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Novel Approach Technologies in Control of Postharvest Losses in Sweet Orange and their Treatments

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ABSTRACT: Fruits are an essential part of our nutrition. Citrus spp., which are mostly found in the Mediterranean basin are the most common fruit consumed by people. In today's environment, postharvest quality retention in supply chain management is a major concern and a critical issue. Fruit continues to breathe after being picked, and the high temperatures in the field and during transportation to pack houses make this process difficult. The fruit shelf life is shortened as a result of the spread of pathogens, which is harmful to the quality of fruits after harvest. Postharvest losses can result in significant waste, accounting for 30 to 50% of the overall crop, and are mostly brought on by infections and metabolic abnormalities of fruits. The right handling, treatment, storage, and transportation of harvested food determine the postharvest technological innovation's primary objectives of maintaining quality and prolonging shelf life. To further reduce the accumulation of artificial pesticide residues on fruit surface and the implications of fungicide waste disposal, new, eco - friendly methods must be used. This review critically evaluates the most efficient and ecologically friendly techniques, as well as cutting edge post-harvest processing and storage technologies in citrus fruits variety sweet orange.

Keywords: Postharvest loss, chilling injury, pathogen proliferation, microorganisms and senescence.

INTRODUCTION

The current global food trends encourage the healthy and long-term consumption of natural products such as fruits and vegetables. Thus, fruits are known for the natural sources of micro and macro nutrients provided to man when they are consumed because many minerals, vitamins, enzymes, antioxidants, anti-ageing and antiseptic properties that are easily digested and provides a good immune system. Apart from the good source of nutrients, it poses various medicinal properties (Lawal, 2007). In subtropical areas, sweet orange is one of the most valuable and popular fruits. The Citrus genus, which belongs to the rutaceae family, contains around 160 cultivated species that may be found in China's subtropical and temperate areas. Citrus species, hybrids, and allies are evergreen woody perennials with 5 to 13 year juvenile phase. Citrus trees are typically evergreen trees or shrubs with glossy oval-shaped leaves and thorns on many species. The blooms are typically white with five petals and have a strong scent. The fruits are hesperidium, which are modified berries with flesh separated into segments packed with small juice-filled vesicles. The fruits peel or rind are leathery and filled with oil glands including different varieties of mandarin (*Citrus reticulate*), citron (*Citrus medica*), sweet orange (*Citrus sinensis*), lime (*Citrus aurantifolia*), and pummelo (*Citrus maxima*) are all species of the citrus genus (2n=18). On the worldwide fresh market, the Mediterranean regions are the biggest producers of oranges. Egypt has led the list of orange exporting countries, with 1.7 thousand tonnes exported in 2019, accounting for 38 % of global orange exports. Among the citrus group, the sweet orange is one of the most major fruit tree crops. Sweet orange is a highly polyembryonic species of chinese origin. Sweet oranges are divided into four categories: Oranges that are common (round oranges), mild in acidity, colored (blood), and navel (Kumar *et al.*, 2022). Citrus trees grow between 10^o to 35^{o}C, with vegetative growth beginning at 12.8^{o}C. Citrus fruits grow best between 25 and 30^{o}C, as 30^{o}C is considered the optimum temperature for photosynthesis and dry matter production, increasing tree vigor and productivity. The fruits of *Citrus sinensis* are well known for its vitamin C content, and it also contains photo chemicals including phenolic and carotenoid compounds that are considered to have many health advantages (Oikeh *et al.*, 2020). Citrus fruits, which are high in vitamin C and folic acid and low in sugar, salt, and cholesterol, offer a number of healthy and nutritional benefits. Potassium, calcium, folate, thiamine, niacin, fiber, vitamin B6, phosphate, magnesium, and copper levels in citrus fruits may reduce the risk of heart disease, cancer, and respiratory disorders, lowering the impact of corona virus pandemics like COVID-19 on humans

(El-Gioushy *et al*., 2021). They may help in reducing the risk of heart disease and certain cancers. They can also enable pregnant women minimize their chances of having babies with birth defects. In roughly 210 to 240 days, the fruit matures. The color varies from green to light green, yellow, or orange. The fruit's outer rind seems to be glossy, and oil glands may appear on the surface. Orange 0.3 % acidity and 12 % TSS Mandarin 0.4 % acidity and 12 to 14 % T.S.S. orange 0.3 percent% acidity and 12 % TSS fruits turn to soft and fleshy. Essential oil (EO) is abundant in orange peel and may be extracted using various physical or chemical means. Citrus EO has a broad spectrum of antimicrobial properties against a variety of pathogenic organisms, making it useful in a variety of sectors related to food chemistry to pharmacology and bio medicine as is often made up of a rich composition of volatile (85%–99%) components like monoterpenes, sesquiterpenes, and their oxygenated derivatives are included (Guo *et al*., 2018). Citrus EO's well-known and described compounds comprise limonene, linalool, and citral, all of which would seem to have substantial, broad-spectrum antimicrobial effects. Despite the non-climacteric nature of citrus fruits, the composition of the fruit changes over time. Due to postharvest losses, 30–50% of horticultural goods never reach the final consumer, which varies depending on physiology of the product and may be lower or higher. Freshly picked fruits and vegetables are alive, and they continue to breathe and transpire, which are the major causes of senescence and degradation. Physical losses (weight loss, texture loss, and mechanical damages), physiological changes/losses (ageing, color changes, chilling injury, freezing injury, and so on), alterations in soluble solids content, titratable acidity, vitamin C, photochemical and other biochemical's as well as changes in enzymatic activity and pathological deterioration (Wan *et al*., 2021). Citrus fruits are perishable, cannot be preserved for longer duration of time without cold storage facilities as a result; producers are forced to sell their crop in bulk, resulting in market gluts. As a result of the low market value, farmers are unable to obtain expected prices. One of the most common sources of postharvest losses is postharvest infections. *Penicillium italicum* and *Penicillium digitatum*, for instance have been reported to cause 50 percent losses in stored citrus fruits in a year. The main causes for decay in fruits are due to blue mould (*P. italicum*) and green mould (*P. digitatum*) in citrus fruits, pome fruits, stone fruits, grapes, and berries and grey mould (*Botrytis cinerea*) in pome fruits, stone fruits, grapes, and berries; alternaria rot (*Alternaria* spp.) in pome fruits and stone fruits; anthracnose (*Colletotrichum* spp.) in apples, avocados, bananas, and mangoes; brown rot (*Monilia fructiocola*) in apples, apricots, peaches and nectarines. To control this losses there are several treatments such as Hot water treatments (48–55°C for 2–5 minutes light irradiation protein hydrolysates), modified atmosphere packing, and edible films (EF)/edible coatings (EC) using plant natural products are commonly used. Apart from this, there are a variety of remedies that are regularly employed. Chemical treatments are frequently accepted because of their rapid reactions and ease of application; nevertheless, in order to protect consumers' health, organic or natural solutions can be used to reduce losses.

Physiology of sweet orange: Floral induction in citrus and floral differentiation occurs two to three months before and immediately before bud release, respectively. The bulk of citrus species self-pollinate extensively, but even moderate levels of cross-pollination enhance the number of zygotic twins. The flattening of the apex, which occurs at first during the transfer from a vegetative meristem to a floral bud, leads to the formation of the flower's receptacle and the initiation of petals, stamens, and carpels. Flower primordia are emerging meristem fingers that curl inward to form the flower bud when the bud is revived from dormancy. Buds begin to develop after the long winter, and bloom development commences in the spring (Augusti *et al*., 2022). Citrus species' juvenile stages, also known as the vegetative and reproductive phases, are rather lengthy, lasting between two and five years to mature and begin to produce blossoms. The developing inflorescence might have one or many blooms and can have leaves or no leaves throughout the maturity phase. The quality of citrus fruit may be assessed using its external qualities, internal morphological and biological properties, such as seediness, fresh juice content, ascorbic acid content, TSS, TA, and TSS: TA ratio, as well as its external characteristics, such as color, texture, and thickness (Ghanghas *et al.,* 2022). Depending on altitude, fruits vary greatly in size, weight, and juice content; those grown at higher altitudes are frequently much smaller and contain a more acidic flavor. Altitude had an impact on mandarins' fruit growth and skin coloring, both of which were vibrant. According to the researchers, physiologic weight loss and liquid content were significantly influenced by the stage of development. Citrus fruits have a significantly longer post-harvest life than those other subtropical and tropical fruits. To be utilized effectively during the excess season, citrus fruits need to be conserved safely for a long period of time.

Respiration rate: Based on the respiration, ethylene generation and response fruits are categorized as climacteric or non-climacteric. Fruit need energy, carbohydrates, and pigments (molecules that alter fruit color) for ripening, thus respiration utilizes oxygen and releases carbon dioxide. Ethylene is a gaseous plant hormone that aids in the ripening of fruit. During the ripening of climacteric fruit, there is a phase of fast respiration and ethylene production. The respiratory climacteric, or peak respiration in such fruit, usually corresponds to the point of ideal maturity for consumption. During ripening, non-climacteric fruit does not have a clear burst in respiration and ethylene production.

Losses due to pathogen effect: Citrus fruits are sensitive to a wide range of phyto pathogens, such as fungus, bacteria, and viruses, which can cause disorders at various phases of citrus production. After harvest, a variety of phytopathogens cause harm to fruits (Wan *et al.,* 2021). During infection, *P. digitatum* and *P. italicum* release organic acids, resulting in an ideal PH for cell wall-degrading enzymes such polygalacturonases (PG). Furthermore, during infection *P. digitatum* produces catalase, an antioxidant enzyme that decomposes hydrogen peroxide, the principal defensive mechanism in citrus. The majority of them is very significant and has a wide range of hosts (Wang *et al.,*2020).

Green mold: Green mould (Penicillium digitatum) is responsible for the most prolific and harmful postharvest deterioration of citrus fruit. It results in enormous losses all around the world, up to 90% of the total postharvest losses in the citrus sector. A water-soaked lesion is the first sign of infection, and then white mycelia and freshly formed grayish/green conidia progressively appear in the infected sites (Papoutsis *et al*., 2019). Fruit degradation occurs at infected damage sites because nutrients are available to support sporulation. A soft rot and a thick, green mass of conidia covering the peel are common symptoms of the disease. *P. digitatum* potential to generate a large number of conidia allows the pathogen's inoculum to travel widely and contaminate citrus fruits in the field, as well as in storage rooms, transport containers, packinghouses, cartons, and market places. Pericarp and mesocarp cells are plasmolyzedfruit rots as the infection spreads, its inclusions and organelles breakdown, and cellular contents ooze from the cells as the disease develops. The fungus can infect the fruits by mechanical injury during harvest or handling and spread from one fruit to another. On the other hand the stem end of the fruits is a major infection site for all *Penicillium* species. As the infection spreads and the fruit rots, the pericarp and mesocarp cells are plasmolyzed, and the inclusions and organelles of the fruit deteriorate as cellular contents spill from the cells (Wang *et al.,* 2020). These current molecular and genetic researches are integrating to provide a more knowledge of the molecular pathways underpinning (*Penicillium digitatum*) pathogenicity and virulence in citrus fruit crops.

Blue mold: The economic losses in fruit and vegetables due to fungal infection along the postharvest chain are varied and poorly studied. They can reach 30–50 percent, and in some cases, product deterioration can result in total loss (Youssef *et al.,* 2020). *Penicillium italicum* infects the citrus fruits causing blue mold symptoms and leads to deterioration of citrus fruits. Due to the synthesis of pathogenic hydrolytic enzymes (e.g. polygalacturonase, glucosidase) which promote softening of tissues and allow fungal colonization, the infection site appears as a soft, watery, and darkened area, finally leading to fruit degradation. The fruit surface is totally enveloped with spores as the disease develops, followed by shrinking that causes a sunken, mummified appearance in the case of green mould and a sticky mass in the case of blue mould.

Challenges related to perishability and shelf life: Citrus fruits are not climacteric, hence they are not susceptible to the same abrupt variations in respiration and ethylene production that climacteric fruits are. Senescence results in a steady decline in respiration rate, although ethylene production is minimal (0.1 mL kg1 h1 at 20 °C) and does not reach a peak. Early fruit senescence or stress carried on by poor postharvest handling and storage are causes of rapid physiological changes, including an increase in respiration, higher ethylene being synthesized, and a faster rate of moisture loss (Rahmanian *et al*., 2020). These changes are symptoms of injuries. Many infections appear during the postharvest period as a result of rough handling, poor infrastructure storage, or unfavorable market conditions. In this part, we'll look at two types of postharvest disorders. (a) Chilling injuries, a serious postharvest condition forced on by inadequate storage temperature, and (b) non-chilling disorders, a collection of deformities brought on by factors other than chilling temperatures. Fruit is typically stored at temperatures ranging from 6 to 10° C, depending on the cultivar, species, and period of storage (Tatari *et al*., 2022). Citrus fruits are susceptible to a variety of physiological peel problems, often known as peel defects, which emerge as morphological abnormalities that might arise before or after harvest.

Chilling injury: When citrus fruits are stored at low non-freezing temperatures (0–10 C) chilling injury (Chilling injury) develops, resulting in dark spots on the rind, ageing is formed by prolonged storage at low temperatures, and it is indicated by shriveling and collapse of the button tissue (Strano *et al.,* 2021). The occurrence of these symptoms degrades the fruit's exterior quality and was amongst the major causes of post-harvest losses and market rejections. Essential oils secreted in citrus fruits' oil glands are quickly oxidized. The gland cells may disintegrate and the essential oil content may evaporate when fruits are subjected to stressful conditions that could injure and severely damage them. The most popular and efficient way to increase the shelf life of citrus fruit after harvest is through low-temperature storage. Furthermore, for export to several markets, in quarantine measures, exposure to cold below 2°C is advised. When exposed to temperatures below freezing but above freezing, citrus fruits and many subtropical fruits are sensitive to chilling harm, although it may also be controlled by environmental and growth circumstances, the temperature at which chilling damage develops varies depending on the variety (Zacarias *et al*., 2020). Oranges and mandarins are reported to be more resistant to low-temperature storage than lemons, grapefruits, and limes. Sensitive mandarins and hybrids were also susceptible to peel-pitting lesions from chilling, which resulted in brown pits covering the fruit's surface. Some cultivars, like nova mandarin, also produce scalding, which is amplified by waxing and packaging line processing. Fruits with chilling symptoms have intact oil glands, whereas fruits with "oleocellosis" have cracked glands with their substance spilling out over the fruit surface. A sign of chilling injury seen in early harvested clementine mandarins is internal oil gland darkening without pits or depressions (Rehman *et al.,* 2018). Rootstock appears to have a role in the emergence of chill as well, though it is unclear if the cause of this impact is the water contact or some other factor. The nadorcott mandarin is sensitive to superficial peel browning when stored at temperatures below 8°C. Fruits with thinner peels and smaller sizes are more susceptible to the illness.

Non - chilling disorders:

Oleocellosis: Oleocellosis is a physiological problem that affects numerous citrus fruits during preharvest ripening and postharvest storage the main damage caused by abiotic stress (wind, hail) during the preharvest period, as well as mechanical damage caused by insufficient postharvest treatment, especially when the fruit rind is ruptured with high turgor pressure, can all cause oleocellosis. It has a substantial impact on the disorder's occurrence (Kassim *et al*., 2020). Fruit should not be harvested in wet conditions that cause a low vapour pressure deficit (VPD), such as after rain or in the afternoon as opposed to the morning. In order to control the disorder, the period of time between fruit harvesting and handling in the packing house should be deferred until the very next day (Zhou *et al*., 2021).

Granulation: Granulation is a serious biological disorder that has a severe effect on the whole citrus economy, impacts most cultivars, and causes massive financial loss including both farmers and processors. Citrus granulation, a physiological malady, is characterized by interior dryness and shrunken juice sacs. Gelatinization and the development of secondary epidermis significantly decrease the amount of extractable juice in granulated tissue. The condition is characterized with a decline in nutritional value, a loss of flavor, and degradation of a number of organic acids and enzymes, albeit the biochemical mechanisms is yet unknown. Beginning at the stem end of the citrus fruit, granulation progressively spreads toward the stylar end (Li *et al*.,2022). The fruit loses organoleptic appeal as a result of the fruit's severe impairment of the sugar/acid balance occurs. Farmers advocate prolonging fruit's on-tree storage for staggered marketing. Prior to cutting or peeling the fruit, the abnormality cannot be noticed. As a result, the farmer is unable to determine how long fruit should be stored on the tree to be marketed. Furthermore, buyers may receive infected fruit, creating mistrust. Additionally, the processing line is hampered and substantially decrease in juice production may lead to financial loss for the firm.

Sour rot:

Citrus sour rot, which is caused by *Geotrichum citri-aurantii*, is the second most prevalent postharvest disease harming citrus exports after the green and blue moulds generated by Penicillium spp. Sour rot disease that affects different citrus kinds. In general, mandarin types are more susceptible to sour rot than grapefruit and orange species (Smilanick *et al*., 2020). Extracellular endo-polygalacturonases (PG), which help in the quick disintegration of diseased tissues and contribute to the disease, are secreted by *G. citri-aurantii* when it infects orange fruit. Azoxystrobin, fludioxonil, pyrimethanil, imazalil, and thiabendazole are a few of the chemical fungicides that are frequently used to manage citrus fruit postharvest infections (Liu *et al.,* 2019). Attributing to *G. Citri-aurantii* resistance, health concerns for humans, and ecological damage brought the widespread and persistent usage of pesticides to the attention of the public.

Peel pitting: Peel pitting or staining is an alteration to the peel that appears days after the fruits have been packaged in the packing process and takes place in non-chilling temperatures. The oil glands in the fruit skin collapse, resulting in the darkening of the peel and the disorder (Strano *et al*., 2022). Sunken patches of the flavedo (referred to as "pits") that eventually spread and affected oil glands are the primary symptom of the condition. Pits may become necrotic and become bronze in extreme situations. The commercial potential of fruit for the fresh market is decreased by these symptoms. Condition may be unpredictable and its occurrence and severity change from season to season or even within one single season. Peel pitting is correlated with coating formulation, gas permeability, and suggests that internal drop in O_2 and internal rise in CO_2 were the key determinants behind the emergence of this disorder. However, there was a minimal association between internal CO_2, O_2 and peel pitting. Avoiding fruit harvesting in moist conditions, such as after rain, quickly chilling citrus fruit after harvest, maintaining the fruit at the proper temperatures and with high relative humidity, in addition to taking species and types into consideration, can usually reduce postharvest physiological abnormalities.

Edible coatings and films: The use of artificial food-grade waxes or films, in addition to or in substitute of naturally occurring protective waxy coatings, to provide surface glossiness is known as edible coatings. There are several commercial formulations that are commonly used on the surface of fruits and vegetables, producing a barrier for moisture, oxygen, and solute movement for the food as well as extending the shelf life by reducing respiration and ethylene. There are several critical applications, such as citrashine, chitosan, sempefresh, shellac wax, carboxymethyl cellulose, guar gum, lasoda gel, Aloevera gel, bee wax, etc are plant-based surface coatings and extracts are more commonly employed than those manufactured by chemical synthesis (Varasteh *et al*., 2018). A thriving market for these goods was facilitated by the use of exudations, leaf extracts, and essential oils. They may be applied directly to the surface of food, unlike chemical non edible coatings that have an adverse effect on the finished product, due to their edible properties, biodegradability, and health advantages and also acts as barrier and an antibacterial measure. They serve as barriers in addition to having antibacterial qualities (Shahbazi *et al.,* 2018). It has a variety of beneficial effects on fruits, such as delaying ripening in pomegranate fruits, preventing the production of ethylene and delaying the softening process in plums, maintaining the firmness of papaya and preventing blueberries from losing weight, and preventing pathogenic spoilage in kiwi fruit slices, fresh cut persimmon, fresh cut orange, and strawberries.

Novel methods and techniques for postharvest citrus:

Irradiation: Irradiation, a non-thermal safe approach, has been approved by the Codex Alimentarius Commission, the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA) also for postharvest treatment of fresh fruits and veggies (Kumari *et al*., 2017). Gamma radiation intervention has been used to prevent the sprouting of tuberous crops and control the ripening of fruit in a variety of commodities. Additionally, it has been licensed for usage at a dose level of around 1 kGy for insect disinfestation and prolonging the shelf life of products **(**Pinela & Ferreira 2017)**.** Gamma radiation provides an efficient decontamination procedure that is quick and easy to apply, with less harmful byproducts and less of an effect on the sensory qualities of food. It may be applied using non-ionizing radiations include ultraviolet light or ionizing radiations like X-rays, electron beams, and gamma rays (60Co or 137Cs), as well as bulk and packaged food products. Insect pest management requires doses of 50–750 Gy, whereas postharvest disease control needs greater doses (1,001–1750 Gy). The potential to use both ionizing (gamma and X-rays) and using non-ionizing radiation to minimize the frequency of fungal infections in citrus fruit (UV-C, UV-B, blue light).

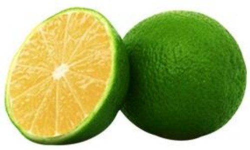
Penicillium rot in "nagpur" mandarins, "mosambi" sweet oranges, and "kagzi" acid limes was effectively delayed by a combination of gamma irradiation (doses up to 1.5 kGy) and refrigerated storage. Mold incidence was decreased in kinnow citrus fruits after 1.5 kGy of radiation treatment (Jo *et al*., 2018). Mandarins from the cultivar "clemenules" that had been infected with Penicillium were treated to doses of 510 and 875Gy of X-ray radiations which delayed the pathogen from sporulating while having no effect on the quality of the fruit. The irradiation techniques must be used in addition with alternate approaches due to their moderate fruit surface penetrating capabilities. The synergistic effects of integrated applications employing GRAS chemicals, process conditions, cold storage, and antagonistic microorganisms still make them effective and generate better outcomes.

LED Blue Light: A number of food processing applications, including the cleanliness of both solid and liquid food items, may make use of LED's a cutting-edge technology. In comparison to conventional light sources, LEDs provide a number of benefits, includes the capacity to concentrate a beam of light, high effectiveness and purity, a small size, a longer shelf life, and less power usage (Poonia & Pandey 2022). This has a small range of emission wavelengths, a high photoelectric efficiency, little heat production, mobility, and simplicity of electronic system integration. It also produces light in a solid-state environment. It uses light energy with frequencies between 200 to 780 nanometer as a non-thermal technique of cooking food. Blue light therapies (LBL) have recently undergone testing and been promoted as energy-efficient, safe, and ability to access that can increase citrus crop yield and nutritional quality often while helping to prevent pathogen proliferation. Lane Late oranges were treated with LBL for two days at a quantum flow of 60μmol m−2 s−1to minimize *P. digitatum* induced decay. The results of LBL therapy on the accumulation of carotenoids and ascorbic acid it was maintained that citrus fruit was acquiring elicit tolerance to *P. digitatum* (Zhang *et al*., 2015).

Ultraviolet radiation:

Ultra Violet (100–400 nm) has been utilized to suppress the recurrence of rot, but it also has the potential to slow fruit ripening and promote the synthesis of beneficial metabolites (Darre *et al*., 2022). Due to its ability to activate defense response mechanisms against the most microorganisms, along with most bacteria, viruses, protozoa, fungus and yeast, are sensitive to UV-C light at the frequency range with the maximum use of (200-280 nanometer). In Satsuma mandarins, lipid peroxidation was decreased and jasmonic acid deposition was raised in order to maintain the structure of the cellular membrane, bioactive compounds were generated, the antioxidant capacity of DPPH radical scavenging ability was boosted and *P. digitatum* (green mould) growth was suppressed when UV-C was applied at 10 kJ m2 (Phonyiam *et al*.,2021). UV radiation is utilized for trapping because it attracts insects. In both pre- and post-harvest, one of most common insect light traps entrap insects by absorbing "black-light" fluorescence lights' generates infrared (UVA) energy.

Efficacy of Novel Treatments on Postharvest Shelf Life of Citrus Fruits

NAME	FRUIT	TREATMENT	EFFECT	REFERENCE
Mandarin		Coconut oil (100%)	Extend the shelf life, improve the quality and prevent the growth of mould	Nasrin *et al*. (2018)
Navel orange		CMC (carboxy methyl cellulose)	Preserved fruit firmness	Arnon *et al*. (2014)
Mosambi		Radiation at (0, 0.25, 0.5, 1 and 1.5 kGy)	Induces greater total soluble solid and *Penicillium rot* was retarded.	Ladaniya *et al*. (2003)
Orange		(Green tea extract, gelatin and aloevera gel)	Weight loss control, microbial growth inhibition, and shelf life extension during cold storage	Radi *et al*. (2017)
Satsuma mandarin		Cinnamaldehyde (cinnamon oil)	Reduces the proliferation of *Geotrichum citri-aurantii* induces defensive mechanism against sour rot	Wu *et al*. (2017)

Cold plasma technique (CPT): This is non - thermal method that has wide range of uses in the food sector. It strengthens the shelf life by decreasing the pathogenic load and deactivating enzymatic activities. The majority of study has focused more on the microbiological disinfection element of CPT (Cold plasma technique) than the quality aspect. Using a carrier gas like atmosphere, nitrogen, oxygen, noble gases, or other gas blends, plasma may be produced using a range of electrical emission techniques such high voltage, pulsed electric release, light discharge, greater transfer, or radiation (Meena and Choudhary 2019). In food technology, it is frequently used for surface cleaning, which is accomplished by placing the food in a strong electric zone, which causes reactive gas species and may change the food's quality and sensory attributes. The quality of fruits and vegetables is significantly impacted by CP method. The mandarin's polyphenols content and total antioxidant capacity are both increased after CP treatment (at 2.45 GHz, 900 W, 1 L/min, 0.7 kPa, N_2, He, $N_2 + O_2$ (4:1) for 10 min) and also effectively inhibited the *Penicillium italicum* species. In citrus fruit the survival of A cold microwave plasma (CP) system using compressed gas at 900 watts for 10 min at quite a vacuum of 0.7 bar pressure and a flow rate of 1000 mL/min effectively reduced the influence of *Penicillium italicum* (by 84%) on artificially infected satsuma mandarin peel. Cold plasma treatment has become more popular in the food industry since it is highly efficient at microbial inactivation, toxicity, enzyme breakdown, and having little to no impact on food attributes. The various novel treatments on postharvest losses of sweet orange is represented in Fig. 1.

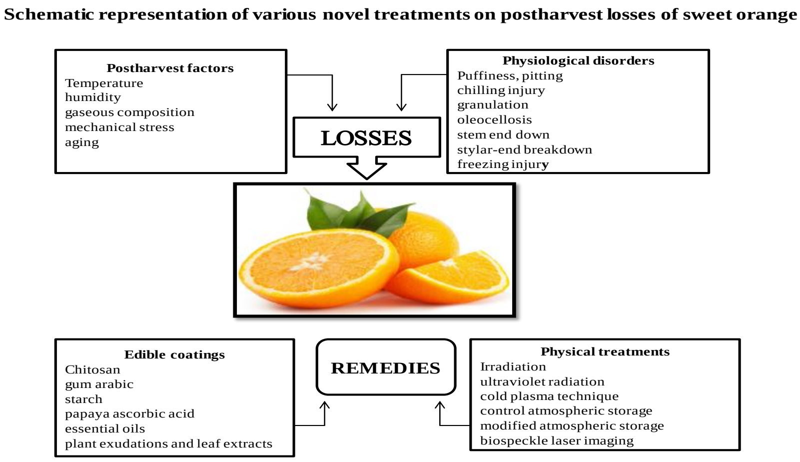


Fig. 1. Schematic representation of various treatments on postharvest losses of sweet orange.

Early diagnosis of chilling and freezing injuries using biospeckle laser imaging:

Introduction: A non-destructive optical application is called a "biospeckle" is used to investigate compounds. The object of interest is enlightened by coherence laser beam. A speckle pattern is generated in an observation plane due to the interference of backscattered light. The speckle pattern of biological samples usually has two components: a static pattern caused by the tissue's fixed particles and a variable pattern caused by the tissues' moving sections. The variable speckle pattern, known as biospeckle (Ansari *et al.*,2012), is a distinguishing property of living material, whereas inorganic portions are connected with static patterns. Since the majority of farm commodities have rough surfaces, biospeckle equipment require laser light (with a wavelength greater than 600 nm) to illuminate them. Biospeckle can disclose guidelines on the tissue's biological and physical characteristics, it thus has a variety of uses in the domains of ensuring food quality and safety. It comprises perceiving changes in fruits and vegetables' bruises, mature, and fruit development (Zdunek and Cybulska 2011). As well as the online analysis of bacterial growth, seed viability, biological leaf tissue assessment, perfusion alterations monitoring, and fungal colony infection and growth detection. Damaged or diseased tissues have decreased biospeckle activity, according to studies. Contamination, damage, maturation, and other factors modify the biological activity of materials. As a result, using the biospeckle approach in combination with a few numerical processing techniques, these variables might be examined non-destructively (Samuel *et al.,* 2016). Typically, the biospeckle laser's (BSL) output to produce pictorial and representational information, numerical data is processed. In order to assess samples physiological condition quickly, BSL can also be conveyed in audio form.

Biospeckle laser method application in perishable goods: Mechanical damage to horticultural goods is the term used to describe tissue damage or failure caused on by external forces in either passive or active conditions. During harvest and post-harvest processes, the tender skin of vegetables and fruits is susceptible to injury. Mechanical damages on the surfaces of fresh produce serve as an essential entrance point for microorganisms, resulting in a loss of quality product and a risk to food safety (Enes *et al.*, 2012). By using the biospeckle imaging technology there is a model for recognizing between apples with mealy and non mealy were identified. The experiment involved 540 apple samples that were stored in the fridge for a period of 0 to 5 months. Other 220 samples were stored for 10–26 days at 20°C and 95 percent relative humidity. Biospeckle pictures of each apple under storage were taken at wavelengths of 680 and 780 nm (Arefi *et al.*, 2016). To justify the method's effectiveness, researchers contrasted Motion History Imaging (MHI) to other intensity-based approaches by employing it to examine the wound surrounding green orange fruit. Apple cultivar *Szampion* and *ligol* were analyzed and estimated individually for biospeckle activity and firmness at four phases of advancement. Using inertia of motion (IM) and spatial time speckle (STS) imaging, bean seeds that have been experimentally contaminated by *Aspergillus flavus* or *Fusarium oxysporum* were analyzed along with charge couple device (CCD) resulted in greater intensities differentiation in IM values of infected and normal seeds, infected seeds showed greater IM values whereas normal seeds showed lower value of intensity. When they employed the Biospeckle laser method to examine metabolic responses in carrots that had received minor manipulation, they discovered that it was feasible to distinguish between different activity levels and assess the expression of water activity and respiration rate individually in a non-destructive manner. These evaluations of modifications within the cells during fruit development affect metabolic processes, and the maturation process's increased respiratory, oxidative metabolism, and enzymatic rate can potentially trigger biosynthesis to diminish. The MHI is often used as a reliable online tool for defect detection, according to the findings (Retheesh *et al.,* 2018). Biospeckle activity was used to establish a way of inspecting medicinal leaves for microbial materials. A laser source was used to illuminate fresh and infected *Ficus religiosa* samples in order to create a biospeckle pattern. A Charge Couple Device (CCD) camera captured dynamic changes in pictures, which were quantized into an 8-bit digital image using an outline grabber (Jitendra *et al.*, 2017).

Biospeckle laser application in orange: Biospeckle imaging is an intra operative method to access and control biological plant tissues and a low cost tool for operating various biological plant processes (Rahmanian *et al.*, 2020). It is a quick, economic and effective tool to detect the quality and freshness of the produce. This technique works on phenomenon that when laser light is subjected to pass from the source through mirror to reflect the light and the light from the various filters passes through the mirror to the source again and the camera captures the images and then processed by a system to produce a speckle pattern. Biospeckle activity involves two designs i.e. forward scattering and back scattering speckles. If the image is clear and accurate then the Many research have examined at the use of laser biospeckle in agriculture in a variety of contexts, including detecting germination progress and visualizing sprouts injury in wheat kernels, monitoring animal reproduction and parasites, and monitoring animal reproduction and parasites (Sutton and Punja; 2017), activity of chlorophyll content in apple leaves, monitoring food emulsions, analyzing meat quality. To simulate freezing and chilling, samples of Thomson navel oranges (Citrus sinensis L. Osbeck) were taken and stored in a customized chest freezer. Treatments included freezing and not chilling, chilling at 1°C, freezing at 7°C, and freezing at 20°C the four temperature treatments performed for 16 hours sound, chilled, mild freezing and intense freezing environments were all simulated using these procedures. The fruit was maintained at 25 °C for approximately 24 hours after receiving each treatment to allow them to defrost and reach room temperature. After that, each sample's biospeckle images are captured. Following the capture of biospeckle images, the samples were examined by a postharvest physiology expert chilling and freezing damages using the standard segment cut technique. The biospeckle pictures of oranges were analyzed using graphical and numerical approaches in this study. The numerical approach generally improves a temporal history of speckle pattern (THSP) from each data set by adopting one row or column from the original picture. The COM (Co-occurrence matrix) is then used toaround the matrix's primary diagonal. Oranges were separated into four groups after the essential components from the COM matrix were extracted: sound, chilled, moderate freezing and intense freezing (Pandiselvam *et al*., 2020). In this study, the performance of five classification methods soft independent modeling of class analogy (SIMCA), linear discriminant analysis (LDA), quadratic discriminant analysis (QDA), artificial neural networks (ANN), and support vector machines was compared in order to find the best classification model (SVM). Overall, all classifiers had low categorization accuracy, with the ANN technique achieving the greatest overall accuracy of 47.2 percent under the best condition. The best network's accuracy rates for classifying temperatures as sound, chilled, mildly cold, and extremely freezing were 38.5 percent, 42.9 percent, 53.9 percent, and 53.9 percent, respectively. The best derived model, the ANN model, was used to use the experiment and error approach to determine the appropriate number of neurons in the hidden layer. From forward-scattering data demonstrates the classification accuracy of ANN models with different numbers of neurons in the hidden layer, ranging from 1 to 11. As shown, the ANN model with four neurons in the hidden layer, i.e., the topology of 12-4-4 produced the highest overall accuracy and consistency, with classification accuracies of 100 percent for sound, chilled, mild freezing, and intense freezing (Ghanghas *et al*., 2022). The forward-scattering biospeckle imaging approach proved to be an excellent tool for assessing and categorizing chilling and freezing damages in oranges. The biospeckle activity increases from sound to chilled and then decreases from chilled to frozen samples, according to both graphical and numerical procedures. According to the classification study clear, blissed, mild freeze, and extreme extremely cold samples could be distinguished more accurately using the forward-scattering arrangement than the back-scattering design. This leads us to the conclusion that biospeckle imaging represents a different and practical method for assessing the chilling and freezing of oranges.

CONCLUSIONS

There is a risk to human and environmental health as well as considerable financial expenses now that pathogen resistance has been connected to the use of synthetic fungicides to minimize pathogen infection. Finding alternative, secure control methods is therefore given more significance. To trigger a fruit's inherent defenses is one such strategy. An effective approach for assessing as well as grading the chilling and freezing damages in orange was the forward-scattering biospeckle imaging method. Utilizing edible coatings and more modern techniques, such as layer-by-layer coatings and their synergistic effects, are far more effective at increasing the shelf life of food. Certain post-harvest illnesses and disinfections have also been reported to be treated by essential oils and plant extracts. The phenols, antioxidants, and senescence delaying effects of LED light on fruits have improved in recent years. It is also possible to apply nanocomposite materials and antibacterial compounds to the surface. By using bioagents to activate natural antagonistic mechanisms, diseases can be effectively managed while preserving ecological equilibrium. Some recently developed technologies, such as cold plasma and irradiation, can reduce pest infestations in quarantine areas while simultaneously improving product quality. Therefore, the combined benefits of these technologies may reduce postharvest losses and maintain quality during supply chain management.

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