma achaeae,* an egg parasitoid, is a potential biological control agent for the South American tomato pinworm, *Tutaabsoluta.* (Cabello *et al.,* 2009; Cascone *et al.,* 2015; Chailleux *et al.,* 2012; Oliveira *et al.,* 2017).
- *Trichogramma cacoeciae* acts as a biological control agent against the tomato pinworm (*Tutaabsoluta*) in northeastern Tunisia. Cherif andKaouthar, 2013).
- *Campyloneuropsiscincticornis* is a potential biological control agent of the South American tomato pinworm (Sola *et al.,* 2025).
- Three microbial control agents, including *Bacillus thuringiensis* varkurstaki, *Beauveriabassiana* (B.b) and *Metarhizium anisopliae* (M.a), were investigated against tomato pinworm (Sabbour, 2014).
- Microbial control agents *Bacillus thuringiensis* Diple (2X), B.t kurstaki HD-73 and B.t kurstaki HD-234 were studied against tomato pinworm (Sabbour and Nayera, 2014).

- *Beauveria bassiana (Balsmo)* used against South american pinworm, *Tuta absoluta (*Kumari, 2023)

2. Thrips:

- The efficiency of controlling *Frankliniella occidentalis* (Pergande) using inoculative releases of the predator *Dicyphus hesperus* Knight (Shipp and Wang, 2006).
- *Neoseiulus cucumeris* (Oudemans) and *Amblyseius swirskii* (Athias-Henriot) are two phytoseiid mites that manage thrips (Ahmed and Lou, 2018).
- Releases of the predatory mite, *Amblyseius cucumeris* for the control of *Frankliniella occidentalis* (Gillespie, 2009).
- At a concentration of 200 infectious juveniles (IJs) per cm^2, entomopathogenic nematode (EPN) species/strains (Rhabditida: *Steinernematidae* and *Heterorhabditidae*) were evaluated against mixed soil-dwelling life stages of the western flower thrips (WFT), such as second-instar larvae, prepupae, and pupae. *Frankliniella occidentalis* (Thysanoptera: Thripidae) in a plant-growing medium in a lab (Ebssa *et al.,* 2004).
- Neem based biopesticides and Tobacco based biopesticides also used to control thrips (Solangi *et al.,*2014).

3. Serpentine leaf miner:

- Azadirachtin used against Serpentine leaf miner (Pathan, 2024).
- Predatory insects like *Trichogramma pretiosum, Nesidiocoris tenuis* and *Macrolophus pygmaeus* are beneficial (Singh andMourya, 2024).
- Fungal agents, like *Metarhizium anisopliae* and *Beauveria bassiana,* attack pest eggs, larvae and adults (Singh andMourya, 2024).
- Parasitic wasps like *Chrysocharis parksi* and *Diglyphus begini* can be used (Singh and Mourya, 2024).
- *Diglyphus isaea* (Walker) and *Dacnus asibirica* Telenga were released to control Serpentine leaf miner (Ozawa *et al.,* 2001; Elkhouly and Alhririg, 2016).
- Garlic extract proved effective in managing *L. trifolli*eggs and larvae, making it a viable alternative to traditional management methods (Rocha *et al.,* 2020).
- NSKP 10% was found most effective against leaf miner *Liriomyza trifolii* (Barde and Shrivastava, 2017).

4. Fruit Borer:

- Neem oil, *Bacillus thuringiensis*, *Helicoverpa armigera* nucleopolyhedro virus (HaNPV), *B. bassiana*and *V. lecanii*have been shown to effectively treat *Helicoverpa armigera* (Shamli *et al.,* 2025).
- *Verticillium lecanii*, *A. indica*and *Beauvarica bassiana* used to control fruit boror (Kaur and Singh, 2014).
- Neem seed kernel extract, Neem leaf extract, Neem oil used to control fruit boror (Biswas *et al.,* 2022).
- *Bacillus thuringiensis* var. kurstaki) and botanical extract of *Derris indica* also used to control fruit borer (Devi *et al.,* 2024).
- Neem oil 5%, *Metarhizium anisopliae, Beauveria bassiana,* NSKE 5% used against fruit borer (Dedeepya *et al.,* 2023).

5. Striped mealybug:

- *Cryptolaemus montrouzieri* as a predator of the striped mealybug, *Ferrisia virgata* (Wu *et al.,* 2014).
- Botanical extracts of bird chili (*Capsicum frutescens* L.), garlic (*Allium sativum* L.), black pepper (*Piper nigrum* L.), and neem (*Azadirachta indica*) were tested on *F. virgata* (Roddee *et al.,*2020).
- Green lacewings and brown lacewings used to control mealybug outbreaks (McCorquodale and Hodges, 2017).

6. Whitefly:

- Parasitoid *Encarsia formosa* were used to control whitefly (van Roermund *et al.,*1997).
- *Beauveria bassiana* acts as an endophytic fungus that controls pests (Wang *et al.,*2023; Haron *et al.,* 2025).
- *A. herbicolus* as potential biological control agent of *Bemisia tabaci* on tomato (Cardoso *et al.,*2025).
- Predators *Macrolophus pygmaeus* (Rambur) and *Nesidiocoris tenuis* Reuter as well as on the parasitoids *Eretmocerus mundus* (Mercet)

and *Encarsia pergandiella* Howard used to control whitefly (Moreno-Ripoll *et al.*, 2012)

- Biopesticide Azadirachtin also used to control whitefly (Abhishek *et al.*,2021).

7. Leaf caterpillar:

- *Heterorhabditis bacteriophora* EUPT-SD as well as *Photorhabdus luminescens* and *Bacillus thuringiensis* var. kurstaki, have been used to control the 4th larval instar of *Spodoptera litura* (Thakur *et al.*, 2023; Thakur *et al.*, 2022).
- A number of *Bacillus thuringiensis* (Berliner) products such as Condor® OF, Dipel® 2X, Javelin® WG, Bactec® III, Biobit® FC, Cutlass® WP and Lepinox® G were biological insecticides. Additional biological therapies included the use of an entomophagous nematode, *Steinernemacarpocapsae* against leaf caterpillars and a baculovirus, SeNPV, which was identified from *S. exigma*(Liburd *et al.*,2000).
- Beneficial bacteria found in tomato rhizosphere soils have the ability to systematically give tomato plants resistance to herbivores that is dependent on jasmonate (Ling *et al.*, 2022). PGPR-based biopesticides provide a sustainable and environmentally benign solution to insect infestations (Bano and Muqarab, 2017).
- Bacillus species such as *B. popilliae, B. lentimorbus, B. larvae, B. thuringiensis,* and *B. sphaericus* are utilized as microbial biological control agents (Saraswathi *et al.*, 2023).

Processing of Tomato

The tomato processing flowchart for whole, sliced, diced, paste and juice is displayed in Figure. Fruit quality gradually deteriorates while awaiting processing. To unload tomatoes, they are either placed on an inclined belt or filled with water from overhead nozzles. To use wateropen the valves on the sides or underneath of the gondolas, allowing tomatoes to flow into water flumes.

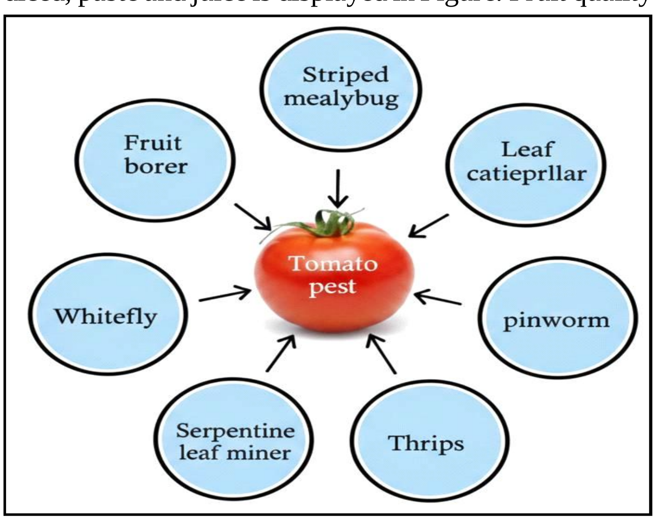

Fig. 1: Major insect pest of tomato.

Grading:

The USDA classifies tomatoes for processing into four categories: A, B, C and culls (USDA, 1983). Grading is based on color and percentage of defects. Color can be evaluated visually by estimating the quantity of red on the surface or using an electronic colorimeter on raw juice samples. Defects may include worms, freezing damage, stems, mechanical damage, anthracnose, mold or decay.

Tomatoes for canning are rated by color, hardness, flaws and size. They can be whole, sliced or chopped. Graders must be trained to assess color and hardness. The tomato's color should be uniformly crimson across its surface. Color is assessed using USDA issued plastic color comparators, the Munsell or Agtron colorimeter or by grinding tomatoes into juice and applying a correlation calculation to convert to the Munsell scale. To ensure a successful canning process, tomatoes should have a firm character. Cultivars with soft, watery or big seed cavities are graded lower due to their unsightly look. Although size is not a grading factor, tomatoes must be larger than a predetermined minimum size.

Washing:

Washing is a crucial step in creating tomato products with low microbial count. Thorough cleaning eliminates dirt, mold, insects, Drosophila eggs and other pollutants. The washing efficiency affects microbiological counts in the final product (Heil *et al.*, 1984, Zacconi *et al.*, 1999).

Warmer water sprays or dips (up to 90°C) have lower microbial counts. warm water is often not used due to economic considerations (Adsule *et al.*, 1982; Trandin *et al.*, 1982). Adding lye or surfactants to water can improve dirt removal effectiveness. However, surfactants have been linked to bacterial infiltration into tomato fruit by lowering surface tension (Bartz, 1999). Washing also helps cool the fruit. Washing tomatoes reduces field heat, slows respiration, and prevents quality loss during hot summer harvests.

Flume water can be recirculated or used in counterflow systems, but in both cases the first flume often spreads contamination instead of cleaning tomatoes, since dirt from the truck washes into the flume water Because contact time is limited, chlorine is added to flume water to control spores in the water rather than on the tomatoes; in dirty water, chlorine depletes quickly and must be monitored constantly (Heil *et al.*, 1984).

Sorting:

A plant uses a set of sorters. An inclined belt is the primary sorter, particularly for tiny plants. The tomatoes are unloaded onto the belt. The circular fruit moves down the belt and into a water flow. The belt transports waste, including leaves, sticks, stones and rotten tomatoes, to a disposal container.

Photoelectric color sorters are widely used to eliminate green and pink tomatoes. Tomatoes pass between conveyor belts in front of sensors and unacceptable fruit is removed by pneumatic ejectors. Small amounts of green tomatoes do not harm juice quality; although they lower pH, they do not affect color and can increase paste viscosity due to lower maturity (Luh *et al.*, 1960, Whittenberger and Nutting, 1957). Pink or breaker tomatoes are undesirable because they reduce juice redness. Both green and pink tomatoes are removed from whole and diced product lines. Size sorters also separate very small tomatoes, which are unsuitable for canning and are instead sent to juice or crushed tomato processing.

The final sorting process involves moving past human sorters, which are more sensitive than automated sorters.

Coring and trimming:

Traditionally, tomatoes were scored by hand or machine to remove stem scars. Modern tomato types have smaller cores, making this procedure unnecessary. Trimming to eliminate rot or green sections is not common in the United States due to high labor costs.

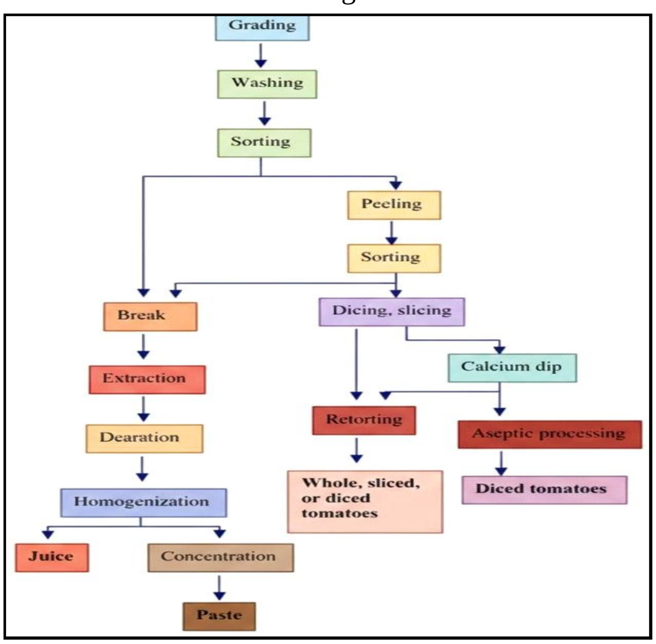

Fig. 2: Flow diagram of tomato processing (Barringer, 2004).

Juice, paste and sauce production:

Most processed tomatoes are juiced and then condensed into paste. The paste is remanufactured into several sauce items.

Break:

Tomatoes go through a break mechanism before being sliced. Some break systems use vacuum to reduce oxidation. Ascorbic acid does not degrade during the break process in a vacuum-operated industrial plant (Trifiro *et al.*, 1998). The loss of ascorbic acid increases with higher break temperatures when no vacuum is applied (Fonseca and Luh, 1976).

Tomatoes can be juiced using either the hot or cold break method. The majority of juice production occurs during a hot break. The hot break method involves fast heating tomatoes to 82°C to inactivate the pectolytic enzymes polygalacturonase (PG) and pectin methylesterase (PME). Inactivating these enzymes helps maintain optimal viscosity. The hot break method is commonly used to concentrate juice into paste, which requires high viscosity for application in various goods. Hot break processes often occur at 93-99°C.

To boost yield and enzymatic activity, tomatoes are diced and mildly cooked during the cold break process. Pectolytic enzyme activity peaks at 60-66°C. Cold break juice preserves color and flavor while reducing viscosity through enzyme activity. Although this juice can be turned into a paste, its reduced viscosity makes it ideal for tomato recipes. Juice and juice-based beverages, both hot and cold break pastes with outstanding color and viscosity are available for purchase (Barringer, 2004).

Extraction:

After the break system, comminuted tomatoes are passed via an extractor, pulper, or finisher to remove seeds and peel. Juice is removed using either a screw or paddle extractor.

De-aeration:

Following breaking or extraction, de-aeration is often used to remove dissolved air. To prevent oxidation at high temperatures, the juice is quickly deaerated by pulling a vacuum. De-aeration helps prevent foaming while concentration. Non-deaerated products lose significant amounts of vitamin C (Barringer, 2004).

Homogenization:

The juice is homogenized to improve viscosity and reduce serum separation. The homogenizer is similar to one used for milk and dairy products. Juice is pushed through a tiny aperture under high pressure, shredding suspended particulates. Increasing particle surface area improves product viscosity.

Concentration into paste:

If the final product is not juice, it is then condensed into paste. Concentration takes place in forced circulation, multiple effect and vacuum evaporators. Typically, three- or four-effect evaporators are utilized, with current equipment utilizing four effects. The temperature increases with each succeeding consequence. A normal temperature range is 48–82°C. Vapor is collected from later effects and used to heat the product in preceding ones, saving energy. Reduced pressure lowers temperature, preventing color and flavor loss.

To meet the USDA's definition of paste, the paste is concentrated to at least 24% NTSS (natural tomato soluble solids). Commercial paste is offered in various solids contents, finishes and Bostwick consistency. bigger screen sizes result in coarser particles and bigger finishes. Bostwick can measure from 2.5 to 8 cm (tested at 12% NTSS) (Barringer, 2004).

Aseptic processing

To pasteurize the paste, it is heated in a tube in tube or scraped surface heat exchanger for a few minutes. After cooling, it is poured into sterile containers using aseptic filler. A common procedure involves heating to 109°C and holding for 2.25 minutes. Heat to 96°C and hold for 3 minute. Aseptically prepared items should be chilled before filling. To ensure good quality and many aseptic packages cannot resist temperatures beyond 38°C. To fill the paste into steam sterilized bags, use an aseptic bag-in-drum or bag-in-crate filler. Paste is commonly available in 55 gallon drums or 300 gallon bag in box containers.

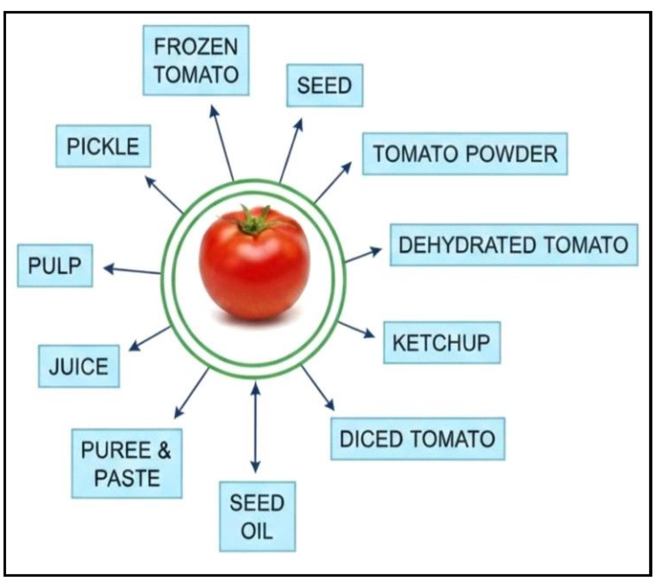

Fig. 3: Tomato processing product.

Remanufacturing into sauce

Convenience meal manufacturers repurpose tomato paste by adding water, particles, and spices to create the desired sauce. During tomato season, some sauces are created with fresh tomatoes, but this is not as frequent. Paste based sauce production is cost effective as it utilizes unused equipment in tomato processing plants during off season. Paste is more cost-effective for shipping than sauce (Barringer, 2004).

Tomato Processing: Advantages and Disadvantages

Advantages

1. **Extended storage life:** Processed tomatoes last much longer than fresh ones, reducing spoilage.
2. **Better use of surplus produce:** Excess tomatoes during peak seasons can be processed instead of being wasted.
3. **Increased economic value:** Processing adds value to tomatoes and increases profit for farmers and industries.
4. **Availability throughout the year:** Processed products can be used even when fresh tomatoes are not available.
5. **Ease of use:** Ready-to-use products save cooking time and effort.
6. **Improved antioxidant availability:** Processing enhances the absorption of lycopene, which is beneficial for health.

Disadvantages

1. **Reduction in certain nutrients:** Heat processing may reduce vitamin C and some natural enzymes.
2. **High processing cost:** Equipment, energy and packaging increase production costs.
3. **Added ingredients:** Some products contain extra salt, sugar or preservatives that may not be healthy in excess.
4. **Environmental concerns:** Processing generates waste and requires large amounts of water and energy.
5. **Limited access for small farmers:** Small scale producers may lack resources for processing facilities.

Tomato processing product

Tomato processing plays an important role to providing healthy, safe, nutritious and acceptable food to consumers all year. Tomato is a climacteric fruit with a limited shelf life, prone to quick ripening, shrivelling and quality loss at ambient temperatures, resulting in post-

Table 1: Pest complex of tomato and their damaging stage.

Sr	Insect pest	Scientific Name	Family	Order	Damaging stage
1	Tomato Pinworm	*Tuta absoluta*	Gelechiidae	Lepidoptera	Larva
2	Serpentine leaf miner	*Liriomyza trifolii*	Agromyzidae	Diptera	Maggot
3	Thrips	*Frankliniella occidentalis.*	Thripidae	Thysanoptera	Nymph and Adult
4	Fruit Borer	*Helicoverpa armigera*	Noctuidae	Lepidoptera	Larva
5	Striped mealybug	*Ferrisia virgata*	Pseudococcidae	Hemiptera	Nymph and Adult
6	Leaf caterpillar	*Spodoptera litura*	Noctuidae	Lepidoptera	Larva
7	Whitefly	*Bemisia tabaci*	Aleyrodidae	Hemiptera	Nymph and Adult

harvest losses and seasonal glut. Processing preserves the product, reduces waste, keeps prices stable and ensures year-round supply. Tomatoes and tomato-based products are low in calories but high in antioxidant micronutrients, making them nutritionally beneficial. Advances in processing technology have increased the availability of items such as juice, puree, paste, ketchup, soups, pickles and canned tomatoes, which are widely utilized in households and the food service industry.

1. Dehydrated tomato:

Dehydration is the process of carefully removing water from tomatoes in order to increase their shelf life. Tomato variety, slice thickness, surrounding humidity and drying equipment performance all affect how long a tomato takes to dry. Because of their high pulp and low seed and moisture content, firm, ripe, meaty tomatoes like Roma, plum, pear or paste are recommended; high moisture tomatoes like beefsteak are inappropriate. Temperature and air circulation must be properly controlled for dehydration to be effective; low temperatures lead to delayed drying and microbial development, while high temperatures promote case hardening and quality degradation. A deep red shade and a leathery, dry texture without surface stickiness are characteristics of properly dried tomatoes. Tomato flakes and powder are made from dried tomatoes, which can also be rehydrated in water or other liquids for use in a variety of culinary dishes (Geetha and Rani, 2020).

2. Tomato powder:

Tomato powder is created from either hot or cold broken paste. It is used for making soup and preparation of different culinary dishes. The paste is filtered to remove skin, seeds and long fibers. It is concentrated to a maximum of 45° Brix for hot break and 50° Brix for cold break (Geetha and Rani, 2020). The hot break method is typically utilized to make the paste because it has superior reconstitution characteristics than cold-break paste. Concentrated paste is often dried by roller drum drying, foam-mat drying or spray drying; spray drying is the best method for creating high quality powder (Goula and Adamopoulos, 2005). Drying processes must avoid overheating and particle adhering since tomato solids are thermoplastic. Additionally, the method should reduce exposure to ambient air during transfer and packaging due to the high hygroscopicity of tomato powder. Vacuum packaging and airtight sealing are important for maintaining product stability since oxygen exclusion and storage temperature have the biggest effects on shelf life (May, 2003).

3. Tomato ketchup:

Ketchup is a product prepared from tomato paste that has been diluted with 15% soluble solids. Sugar, salt, vinegar, spices, red pepper extract, and other ingredients including onions, garlic and extracts of spiced herbs are used to add taste it. It is currently one of the most widely used, commercially available table sauces, especially among young people and families who use a lot of ketchup (Intelmann *et al.,* 2005).

4. Tomato juice:

Tomato juice is made from completely ripe, well-colored tomatoes by crushing the entire fruit and using fine screening to remove the skins and seeds. The result is a smooth liquid that can be consumed directly without dilution or concentration. The processing begins with the wash and trimming of tomato, followed by steam and cutting or crushing. To separate the juice from the skins and seeds, the crushed mass is heated until it becomes soft and then run through a pulping machine equipped with a fine mesh filter. The juice is heated to 85–90 °C, hot-filled into bottles, sealed right away, pasteurized in boiling water for about 30 minutes and chilled after adding sugar and salt (about 1%). The final product is a smooth liquid that is frequently packaged in bottles or cans and used either directly as a beverage or in recipes that call for a consistent texture and moderate tomato taste (lThakur *et al.,* 1996).

5. Tomato pulp:

Tomato pulp is made from completely ripe tomatoes, preferably small kinds with a high solid content and is used as a raw material for many preserved items such as juice, sauces, puree and paste. The tomatoes are sorted, cleaned, washed then blanched in boiling water for about 2 minutes to minimize microbial contamination and aid in pulping. Blanched tomatoes are pulped by hand or machine and the skins and seeds are sieved through coarse and fine meshes. The resultant pulp is utilized immediately for further processing and is usually heated to inactivate enzymes and bacteria or it is frozen immediately to prevent quality deterioration (Dam *et al.*, 2005).

6. Tomato puree and paste:

Tomato puree and paste are made by concentrated tomato pulp using controlled evaporation. Fresh tomato pulp comprises approximately 5-6% total solids, which rises to 10-12% when boiled to half its volume (puree) and up to 35-40% with additional concentration (paste). Concentration is achieved through careful boiling with constant stirring to avoid burning; the use of steam-equipped pots increases color and efficiency, but is most appropriate for large-scale operations. The concentrated product is transferred to containers and pasteurized in a hot water bath for approximately 30 minutes. Additionally, tomato paste can be made by filtering unheated pulp in sterilized cotton sacks to remove serum, followed by salting and pasteurization, resulting in a more natural flavor. Industrial vacuum evaporators are used to produce bright red purees and pastes (Dam *et al.*,2005).

7. Diced tomato:

Diced tomatoes are the tomatoes that have been sliced or chopped. In the United States, it describes canned chunks of plum tomatoes in tomato juice or puree. Calcium chloride is used to maintain the cell structure of preserved tomatoes, resulting in a firmer texture. Tomatoes are available in two sizes: standard (approximately 2 cm or 7/8 in) for long cooked meals and tiny (about 1 cm) for rapid applications. A relatively newcomer to the processed tomato market, they are frequently more flavorful than commercially manufactured fresh tomatoes. Diced tomatoes are additionally possible preserved via high pressure processing, a non-thermal approach (Geetha and Rani, 2020).

8. Tomato pickle:

Tomato pickle is a popular condiment in South Asian cuisines due to its spicy-tangy flavor and long shelf life. Fully ripe tomatoes are properly cleaned under running water to remove dust and foreign matter then wiped with a muslin cloth to remove surface moistness. The tomatoes are chopped up and dried in a cabinet tray dryer. The dry material is crushed with a mixer and sieved through mesh to produce tomato powder. To make a spice mix, grind red chillies, cumin seeds, and dry ginger in the specified ratio and sift through mesh. To make a homogenous pickle, the necessary amount of edible oil is heated separately, cooled somewhat, and then blended evenly with the dry mixture. The prepared pickle is put into clean, dry, sealed glass bottles and stored at room temperature (Narsing Rao *et al.*, 2011).Pickling with salt and acid is a well known method of preservation that extends shelf life and stabilizes sensory properties.

9. Frozen tomato:

Tomatoes have been frozen to a lesser extent than other processed tomato products. To freeze tomatoes, they are washed, sorted, blanched, peeled and processed as whole, sliced, or diced before being frozen using individually rapidly frozen (IQF) belt freezers. Whole tomatoes undergo rapid crust freezing followed by finish freezing to "13 °C (8 °F). Whereas cryogenically frozen sliced tomatoes demonstrated acceptable firmness, their commercial potential was limited due to costly storage expenses and low temperature requirements (Barringer, 2003). Studies have revealed that osmodehydrofreezing tomato slices improves quality and functional qualities during extended frozen storage when compared to traditional freezing procedures (Dermesonlouoglou *et al.*, 2007).

10. Waste from tomato:

Tomato processing creates a significant amount of waste, particularly skins and seeds, which constitute around 40% of the fresh fruit processed. Due to restricted utilization technology, this trash is frequently thrown in open locations, causing environmental and insect issues. As a result, there is a critical need to develop effective technology for valorizing tomato processing waste. Tomato peel is an useful by product high in dietary fiber (299.4 g/kg), ash (256.4 g/kg), proteins (100.8 g/kg) and lycopene (734 µg/g dry weight). It also contains bioactive chemicals like lutein, -carotene, flavonols, quercetin, and kaempferol. These chemicals provide considerable cardioprotective and antioxidant effects. Enzyme-assisted solvent extraction allows for efficient lycopene recovery (77-88%), whereas extraction with supercritical fluid produces very pure lycopene. The use of recovered lycopene in nutraceuticals and supplements improves both health and economic returns from tomato processing waste(Geetha and Rani, 2020).

11. Tomato seed:

Tomato seeds and skins, while nutritionally beneficial, are frequently removed during the manufacturing of most products made from tomatoes. Tomato seeds contain important fatty acids, antioxidants, vitamins, minerals, carotenoids (including lycopene) and phytosterols. The oil is normally extracted using the cold pressing technique, which maintains its bioactive components, and has a shelf life of around two years under optimal storage conditions(Geetha and Rani, 2020).

12. Tomato seed oil:

Tomato seed oil is very rich in essential fatty acids, including 50-70% linoleic acid (omega-6), 10-25% oleic acid (omega-9) and up to 1% linolenic acid (omega-3). It contains important amino acids, including lysine as well as minerals like copper, iron, manganese and zinc, and it has been shown to protect against UVA and UVB radiation. Because of its stability and good skin penetration, tomato seed oil is frequently used in cosmeceutical formulations such as face creams, anti-aging and anti-wrinkle serums, lip care, hair care, makeup, sun-care, and shaving products. It is ideal for dry, oily and combo skin(Geetha and Rani, 2020).

Conclusion

Biological pest control in tomato cultivation is an effective and environmentally benign alternative to synthetic pesticides, reducing pest pressure and lowering chemical residues in harvested fruits. The quality of tomatoes grown under biological management has a direct impact on chemical processing operations and the properties of processed goods such as paste, puree, ketchup and juice. Integrating sustainable biological control with optimum processing processes guarantees the production of safe, consistent and high quality value added tomato products while also benefiting the environment and health.

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