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# Alternative technologies for tomato post-harvest quality preservation

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**Abstract**
Tomato (*Solanum lycopersicum* L.) is an important crop cultivated and consumed worldwide. It provides a wide variety of nutrients and many health-related benefits to the human body. Tomato production can improve the livelihoods of small-scale producers by creating jobs and serving as source of income for both rural and semi urban dwellers. However, postharvest losses make its production unprofitable in these parts of the world. Postharvest losses in tomatoes can be as high as 42% globally. Fresh tomato is one of the most consumed fruits and the preservation of its quality and shelf-life extension is a continuous challenge. An understanding of fruit deterioration factors allows the investigation of new approaches to reach this objective. Fruit preservation is achieved by destroying enzymes and micro-organisms, and reducing physiological disorders, using treatments such as, refrigeration, modified atmosphere packaging (MAP), edible coatings, 1-methylcyclopropene (1-MCP), chlorinated water (HIPO) and temperature. In this review, a description of action, advantages and disadvantages of each preservation treatment, and corresponding effects on tomato quality and safety are presented.

**Keywords:** Alternative technologies, tomato post-harvest

## Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and extensively consumed horticultural crop S. Grandillo *et al.* [1], the nutritional and economic importance of the crop has led to its global production. Tomatoes can be consumed in many ways. The fresh fruits are eaten in salads and sandwiches as whilst the processed ones are consumed dried or as pastes, preserves, sauces, soups, juices, and drinks T. Alam *et al.* and D. M. Beckles [2, 3]. Tomatoes and tomato-based foods provide a wide variety of nutrients and many health-related benefits to the body. Tomato contains higher amounts of lycopene, a type of carotenoid with antioxidant properties L. Arab and S. Steck, [4] which is beneficial in reducing the incidence of some chronic diseases A. Basu and V. Imrhan [5] like cancer and many other cardiovascular disorders B. Freeman and K. Reimers [6]. These fruits have grabbed the attention of millions of health seekers because of the high levels of vitamins A, E (tocopherols) and C, lycopene, b-carotene (precursor of vitamin A inthe human body), fibres and phenolic compounds, namely flavonoids and phenolic acids Soto-Zamora G *et al.* [7]. It is widely grown around the world with a total annual production of approximately 159 million tons on a cultivated area of about 5 million ha Fao stat [8]. Despite of production of tomato, postharvest losses make its production in most parts of the world unprofitable. Postharvest losses in tomatoes can be as high as 25–42% globally M. Rehman *et al.* [9]. These losses bring low returns to growers, processors, and traders as well as the whole country which suffers in terms of foreign exchange earnings A. A. Kader [10].

Postharvest loss is a major challenge hampering tomatoes production in most developing countries. Over the last century, the growth in fresh fruit consumption, in particularly whole tomato, has led to improvements in preservation treatments to control post-harvest disease proliferation and maintain fruit quality (i.e. flavour, colour, texture and nutritional parameters) and consequently to extend its shelf-life Brummell DA *et al.*. [11]. Many difficulties work against these objectives. The first is the physiological weight loss of horticultural commodities determined by both water losses, due to transpiration of living plant tissues, and by drymatter loss due to product respiration. Other losses are determined by some physiological disorders, such as chilling injury, which can occur during and after cold storage. Cold storage is often a need in order to preserve the product quality by minimizing the physiological losses and the mould decay. Finally, the biggest losses are caused by the specific post-harvest diseases. Fungi and other micro-organisms may be responsible for 15–25% decay of horticulture commodities during storage and transport Barkai-Golan R, Phillips [12]. Currently, several chemical treatments are used to preserve these products, chlorine and fungicide being the most common.

The chemical treatments are rather limited in their effectiveness in reducing the micro-biological populations on the surfaces of fresh produce, partially because of the inherent cracks, crevices, pockets and other openings that provide a protective environment to micro-organisms and make it difficult for chemical sanitizers to gain access. Fungicide treatments have been applied to horticultural commodities in order to reduce mould decay in the most effective way. Alternative preservation post-harvest treatments include chemical, such as, refrigeration, heat treatment, modified atmosphere packaging (MAP), edible coatings and 1-methylcyclopropene (1-MCP), chlorinated water (HIPO), low or high temperatures and ultrasounds. The application of these merging (innovative) techniques and treatments (singular and combined) and their effects to preserve tomato quality and extend its shelf-life will be discussed in this review.

**Post-harvest handling systems of tomato fruit**.

The transfer of the produce out from the field to the packing house should be made carefully and rapidly to avoid the decline of fruit quality and safety. Therefore, some considerations of post-harvest handling fresh tomato fruits are given below.

Tomato harvesting is done manually, with or without calyx. The fruit is placed in plastic boxes with holes for better ventilation. Cooling is a priority for maintaining products quality with a longer shelf-life. The fruit temperature at harvest is close to that of ambient air and can be as high as 30 ºC. Under such high-temperature conditions, the respiration rate of produce is extremely high and storage life very short. Rapid cooling of the fruit immediately after harvesting in order to remove field heat, referred to as pre-cooling, can therefore slow down the rate of post-harvest deterioration. Fresh tomato preparation includes phases such as reception, cleaning, washing, calibration and selection. However, these operations can lead to product physical changes, if not carried out properly. Fresh tomato is generally packed in plastic crates, plastic bags, or corrugated paper boxes with or without mono-layer separated into alveoli. All these packaging systems should protect the commodity, allow appropriate ventilation and facilitate the handling throughout distribution and marketing. The best storage environment for an individual fruit depends on its unique requirements for temperature, RH and ethylene exposure Kader AA [13]. Tomato transport can be done in various ways, depending on the chain length. However, it must follow some recommendations, such as FDA guidelines [14].

**Refrigeration**

Refrigeration is one of the most effective methods of preserving the quality of many fruits and vegetables for several days Rodriguez *et al.* [15]. Low temperature storage can protect nonappearance quality attributes like texture, nutrition, aroma, and flavour in many harvested fruits R. E. Paull [16]. Tomato handlers have also used refrigeration storage for tomatoes in attempt to extend shelf life. However, some fruits and vegetables of tropical origin, like tomatoes, are sensitive to chilling injury when they are stored below their critical temperature of 10 ◦C J. K. Raison and J. M. Lyons [17]. Short coming of refrigeration storage was reported by Lee *et al.* [18] and Babitha *et al.* [19] where low temperatures from refrigeration storage caused chilling injuries which resulted in pitting, uneven ripening, and fungal infestation of stored fruits. This gives an indication that refrigeration storage may not be the most effective method of storing tomatoes for a long period. Another challenge in using refrigeration storage in tomato handling in most developing countries is the huge initial cost which is beyond the reach of most of under resourced handlers. However, in situations where handlers can afford refrigeration storage and temperature regulation is possible, temperatures of about 10–15∘C should be maintained to avoid chilling injuries. In spite of the high cost of refrigeration, it is very important to control storage temperatures and relative humidity during storage, as these two parameters are the main causes of deterioration in fruits and vegetables. The required optimum temperatures of about 10–15ºC and 85–95% relative humidity can be achieved by using less expensive methods of cooling such as evaporative cooling system as suggested by Workneh and Woldetsadik [20]. In such cooling system, air temperatures can be decreased to about 16∘C, whilst relative humidity can be increased to about 91%, which is appropriate for reducing deterioration of harvested tomatoes due to physiological weight loss T. S. Workneh, [21]. Evaporative coolers can be manufactured locally using low cost materials like jute sacks, wooden planks, and basins.

**Modified atmosphere packaging**

Another interesting technique used for prolonging fruits shelf-life is MAP. In this technology, no active control over the atmospheric composition is carried out, which initiated from a defined initial gas composition and is subject to changes because of product physiological activity and physical environment (temperature, RH, gas atmosphere composition, packaging material) by Gorris *et al.* and Sandhya S [22, 23]

MAP technology has been used as a complement to low-temperature storage to attain shelf-life extension of fruits by the ability of plastic containers or film packaging to modify gas composition and reduce moisture loss. The increase of $CO_2$ and reduction of $O_2$ to beneficial levels by the application of MAP is known to present several advantages, such as chilling symptoms reductions, lower respiration rate and ethylene level that prevent or retard post-harvest fruit ripening, and therefore contribute for shelf-life extension by Hong *et al.* [24]. The gases mixture in the package depends mainly on product type, packaging materials and storage temperature. Since fruits have different levels of respiration rate, it is necessary to study the interaction of the packaging material with the product. If the permeability (for $O_2$ and $CO_2$) of the packaging film is adapted to the product respiration behaviour, an equilibrium-modified atmosphere will be established in the package and the shelf-life of the product will increase. The basic difference between controlled atmosphere storage (CAS) and MAP systems is that gas levels are strictly maintained at all times under CAS system, whereas the gas mixture is flushed into the package by Choubert *et al.* [25]. CAS or modified atmosphere packaging, combined with low-temperature storage, can reduce respiration and ethylene production rates, then retarding the softening and slowing down changes related to ripening and senescence.

**Edible coatings**

In the last several years, the application of edible coating on fruits surface, have also been evaluated for shelf-life extension by Colla *et al.* [26]. Appropriate formulations of an edible coating may provide an excellent barrier against gaseous exchange and water loss, which are unfavourable to post-harvest quality. The main constituents of edible coating are lipids (including waxes, acylglycerols and fattyacids), polysaccharides (including cellulose and derivatives, alginates, pectin, starch and derivatives and others), proteins (including wheat gluten, corn zein, soya protein, rice protein, egg albumin, milk proteins and gela-tine) and their combinations by Guilberts *et al.* [27]. Each constituent group has advantages and disadvantages and for this reason, many coatings are actually formulations of any or all of the above. Polysaccharides and proteins are known to form films with good mechanical properties, but with poor permeability, while the lipids form brittle films but with improved permeability. Therefore, a new developed coating appeared, focused on combining the polymer matrix with some hydrophobic component.

The edible coating acts as a semi-permeable barrier, helping to reduce respiration, retard water loss and co-lour changes, improve texture, mechanical integrity and handling characteristics, help retain volatile flavour com-pounds and reduce microbial development Molda-Martins *et al.* [28]. After application, the coating remains on the fruits surface during storage and will be dissolving during mastication process, so the consumer acceptance is very important and must be evaluated by organoleptic quality. Flavour impact by the coating materials, unattractive surface appearance and others factors (colour, taste and texture) may affect consumer acceptance.

A study developed by Ali *et al.* [29] found that gum arabic not only enhanced shelf-life, but also maintained post-harvest quality of mature-green tomatoes for up to20 days during storage at 20 ºC. Zapata *et al.* [30] suggest a beneficial effect in delaying ripening process and preserving tomato quality by plant-based edible coatings, such as alginate or zein. Casariego *et al.* [31] indicated that chitosan obtained from lobster of Cuban coasts can be used as edible coating applied on fruits and vegetables, as tomato fruits, for contributing to shelf-life extension

**1-Methylcyclopropene (1-MCP**).

The use of 1-methylcy-clopropene (1-MCP) has been shown to suppress the action of ethylene in many fruits and vegetables M. Cliff *et al.* [32].1-MCP treatments present some advantages such as: this technology was active at very low concentrations, resulting in residual residue; lower quality changes and processes in fruits such as primary and secondary metabolisms; lower physiological disorders; enzymatic activity increase or reduction depending of products treated; inhibition of ethylene production and thereby extension of fruits storage life Wills RBH [33]. The efficiency of the 1-MCP application can be limited by cultivar, maturity, uneven ripening, and achieving increases in storage potential without excessively delayed ripening that can increase decay development or prevent proper ripening Argenta LC [34].

The delay of softening, red colour development and respiratory rate of tomato fruits may be desirable, and are the major factors in successful commercial development of 1-MCP technology [98–100]. Guillen *et al.* [35] reported a delay and/or inhibition of tomato quality (colour, texture and respiration rate) at maturity stage ofred light after 1-MCP treatment at 0.5 ml/l for 24 h during storage at 10 ºC for 28 days. A high concentration of 1-MCP with reduced exposure time was tested by Wills and Ku [33], who concluded that 5 ml/l for 1 h resulted in about a 70% increase in time to ripen and for this reason may be considered as a potential commercial treatment.

**Chlorinated water**

Washing whole produce by dipping or submerging in chlorinated water is routinely used and has a sanitizing effect, even if reduction in pathogenic and other micro-organisms is minimal and cannot reach total elimination.

Some of the advantages of chlorine solution treatment are its low cost, ease of utilization, application through several forms, broad-spectrum of bactericidal activity, and its effective product removal of foreign substances and pesticides Okull DO *et al.* [36]. On the other hand, the use of these products has disadvantages, such as the corrosion of metal equipment, reliance on manual monitoring of chlorine concentrations, sensitivity to organic load, effectiveness within a narrow pH range, and the formation of harmful chlorinated by-products. An EFSA evaluation of the toxicological risks from disinfection with different compounds, including chlorine dioxide and acidified sodium chlorite, found no evidence of chlorinated organic by-products and concluded their use presented no safety concern EFSA [37]. However, and because of negative factors posed by the use of chlorine, its use inorganic production is forbidden in some European countries. There is a trend for eliminating chlorine from the disinfection process.

Inhibitory activity of chlorine solution depends on the amount of free available chlorine (as hypochlorous acid HOCl) in the water that comes in contact with microbial cells. The dissociation of HOCl depends on the pH, and chlorine is consumed in contact with organic matter. Still, the effectiveness of hypochlorite solution depends on temperature, concentration, treatment time and state of pathogenic micro-organism's growth. It has been observed that the effects of chlorine concentration on pathogen populations are markedly increased with increased concentrations until a concentration of 50 ppm, but further concentration increases to 200 ppm did not have a substantial additional effect. Increasing the washing time in hypochlorite solution from 5 to 30 min did not decrease numbers of microbes further, whereas extended washing in tap water resulted in a reduction comparable with hypochlorite. Further to the pH and temperature influence on the effectiveness of chlorine for killing naturally occurring micro-organisms, the type of produce and micro-organisms diversity can also greatly influence treatment efficacy Zhuang RY [38]

A reduction on tomato mesophylic and yeasts and moulds load of 1.3 and 1.1 log 10,, respectively, was achieved (data not yet published), after treatment with chlorinated water at 150 ppm, 5 ºC, pH 6.5 for 2 min. Similar treatment effectiveness was observed in another study using water containing up to 200 mg/ml chlorine, where the reduction in tomato naturally occurring and pathogenic micro-organisms did not exceed 2 logs.

**Temperature**

Temperature management is the most important tool for fruit shelf-life extension and freshness maintenance. Most of the physiological, biochemical and microbiological activities contributing to the deterioration of produce quality are largely dependent on temperature by Tano K *et al.* [39]

The harvested produce contains a substantial amount of heat associated with its temperature, known as field heat, which is a significant part of the cooling load. Pre-cooling is the rapid extraction of heat from the produce before transportation, storage and processing. The product will rapidly lose its quality, unless promptly and appropriately cooled. Therefore, refrigeration is required for ensuring short cooling time, which is crucial or avoiding quality losses. Cooling rates depend on the type of product characteristics such as composition, size, weight and the surface-to-volume ratio.

The choice of an appropriate cooling method is a very important decision that a grower or a packinghouse needs to make. The decision is based on the following factors: (i) product nature (e.g., chilling sensitivity), (ii) produce temperature at the harvest time, (iii) required cooling time, (iv) product throughput, (v) packaging type, (vi) desired storage life and (vii) other considerations, such as comparative energy efficiency, availability, and associated capital and operating cost by Kashmir RF *et al.* [40]. For tomato fruits, room and forced-air cooling are the most common pre-cooling methods.

Refrigerated or cold storage: One of the most important functions of refrigeration is to control crop's respiration rate. The higher storage temperature, the higher the respiration rate will be. However, very low storage temperatures can induce chilling injuries and therefore must be avoided. the storage conditions (temperature (□C), RH (%) and CO2(%) andO2(%)) for tomato fruits during post-harvest. As can be noted, temperature plays an important role in post-harvest quality maintenance. The storage temperature effect on tomato physicochemical quality changes, varies with cultivar, exposition time and harvesting conditions. Wilson and Wisniewski [41] defined a storage life of 7–14 days for tomato at pink maturity stage when stored at a temperature range of 8.9–10□C and RHof 85–95%. Pinheiro *et al.* [42] evaluated the effects of five storage temperatures (2, 5, 10, 15 and 20□C) at RH of 90% on physical–chemical quality of mature-green tomato (cv. Zinac), concluding that at the optimal storage tem-perate of 10□C tomato shelf-life is extended without losing significant quality.

**Conclusion/summary**

Tomatoes have received heightened recognition in recent years for their contribution of flavour and nutrition to the human diet. The reduction of tomato post-harvest losses is therefore very important and should be minimized to provide fruits with high quality along fresh post-harvest chain to the final consumer. Some post-harvest treatments are available and can be used in order to attain this goal.

The main focus in this review is to examine alternative preservation methods for tomato fruit. Therefore, this literature surveyed included the commonly used sanitizers such as chlorinated water, conventional technologies such as low temperature, and emerging treatments such as, 1-Methylcyclopropene (1-MCP), e edible coatings to find out their advantages and disadvantages and to report some of their effects on tomato quality and shelf-life. Despite the number of authors that have obtained good results in tomato disinfection methods, more research is needed, mainly to develop preservation technologies for this fruit. Therefore, it should be able to make a comparison not only in terms of the antimicrobial efficacy between methodologies, but also their shelf-life prolonging effects. Research in this field should be carried out to provide treatments recommendations conditions to industry to assure and improve tomato's quality and safety

Further to this knowledge, alternative technologies should be needed to develop fruit quality and post-harvest life and it should be eco-friendly and it also take into account the compatibility, regulatory provisions and cost factors. The new technologies must be more effective and cheaper than the existing ones in order to become an alternative.

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