Heliyon 9 (2023) e15302

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Recent advances on postharvest technologies of bell pepper: A review

Quazeem Omotoyosi Tiamiyu [a], Segun Emmanuel Adebayo [a,*], Nimat Ibrahim [b]

[a] Department of Agricultural and Bioresources Engineering, School of Infrastructure, Process Engineering and Technology, Federal University of Technology Minna, Niger State, Nigeria
[b] Department of Crop Production, School of Agriculture & Agricultural Technology, Federal University of Technology Minna, Niger State, Nigeria

ARTICLE INFO

Keywords:
Artificial intelligence
Edible coating
Irradiation
Bell pepper
Disease

ABSTRACT

The bell pepper (*Capsicum annuum* L.) is a commercially important horticultural crop grown in tropical and sub-tropical areas across the world. Despite this importance, it is a perishable vegetable with a limited shelf life and high disease susceptibility. Bell pepper output has expanded significantly in recent years. However, this crop is still experiencing close to 40% postharvest losses annually. Chemical fumigation for postharvest disease control of bell pepper has been shown to be efficient against fungal infections, but environmental impact and consumption hazards limit its full use. Recently, non-chemical techniques including biological and botanical methods, non-destructive technologies and Artificial intelligence have been demonstrated to be effective as postharvest management of bell pepper. The paper provides exciting information on recent and emerging techniques for curtailing these losses in bell pepper, alongside their mechanism and existing benefits. The current limitations of these techniques as well as recommendations for potential applications are also addressed.

1. Introduction

Bell pepper (*Capsicum annuum* L.) is one of the most economically important horticultural crops cultivated in tropical and sub-tropical parts of the world [1]. Its use and demand have risen in recent years as a result of the significant growth in population and its usage in various meals. Bell pepper has been receiving a lot of attention recently due to its suspected linkages to cardiovascular disease prevention, atherosclerosis, cancer, hemorrhage prevention, slowing of the aging process, avoidance of cholesterol, and enhancement of physical resistance [2]. However, it is a perishable vegetable with a limited shelf life. It is vulnerable to flaccidity, wilting, shriveling, fungal infections, and deterioration as a result of its short shelf life [3]. These undesirable qualities often affect the consumer acceptability of the fruit.

The quality of bell pepper has been maintained throughout storage using various postharvest methods such as chemical and non-chemical treatments [4]. Synthetic compounds have traditionally been used to manage postharvest infections as well as maintain metabolic processes in bell pepper [5]. With the passage of time, bell pepper postharvest preservation techniques had progressed. For example, modified atmosphere, hot water dipping, edible coatings, use of essential oil, and other innovative and environmentally friendly techniques have all been used to help protect bell pepper against spoilage. The use of these treatments has proven to be a viable technique for improving bell pepper fruit quality and preventing postharvest losses during storage. The desire to create

* Corresponding author.
E-mail address: segun.emma@futminna.edu.ng (S.E. Adebayo).

https://doi.org/10.1016/j.heliyon.2023.e15302
Received 12 July 2022; Received in revised form 30 March 2023; Accepted 2 April 2023
Available online 17 April 2023

acceptable substitutes that can provide safe and premium-quality products has been sparked by a number of factors, including consumer demand for high-quality and safe products, combined with the environmental impact of chemical treatments, and the emergence of resistant pathogens [6]. As a result, the focus of bell pepper postharvest research has lately switched to environmentally friendly and non-chemical treatments.

Edible coatings and essential oils have evolved as a viable and environmentally acceptable postharvest storage solution for bell pepper because they provide a moisture and gas barrier while selectively keeping the product's freshness and quality [6]. Edible coatings have the benefit of being natural, containing antioxidants and, in certain cases, vitamins that are helpful to consumers [4]. The use of different edible coatings containing functional substances has been shown to minimize microbial population and improve bell pepper storage quality [7–10]. Non-chemical techniques such as hot water treatment, modified atmosphere, UV-C irradiation, ozone fumigation, and pulse electric field are some of the current postharvest technologies that have shown positive results in decreasing physiological changes and microbiological deterioration in bell peppers [11–13]. Recently, non-chemical approaches have received lots of attention from researchers due to their eco-friendly nature. The ultimate goal of this study is to present a comprehensive assessment of some current and emerging postharvest techniques for preserving bell pepper quality during storage, alongside their mechanism of action on spoilage pathogen, as well as current drawback of these techniques.

2. Economic importance of bell pepper

The bell pepper is one of the vegetables crops with the highest production worldwide [14]. According to 2019's FOASTAT data as cited in Ref. [15], the world bell pepper's area and production has been reported to be 1.99 mha and 38.02 MT respectively. Fresh pepper is being cultivated in 126 countries of the world, China being the world's largest producer followed by Mexico [15]. In Mexico 152,772.55 ha of bell peppers were planted, of which a production of 3,238,244.81 tons was gotten, with a yield of 21.65 t ha-1 [16]. Decades ago in India, bell pepper cultivation has gained attention due to suitable growth conditions, with acreage and production figures of 34,000 ha and 4,87,000 metric tons, respectively [17]. Florida's bell pepper sector is worth $247.5 million and has 7.3% growth in value since 2007 [18]. Also, according to the Farmgate survey, bell pepper was also rated 24th among all Georgia agricultural commodities in 2004, generating more than $600 million [19]. Nonetheless, inappropriate post-harvest management techniques have resulted in a considerable decrease in the food value of bell pepper in recent years, resulting in a very significant economic loss. During the dry and wet seasons, respectively, there were 28.6 and 38.7% post-harvest losses [20]. Food losses in most fresh fruits and vegetables are greater than 40% over the world, and are mostly caused by inadequate handling and storage after harvest [21–23]. However, a good postharvest handling and storage system eliminates waste, adds value, and improves the product's quality and quantity [24].

3. Some prevalent postharvest diseases of bell pepper

Bell peppers are susceptible to a variety of postharvest diseases. *Alternaria alternate* (Black Mold) and *Botrytis cinerea* (Grey Mold) are the two most prevalent fungi causing diseases in bell pepper [25]. During harvesting, these pathogens are present on the surface of the fruit, and they infest the tissue during handling and storage [6]. Internal fruit (IFR) rot is another fungal disease that significantly affects bell peppers. A complete description of these fungi causing disease in bell pepper, their source of infection, and symptoms of spoilage are discussed below.

3.1. Grey mold

Grey mold, produced by *Botrytis cinereal*, is a key limiting factor in postharvest storage and long-distance transportation of peppers [26]. *Botrytis cinereal* is the fungus that causes grey mold in bell peppers. It is frequently the second-worst postharvest disease of peppers. This pathogen is ubiquitous in nature, very aggressive and capable of causing spoilage even when transported and stored in cold refrigerated conditions [26]. At cold storage temperatures, grey mold can spread quickly from diseased fruit to healthy fruit [27]. Soft, water-soaked sores appear on the fruit, which becomes brown before being coated with powdery, grey spore masses (Fig. 1a) [28]. Although the disease cycle of *Botrytis cinereal* which causes postharvest fruit rot of pepper has not been fully investigated but is believed to be comparable to that of other crops [29].

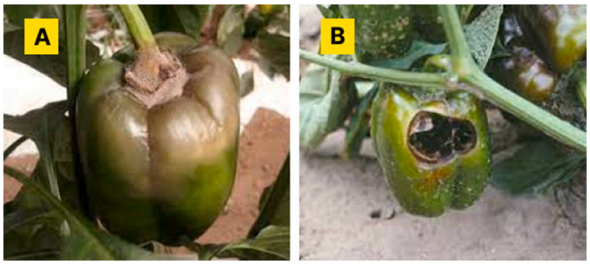

Fig. 1. (A) Symptoms of Grey mold in Bell pepper (B) Symptoms of Black mold in Bell pepper.

3.2. Black mold

Alternaria alternate causes black mold in bell peppers. It is a fungus that damages a wide range of crops globally, not only bell peppers [30]. Due to its polyphagous nature and synthesis of poisonous, carcinogenic, and even teratogenic compounds, it is considered to be a potentially deadly food-spoiling agent [31]. It is distinguished by dark sunken lesions that are accompanied by white to grey-green mycelial development and dark green to black conidia (Fig. 1b) [32]. This fungus thrives at cold temperatures and has been linked to the widespread spoiling of cold-stored fruits and vegetables [33]. Synthetic fungicides are majorly used to combat black spot rot after harvest [6].

3.3. Internal fruit rot

A dangerous fungus known as bell pepper internal fruit rot develops mycelium and necrosis on the ovary and fruit flesh. Fusarium lactis species complex (FLASC) members are the primary causes, and it has become a significant global threat to the production of bell peppers [34]. Internal fruit rot usually manifested itself as whitish-grey hyphal development on the seeds, placenta, and inside the fruit wall [35]. Infected fruits usually have little or no outward illness indications, such as sunken sores [36]. Only in severe infections can outward signs appear on the fruit's exterior surface as greenish to dark brown blemishes [35]. However, due to the fact that this infection occurs inside the fruit before harvest, standard post-harvest methods such as disinfection with hot water, UV irradiation, or chlorinated water, are ineffective in preventing internal fruit rot. Because of their interior cavity, non-destructive technologies for testing internal fruit quality in real-time modes, such as X-ray radiography and VIS/NIR 5 spectroscopy have not been adequate enough to sort out this disease in bell pepper fruit [37].

4. Recent postharvest disease control of bell pepper

4.1. Chemical methods

Chemical treatment, especially for perishable fruits, is the most common conventional postharvest management strategy [6]. Moreover, the major mechanism of chemical treatment for postharvest disease control could be related to the ability to induce antioxidant activities and enhance the defense response in the fruit against fungi, however, while this technique has been proven to be efficient, environmental impact and the emergence of resistance strains limit its full use [6]. Nevertheless, chemical compounds such as Salicylic acid, Hydrogen peroxide, and 1-Methylcyclopropene have been demonstrated in several studies to enhance bell pepper storability.

Salicylic Acid (SA) is a plant hormone that controls a variety of physiological processes in plants [38]. SA and its natural analog, acetylsalicylic acid (ASA), have been shown to have a lot of potential for delaying ripening, improving quality, and reducing post-harvest losses in fruits and vegetables [39]. The effectiveness of SA in the improvement of bell pepper postharvest quality has been proven. For example, SA has been shown to be effective in preserving the quality of bell peppers after harvest [40]. SA also preserved firmness, green color, and total acidity in green bell pepper [41]. Exogenous applications of SA in bulk and nanoscale forms have been studied for their efficacy in controlling black mold in an investigation, at 1.4 mM, both SA bulk materials & SA nanoparticles (SANPs) significantly inhibited the growth of *A. alternata*, but SANPs had a stronger suppressive effect than SA bulk equivalents [42].

Hydrogen peroxide (H_2O_2) possesses a bactericidal, sporicidal, and inhibitory ability, this is due to its ability to operate as an oxidant and produce other cytotoxic oxidizing species including hydroxyl radicals [43]. Treatment of bell pepper with H_2O_2 has been seen to extend its shelf life and reduce natural and pathogenic microbial populations. For instance, H_2O_2 (5%) was found to provide the highest reductions of *Listeria innocua* in bell pepper [44]. Also, 15 mM Hydrogen peroxide treatments significantly reduced weight loss, rot rate index, and nitrate content of bell pepper as compared with the control treatment [45]. Hydrogen peroxide is widely regarded as safe for various food uses, although it has not yet been approved as an antimicrobial agent [43]. However, it has a number of drawbacks, including a long application time and the potential harm to some products.

1-Methylcyclopropene which is a popular ethylene antagonist is being utilized in a variety of fresh horticulture fruits and vegetables [4]. The use of 1-MCP in the postharvest treatment of bell pepper cultivars has been thoroughly researched (Table 1). The Influence of 1-MCP on the Postharvest Storage attribute of Green bell pepper was investigated by Ref. [46], and the outcome shows that 1-MCP had a great effect on delaying the ripening process, reducing softening, weight loss, and decay development. Despite the fact that ethylene supplementation did not accelerate ripening [47], discovered that treating 'Aries cultivar' in the breaker stage with

Table 1
The effect of 1-MCP on postharvest quality of bell pepper fruit.

1-MCP rate	Species	Key findings	Reference
1.0 μl·dm-3, 3.0 μl·dm-3, and 5.0 μl·dm-	'Yecla F1' & 'Roberta F1'	softening of pepper strips was slowed down	[48]
27 pmol L−1	'Selika' 'H1530'	Rots decreased, color development & weight loss delayed	[46]
40 pmol L−1	'Setubal'	color development delayed, rots, shriveling & pitting increased	[49]
45 pmol L−1	'Sujiao 13'	Respiration Reduced, senescence delayed	[50]
22 pmol L−1	'Aries'	color development delayed	[47]
29 pmol L−1	Unspecified	chilling injury reduced	[51]

1-MCP slowed ripening by roughly 7 days, indicating that ethylene perception was critical for color change.

4.2. Physical treatments

4.2.1. Heat treatment

The spectrum of non-chemical treatment technologies has increased because of the desire for fresh products of excellent quality and with minimal chemical residue. The most promising substitute for synthetic fungicides for postharvest disease management has been seen to be natural and commercially viable methods such as hot water treatment (HWT) [6]. Heat treatment of pepper fruit before storage can directly inhibit pathogens and improve the fruit's resistance [52,53]. However, improper temperature and duration of HWT can have a negative impact on fruit quality [54]. Heat treatment has been extensively studied and documented as an efficient postharvest treatment for bell pepper fruit (Table 2). For instance, Heat treatments between 45 and 55° Celsius reduce spore germination and germ tube lengthening [26]. Dipping sweet pepper 'Miogi Cultivar' in 45 °C hot water for 15 min significantly increased fruit tolerance to chilling injury at 6 °C cold storage, improved the ascorbate-glutathione cycle, and prolonged storage life [55]. [56] found that hot water wipping at 40 °C was effective in maintaining bell pepper flexibility, weight loss, decay incidence, membrane leakage, ascorbic acid content, soluble solids content, & total chlorophyll content. Also, after storing bell pepper in cold storage of 2 °C for 21 days plus 3 days at 20 °C [market simulation], bell pepper treated with hot water (55 °C for 15s) was reported to have significantly decreased weight loss, softness, decay, and chilling injury, while maintaining quality [57]. *B. cinerea* and *A. alternate* decay development were totally stopped or greatly decreased by dipping naturally infected or fruits inoculated artificially at 50 °C for 3 min [58]. Besides the efficient and complete microbial eradication by non-chemical treatments, this technology is believed to be more effective than other postharvest treatments in several aspects such as control efficiency and fruit quality retention. With regard to the mechanisms of control of postharvest decay by HWT, several studies have indicated that HWT could induce a defense response of fruit and vegetables, sequentially preventing the pathogen from spreading throughout the tissue [54]. However, when applying this technique alone, it may only partially be effective in preventing postharvest infections [6].

4.2.2. Edible coatings

In the past two decades, studies have focused on edible coating application on fruits and vegetables [65]. Edible coatings increase the storage life of fruits and vegetables while also being environmentally friendly at the same time [66]. They are a semipermeable barrier on the fruit's surface that modifies the inside environment, reducing respiration rate & moisture loss [67]. They are usually made from lipids, proteins, polysaccharides, and resins [68], and they're safe to eat as part of the product because they don't add any undesirable properties [69]. Edible coatings are proving to be a relatively novel and simple innovation [70]. Their films help to maintain antioxidant activity, extend shelf life, reduce respiration rate, and mass loss, and maintain color and firmness in treated fruits [4]. Many edible coatings have demonstrated desired results after treating with bell pepper (Table 3). For instance, Aloe vera displays excellent inhibitory properties against several bacteria and fungi in green *capsicum* [71]. Chitosan or Aloe vera inhibits the mycelium growth of Colletotrichum capsici in bell pepper fruit [8]. Bell pepper fruits immersed in a chitosan solution with a concentration of 2% had greater levels of total soluble solids, ascorbic acid, total chlorophyll & phenolic compounds [72]. Aloe vera gel coating decreased respiration rate, weight loss, degradation, and color retention while maintaining firmness, ascorbic acid content, and other quality metrics [73]. The mechanism of edible coatings on fruit preservation has been ascribed to their excellent gas and moisture barrier properties (Fig. 2) [6]. However, some edible coatings have limited antimicrobial effects on postharvest diseases when used alone [6].

4.2.3. Nano-based formulations

The application of nano-based formulations for bell pepper fruit is an area of research that has gained considerable attention in recent years. Nano-based formulations are composed of nanoparticles that are designed to enhance the bioavailability and efficacy of active compounds in plants. Several studies have investigated the effectiveness of nano-based formulations in improving the quality and nutritional content of bell peppers. For instance, a study by Ref. [77] reported that the use of chitosan nanoparticles coatings could represent a good alternative for the protection of bell pepper against the pathogenic bacteria *P. carotovorum*. Similarly, another study by Ref. [78] found that the application of the combined use of grafting and zinc oxide nanoparticles increased the nutritional quality of the levels of nutraceutical components of bell pepper fruit. Likewise [79], also conducted a study on the application of Chitosan nanoparticles as an edible surface coating agent to preserve the fresh-cut bell pepper. The experimental results showed that the

Table 2
Bell pepper fruit quality as influenced by Hot Water Treatment.

Treatments protocol	Key findings	Reference
45 °C for 15 min	Reduced chilling injury	[59]
53 °C, 1 to 3 min	Induced chilling injury tolerance	[60]
53 °C, 1 to 3 min	Reduced decay and chilling injury indexes, maintained quality parameters, ascorbic acid, and total phenolics content	[61]
55°C for 15 s	softening, decay incidence, and chilling injury	[57]
40, 50, 60°C for 2 min	soluble solids content, weight loss, decay incidence, ascorbic acid content, total chlorophyll content, and membrane leakage	[56]
53°C for 4 min	Reduced weight loss and chilling injury	[62]
4 min dip at 53C	Inhibited respiration rate, reduced decay, retained turgidity and green color, and maintained excellent overall quality	[63]
55 ± 1°C for 12 ± 2 s	Improved the general appearance of the fruit, reduced decay incidence, and maintained fruit firmness	[64]

Table 3
The effects of edible coatings and essential oil on bell pepper postharvest quality.

Edible films	Formulation	Storage regime	Key findings	Reference
gum arabic or Aloe vera gel or cinnamon oil	Aloe vera gel [4%, 5%, 6%], gum arabic [6%, 9%, 12%] and cinnamon oil [0.5%, 0.75%, 1%]	8 ± 1 °C with 80–85%	antioxidant enzyme activities significantly higher activities of browning and fruit softening enzymes inhibited	[7]
Chitosan or A. vera	chitosan [1, 1.5, and 2%] and A. vera [5 and 10%]	–	mycelium growth of Colletotrichum capsici inhibited	[8]
Chitosan and pullulan enriched with pomegranate peel extract	Chitosan [50%]-pullulan [50%]	room [23 ± 3 °C, RH: 40–45%] and cold [4 ± 3 °C, RH: 90–95%]	physiological loss in weight & color browning reduced total soluble solids, titratable acidity, pH phenolic content, flavonoid content, antioxidant activity, firmness, and sensorial attributes maintained	[74]
starlight wax emulsion or Aloe vera or garlic or mint leaf extract	Garlic extract [10, 20 and 30%], Aloe vera gel [5, 10 and 15%] and starlight wax [10, 25 and 50%]	10 ± 2 °C	metabolic activities restricted and senescence delayed	[75]
Guar gum	0.2%, 0.3%, 0.4%, 0.5%, 0.6%	2 °C, 6 °C, 10 °C, 14 °C	weight loss, firmness, total soluble sugar and carotenoid maintained	[9]
Chitosan or Aloe vera gel	1.5% and 2%	25 ± 2 °C and 55 ± 5% RH	weight loss, respiration rate, decay reduced colors, firmness, ascorbic acid content, and other quality parameters preserved	[73]
gum Arabic or *Aloe vera*gel or cinnamon oil	gum arabic [6, 9, and 12%], Aloe veragel [4, 5, and 6%], and cinnamon oil [0.5, 0.75, and 1%]	8 ± 1 °C with 90–95% RH	membrane leakage, weight loss, chilling injury, and decay incidence reduced Less increased in pH, sugar percentage, total soluble solids, appealing fruit color, ascorbic acid, titratable acidity, and firmness, were higher in treated fruits	[3]
ethanolic extracted propolis [EEP]	0.25%, 0.50% and 0.75%	10 °C and 90% RH	incidence of disease reduced moisture retained	[76]
Pectin or Arabic or xanthan gums with candelilla wax, jojoba oil, and extract of polyphenols	–	[25 ± 2 °C	quality physicochemical parameters of green bell peppers such as appearance, weight loss, color changes, total soluble solids pH, and texture were maintained in treated fruits	[10]

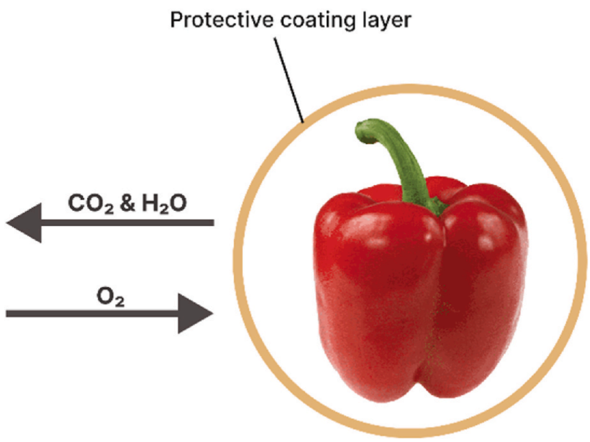

Fig. 2. Action of edible coatings on the storage quality of bell pepper.

application of chitosan nano-coating maintained the FCP for 12 days at 5 °C without loss of weight, and sensory quality. In another study reported by Ref. [80], chitosan nanoparticles inhibited *A. alternata* during the cold storage period of bell pepper and preserved the physicochemical quality. Other similar studies on bell pepper fruit have also been reported [81–83]. Overall, the use of nano-based formulations for bell pepper fruit holds great promise in improving the nutritional value and yield of this important crop. However, combining Nano-based formulations with other technologies, such as microencapsulation, could lead to further improvements in the delivery and efficacy of bioactive compounds in bell peppers.

4.2.4. Ozone (O_3)

O_3 is an oxidizing agent that has been shown to be effective in preventing weight loss, degradation of firmness, and microbial assault in a variety of fresh food [84,85]. The use of ozone as a postharvest treatment for fruits and vegetables has lately grown in popularity due to its ability to minimize microbial contamination while leaving no chemical residues and having no negative impact on the product's quality [11]. O_3 is a naturally occurring gas that is one of the most effective sanitizers against many food bacteria, and it is also employed in fruits and vegetables [86]. A number of writers [87–91] have studied the efficacy of O_3 in lowering microbial counts on bell pepper and few of them have [90–92] also assessed its effect on physicochemical properties. Based on these findings, O_3 appears to be a potential method for improving bell pepper postharvest quality. For example, continuous ozone treatment of red bell peppers at 0.1 and 0.3 mol mol-1 showed no impact on weight loss, texture, or color, but continuous ozone exposure at 0.1 mol mol-1 makes fructose and glucose levels increase, as well as total phenolics in red bell peppers [90]. [93] also found that 2 ppm ozone is effective in suppressing respiration rate and weight losses of peppers compared to control groups was decreased and maintained green color of bell peppers. Recent studies of ozone treatment on bell pepper and their key findings were presented in (Table 4). Commercial application of ozone among farmers and processors has been further expanded by the quick on-site ozone generation and their non-toxic waste output [94]. The mechanism of ozone against diseases could be ascribed to its penetrability, oxidizing ability, and spontaneous decomposition of the pathogen [84]. However, ozone has some limitations when used on food. Complex processes are needed to decompose ozone based on the radical types that form in solution and the different forms of organic materials in the medium that either initiate, enhance, or impede the reaction chain [95]. Low doses of ozone, which can inactivate pure microbial cultures, may be inefficient against viruses, spores, and cysts [96].

4.2.5. Modified atmosphere packaging (MAP)

MAP is the process of sealing actively respiring products in polymeric film packages to vary the composition of internal atmospheres within the container [100]. Microbial growth is suppressed, respiration, ripening, and senescence are delayed, and oxidative processes that need free oxygen are inhibited in sealed packaging such as MAP [101]. MAP has been used to extend the shelf life and keep the quality attribute of various horticultural crops after harvest [4], including bell pepper. The fundamental idea of MAP is to create a gaseous equilibrium between the product and the sealed environment, resulting in lower O_2 and higher CO_2 levels, so as to extend their shelf life, and improve their quality [100]. [37] found that MAP storage of bell peppers in 60 m low-density polyethylene (LDPE) 429 pouches can significantly reduce visible post-harvest internal rotting caused by Fusarium spp., at the end of 14 days at 20 °C. Bell pepper stored in perforated LDPE packets exhibited reduced weight loss, increased shelf life, and higher vitamin C content compared to fruits kept in an open tray [100]. An extensive overview on the influence of MAP on bell pepper was presented below (Table 5). The use of MAP in conjunction with low temperatures is critical for lowering respiration rates and other metabolic processes that might degrade fruit quality during postharvest storage and shelf life [4]. However, the advantages of this method are lost when the package is opened, and also, different items require different gas formulations [102].

4.2.6. Elicitors

Elicitors are substances that can trigger the plant's defense mechanisms against diseases. Elicitors may be biological, chemical or physical and may induce local acquired resistance, systemic acquired resistance or induced systemic resistance [108]. The mechanism of elicitor action in fruits and vegetables preservation involves the activation of the plant's defense responses. This, in turn, results in the production of various defense molecules, such as phytochemicals, antioxidants, and enzymes, which help to protect the fruits and vegetables from microbial and oxidative degradation. Several studies have investigated the use of elicitors in the control of postharvest diseases in bell peppers. For example [109], reported that the application of mixed of Jasmonic acid, hydrogen peroxide, and chitosan to fruits and plants of bell pepper induced an increase in bioactive compounds in mature sweet bell peppers. Similarly [110], reported that the application of combined salicylic acid and Hydrogen peroxide elicitor were capable to improve sensory quality and shelf life of bell peppers. Overall, the use of elicitors as a natural alternative to chemical fungicides shows potential in the control of postharvest diseases in bell peppers. Further studies are needed to optimize the application methods and concentrations of the elicitors and to assess their safety for human consumption. Researchers can also explore the potential of integrating elicitors with other management strategies, such as biological control agents and cultural practices, to enhance the overall effectiveness of pest and disease management.

4.3. Biological and botanical treatments

Due to growing concerns on the health effects of chemical residues, biological and botanical treatments are becoming an alternative to chemical treatments. The use of biological and botanical treatments offers many advantages such as reduced health risk, non-

Table 4
Influenced of ozone treatment on bell pepper's fruit quality.

Concentration	Key findings	Reference
2 ppm	respiration rate suppressed, weight losses decreased, and green color of peppers maintained	[93]
3 mg L^{-1}	fungicide residues efficiently removed and quality of the fruit preserved	[97]
1–3 mg/L	microbial load reduced, ascorbic acid, firmness, color and overall acceptability retained	[98]
1, 3, 5, 7, and 9 ppm	ascorbic acid content was increased, disease incidence was reduced and Physico-chemical quality maintained	[99]
0.1 and 0.3 μmol mol−1	Sugars and phenolics content Increased, vitamin C content enhanced, and total phenolics content increased	[90]
0.45, 0.9 and 2 μmol mol−1	disease incidence, antioxidant activity and weight loss during storage reduced, firmness improved	[11]

Table 5
Bell pepper fruit quality as influenced by MAP.

Storage condition	Atmospheric condition	Key findings	Reference
22 °C	Not reported	reduced weight loss and retained pericarp firmness	[103]
5 ∘C	10% O2 and 45% CO2	Retained quality characteristics	[104]
20 °C	Not reported	ameliorate internal fruit rot development during post-harvest storage	[37]
95 ± 5% RH and 10 ± 1 °C	5% O2 + 5% CO2	maintained the physicochemical quality	[105]
5, 10, and 15 °C and RH of 85 ± 5%	4.8% O_2 and 7.1% CO_2	Retarded senescence & extended the shelf life.	[106]
10°C and 5°C	Not reported	There is better visual fruits quality with less leaked juice and higher firmness	[107]

environmentally persistent, site specific action, cost effective and less prone to resistance [111]. The biological postharvest management involves the use of living organisms such as bacteria, fungi, and yeasts to control the growth of harmful microorganisms. For instance, Compost bacteria provide antifungal activity against grey mold and*Alternaria* rot on bell pepper fruit [112]. Likewise, olive oil mill wastewater was reported to inhibits the growth of *B. cinerea* mycelium and significantly decreased fungus mold formation in red bell pepper [113]. Similarly, isolates of three Bacillus spp. Has also reported to inhibit *P. capsici*mycelial growth invitro bell pepper fruits [114].

The botanical postharvest management involves the use of plant-derived substances such as essential oils and plant extracts to control pests and diseases. Numerous plant oils and extracts have been developed as bio-fungicides as a result of a strong desire to find chemicals that are safe for people and the environment [26]. Essential oils are plant extracts produced by aromatic plants as secondary metabolites that have potent antifungal and antioxidant properties [115]. A unique method for making up for biopolymers' unstable and volatile properties and enhancing coating functionality is to add essential oils and plant extracts to them [116]. Essential oils have been researched widely for activity against Black mold disease and other pathogens in Bell pepper. "Hinokitiol" which is an oil extract from Japanese Cyprus, provided prevention against grey mold on bell peppers that were dipped in a solution at 750 μL/L [117]. Vapors from sage essential oils lowered postharvest pepper rot [118]. Clove and olive oil [0.125–0.5%] have also been investigated and found to reduce fungal growth on bell peppers when applied as a pre-harvest spray [119]. Compost water extracts and olive oil mill wastewater are examples of natural agricultural byproducts that can suppress pepper grey mold, although formulations must be improved for practical application [26]. In general, the usage of agrochemicals and other synthetic substances for postharvest fruit disease prevention can be decreased with the promotion of plant extracts and essential oils due to their numerous benefits [6].

4.4. Non-destructive technologies

4.4.1. UV irradiation

UV Irradiation is a non-thermal innovation that has a wavelength of 190–280 nm [120]. UV Irradiation exposes food to radiant energy from rays and e-beam (high-energy electrons) that penetrate substances and disrupt chemical bonds, including the DNA of living organisms. Postharvest irradiation is used to improve fruit quality and increase the storage life of fresh food commodities [4]. Numerous investigations have been recently made on the effect of irradiation on bell peppers (Table 6), and this technique has proven to be effective [121]. investigated the effects of UV-C irradiation on postharvest characteristics and bioactive compounds of yellow *capsicum* during refrigerated storage and found that UV-C illumination at 6.6 kJ m-2 had the best outcome in keeping the firmness and limiting weight loss and electrolyte leakage throughout storage. UV-C and UV-B enhanced biosynthesis of flavonoids and carotenes in bell peppers (Fig. 3) [122]. Chilling damage is a catastrophic postharvest condition that can arise following low-temperature storage and cause fruit to be downgraded or rejected in the market [123]. investigated the effect of UV-C on bell pepper chilling damage and found that brief UV-C treatments can lower the incidence and severity of bell pepper chilling injury. The pace at which microbiological activity such as bacteria develops in the food is also a major indicator of food quality during storage. UV-C irradiation reduced the number of mesophile bacteria and molds but had no effect on bell pepper acidity or sugars [13]. It is notable that the primary mechanism of irradiation technology for the treatment of postharvest diseases is the development of fruit resistance and the penetration of phytopathogen cell components [6]. However, fruit's sensory and edible properties could be harmed by unregulated and repeated usage of this treatment. Additionally, repeated exposure to radiation may weaken its impact on infections due to the emergence of resistant strains [124].

Table 6
Effects of UV irradiation bell pepper postharvest quality.

Treatments	Formulation	Key findings	Reference
UV-C	6 kJ m− 2	biosynthesis of carotenes and flavonoids in bell peppers enhanced	[122]
UV-B	6 kJ m− 2	biosynthesis of carotenes and flavonoids enhanced	[122]
UV-B	9 kJ m^{-2}	Total antioxidant capacity [TAC] increased	[125]
UV-C	3 and 5 min at 254 nm	changes in titratable acidity [TA], firmness, levels of ascorbic acid, fruit color development, and soluble solids content [SSC] delayed	[126]
UV-C	0, 1, 3, 5, 10, and 20 min at 254 nm 108 ± 10 mW cm^{-2}	*Rhizopus*and decay reduced in all cultivars	[127]
UV-C	1.3, 2.4, and 3.6 kJ.m-2	storage decays controlled	[128]

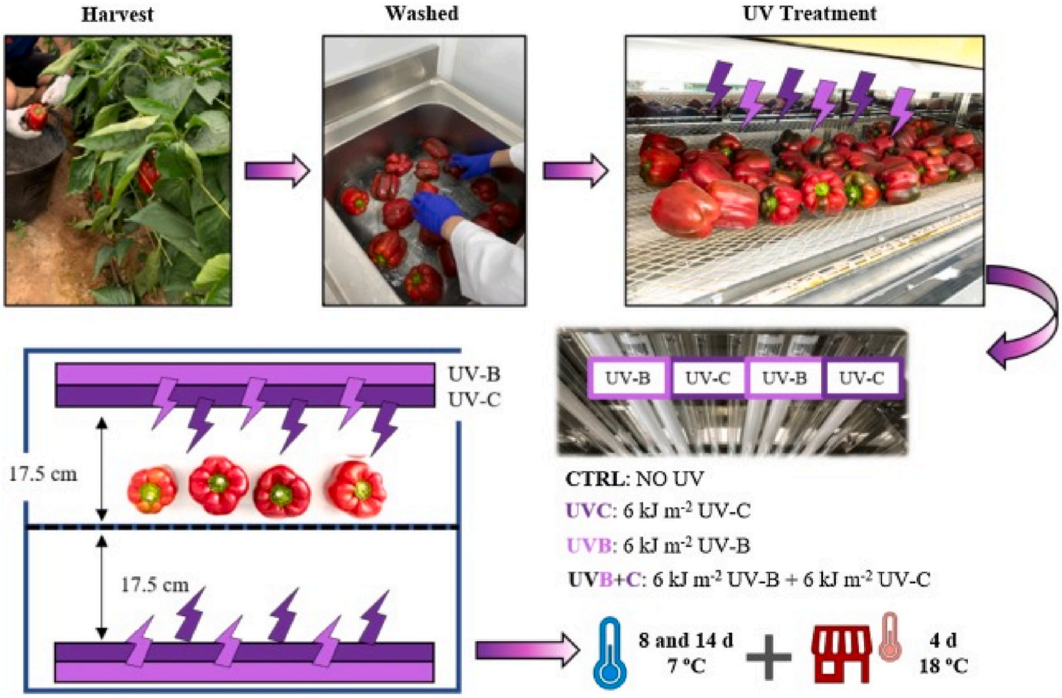

Fig. 3. UV Irradiation Schematic representation of an experimental design for bell pepper [122].

4.4.2. *Pulse electric field (PEF)*

Another new storage method that is widely employed in the preservation of food and microbial inactivation is the pulsed electric field [129]. It is a non-thermal technique that involves passing brief high-voltage pulses across a food product [usually in semi-solid to liquid form] between two electrodes [130]. PEF technology has been widely researched as a food preservation method [131]. The usage of PEF has been connected to a reduction in the rate of respiration as well as the conservation of nutritional quality traits such as antioxidants & ascorbic acid [129]. The application of very brief, high-voltage pulses to food put between electrodes causes electroporation, which results in the development of new and expansion of existing membrane holes, rupture of the cell membrane, and intracellular content leakage [132]. PEF treatment with fluences greater than 4 J/cm2 has been proven to be effective in decontaminating red bell peppers without affecting their chemical qualities [12]. PEF, or a combination of PEF and ultrasounds [US], also suppresses the bioactive component in bell pepper and improves its quality [133]. PEF is also capable of retaining the chemical content of fruits. Freeze-dried bell pepper exposed to non-thermal pretreatment had greater vitamin C carotenoids content and total phenolic more than blanched material [134]. The mechanism of action in postharvest bell pepper disease control has not been well understood due to limited studies [6]. However, the current challenges of this technology include high capital cost, Inefficient in spore inactivation, Unavailability of commercial units in many regions of the world, presence of bubbles may lead to non-uniform treatment as well as operational problems, and limited economic and engineering studies for up-scaled continuous [135].

4.5. *Artificial Intelligence as postharvest technology for bell pepper*

In recent years, the integration of Artificial Intelligence (AI) in various agricultural processes has shown great potential for revolutionizing the way we grow, harvest, and store crops. One area where AI can make a significant impact is postharvest storage and management of crops. With the help of AI-powered tools and techniques, farmers and agribusinesses can optimize their postharvest management processes to minimize losses, improve crop quality, and reduce waste. Lately, the application of AI as bell pepper's postharvest practices has attracted some interests in the field of research. For instance, [136], reported "visible to near-infrared" (VIS-NIR) hyperspectral imaging as a reliable option for identifying early incidence of Chilling injury in bell pepper fruits [137], also applied Image Features and Machine Learning in distinguishing fresh and lacto-fermented red bell pepper samples. Grading and sorting are essential processes in postharvest handling of bell peppers. Traditional methods are time-consuming and labor-intensive. AI-based systems have been developed to automate these processes, leading to increased efficiency and accuracy. Machine Vision intelligent modelling have been applied to grade bell peppers based on their sizes and colors [138]. Similarly [139], also develop an in-line sorting system using a deep convolutional neural network (DCNN) for grading bell peppers based on maturity stage and size. Likewise, red and yellow sweet peppers were classified into immature and mature classes on the basis of color and morphological features using machine learning algorithms [140]. Nevertheless, AI is an emerging technology for postharvest management, thus, studies on the application of AI in postharvest practices of bell pepper are still very scanty. Future studies are still highly required in this area.

3. Conclusion and recommendations

Bell pepper is an important crop that suffers significant postharvest losses, but recent advancements in postharvest technology offer solutions to these challenges. This review paper provides an overview of the effects of recent and emerging postharvest techniques to preserve the high nutritional value and safety of bell pepper fruits. The use of non-chemical techniques such as modified atmosphere packaging, hot water treatment, edible coatings and others have shown promising results in improving the shelf life of bell pepper. The literature also provides exciting findings on non-destructive technologies such as Pulse electric field and UV radiation. However, while the use of such postharvest treatment has yielded exciting results, their commercial adoption is still falling short. Machine learning and other AI tools such as hyperspectral imaging, deep convolutional neural network are emerging postharvest technology that have display impressive findings for bell pepper with great future potentials.

Overall, while those postharvest techniques have yielded amazing results for bell peppers, some crucial observations and recommendations have been pointed out regarding their prospect applications in the following paragraphs.

- ➢ Recent investigations of these postharvest techniques on bell peppers were mainly based on a laboratory scale. More investigations are therefore needed to be piloted commercially in order to gather adequate information regarding their commercial viability.
- ➢ The mechanism of some of these postharvest techniques are not yet understood well. Further researches are needed to deeply investigate the mechanisms underlying their resistance to diseases. This will enhance the knowledge on their formulation, optimization, and application.
- ➢ Though utilization of a single treatment techniques has shown some positive results, however, as reported by various researchers, combination of some of these techniques often yield a more effective result. Thus, researchers should explore the potential of integrating these postharvest technologies with one another or with other proven methods to enhance their overall effectiveness on bell pepper disease control.
- ➢ Further research is needed to better understand the potential health risks associated with the use of nanoparticles in food systems, including Nano-based formulations for bell peppers. This can help inform the development of safer and more effective nanoparticle formulations.
- ➢ Since the internal fruit rot disease often attack bell pepper before the harvest, it is highly recommended that more researches should be focused on the use of non-destructive technologies such as X-ray radiography and VIS/NIR spectroscopy which can detect diseases in real-time mode, in order sort out this disease in bell pepper fruit before storage.

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Data availability statement

Data included in article/supplementary material/referenced in article.

Additional information

Supplementary content related to this article has been published online at [URL].

References

[1] D. Tsegay, B. Tesfaye, A. Mohammed, H. Yirga, Effects of harvesting stage and storage duration on postharvest quality and shelf life of sweet bell pepper (*Capsicum annuum L.*) varieties under passive refrigeration system, Int. J. Biotechnol. Mol. Biol. Res 4 (7) (2013) 98–104.

[2] A. Marin, F. Ferreres, F. Tomas-Barberan, M. Gil, Characterization and quantitation of antioxidant constituents of sweet pepper (*Capsicum annuum L.*), J. Agric. Food Chem. 52 (2004) 3861–3869, https://doi.org/10.1021/jf0497915.

[3] A. Ullah, N.A. Abbasi, M. Shafique, A.A. Qureshi, Influence of edible coatings on biochemical fruit quality and storage life of bell pepper cv."Yolo Wonder", J. Food Qual. 2017 (2017) https://doi.org/10.1155/2017/2142409.

[4] N.L. Bambalele, A. Mditshwa, L.S. Magwaza, S.Z. Tesfay, Recent advances on postharvest technologies of mango fruit: a review, Int. J. Fruit Sci. 21 (1) (2021) 565–586, https://doi.org/10.1080/15538362.2021.1918605.

[5] Y. Liu, Y. Li, Y. Bi, Q. Jiang, R. Mao, Z. Liu, D.B. Prusky, Induction of defense response against *Alternaria* rot in Zaosu pear fruit by exogenous L-lysine through regulating ROS metabolism and activating defense-related proteins, Postharvest Biol. Technol. 179 (2021), 111567, https://doi.org/10.1016/j.postharvbio.2021.111567.

[6] W. Oyom, Y.C. Li, D. Prusky, Z. Zhang, Y. Bi, R. Tahergorabi, Recent advances in postharvest technology of Asia pears fungi disease control: a review, Physiol. Mol. Plant Pathol. 117 (2022), 101771, https://doi.org/10.1016/j.pmpp.2021.101771.

[7] Ajmal, U., Manzoor, A., Bashir, M. A., Naveed, M. S., Akhtar, M. T., & Rehan, M. Enzymatic profile of bell pepper (*Capsicum annuum*) cv.'Yolo Wonder'as affected by different edible coatings during cold storage. https://doi.org/10.26353/j.itahort/2002.1.182195.

[8] Y. Faramitha, F. Febriyanti, T. Fitrilia, F. Dimawarnita, S. Siswanto, Application of chitosan-aloe vera gel based coating on postharvest quality and storability of red chili (*Capsicum annuum L*, in: 7th International Conference on Biological Science (ICBS 2021), 2022, pp. 238–245, https://doi.org/10.2991/absr.k.220406.034. Atlantis Press.

[9] N.P. Minh, T. Van Tuan, T.T. Tuyen, D.K. Mai, Application of guar gum as edible coating to prolong shelf life of red chilli pepper (*Capsicum frutescens L.*) fruit during preservation, J. Pharmaceut. Sci. Res. 11 (4) (2019) 1474–1478.

[10] E. Ochoa-Reyes, G. Martínez-Vazquez, S. Saucedo-Pompa, J. Montañez, R. Rojas-Molina, M.A.D. Leon-Zapata, C.N. Aguilar, Improvement of shelf life quality of green bell peppers using edible coating formulations, J. Microbiol. Biotechnol. Food Sci. 2021 (2021) 2448–2451.

[11] M. Glowacz, D. Rees, Exposure to ozone reduces postharvest quality loss in red and green chilli peppers, Food Chem. 210 (2016) 305–310, https://doi.org/10.1016/j.foodchem.2016.04.119.
[12] K. Rybak, A. Wiktor, K. Pobiega, D. Witrowa-Rajchert, M. Nowacka, Impact of pulsed light treatment on the quality properties and microbiological aspects of red bell pepper fresh-cuts, LWT 149 (2021), 111906, https://doi.org/10.1016/j.lwt.2021.111906.
[13] L.M. Rodoni, A. Concellón, A.R. Chaves, A.R. Vicente, Use of UV-C treatments to maintain quality and extend the shelf life of green fresh-cut bell pepper (*Capsicum annuum L.*), J. Food Sci. 77 (6) (2012) C632–C639, https://doi.org/10.1111/j.1750-3841.2012.02746.x.
[14] FAOSTAT, Food and Agriculture Organization of de United Nations, 2019. Retrieved 2020 September 20 from, http://www.fao.org/faostat/es/#data/PP.
[15] M. Mangal, K.P. Sahana, A. Srivastava, A. Khar, N. Jain, P.K. Jain, M. Harun, Haploid Induction through Microspore Embryogenesis in Bell Pepper Genotypes, 2023.
[16] SIAP, Servicio de Información Agroalimentaria y Pesquera [Agri-Food and Fisheries Information Service], 2019. Retrieved 2020 October 20 from, https://nube.siap.gob.mx/cierreagricola/.
[17] NHB, National Horticulture Board Database 2018-19, 2019. www.nhb.gov.in.
[18] S.R. McCoy, R.C. Hochmuth, W.L. Laughlin, A. Gazula, D.K. Fenneman, Economic analysis of fresh green bell pepper (*Capsicum annuum*) production under shade structures, in: Proceedings of the Florida State Horticultural Society vol. 126, 2013, pp. 101–106.
[19] M.M. Byrd, E.G. Fonsah, C.L. Escalante, M.E. Wetzstein, The impact on farm profitability and yield efficiency of bell pepper production of the methyl bromide phase-out program in Georgia, J. Food Distrib. Res. 37 (2006) 48–50, https://doi.org/10.22004/ag.econ.8571, 856-2016-57541.
[20] T. Tunde-Akintunde, T. Afolabi, B. Akintunde, Influence of drying methods on drying of sweet bell pepper (*Capsicum annuum*), J. Food Eng. 68 (2005) 439–442, https://doi.org/10.1016/j.jfoodeng.2004.06.021.
[21] G. Malorgio, F. Marangon, Agricultural business economics: the challenge of sustainability, Agri. Food Econom. 9 (1) (2021) 1–4, https://doi.org/10.1186/s40100-021-00179-3.
[22] G. Brunori, Biomass, biovalue and sustainability: some thoughts on the definition of the bioeconomy, EuroChoices 12 (1) (2013) 48–52, https://doi.org/10.1111/1746-692X.12020.
[23] C. Sawatdeenarunat, D. Nguyen, K.C. Surendra, S. Shrestha, K. Rajendran, H. Oechsner, S.K. Khanal, Anaerobic biorefinery: current status, challenges, and opportunities, Bioresour. Technol. 215 (2016) 304–313, https://doi.org/10.1016/j.biortech.2016.03.074.
[24] R. Renu, D.V. Chidanand, Effect of modified atmosphere storage conditions on biochemical parameters of bell peppers, Int. J. Agric. Food Sci. Technol. 4 (2013) 915–922.
[25] M.J. Ceponis, R.A. Cappellini, R.A. Lightner, Disorders in fresh pepper shipments to the New York market, Plant Dis. 71 (1987) 380–382.
[26] C. Krasnow, C. Ziv, Non-chemical approaches to control postharvest gray mold disease in bell peppers, Agronomy 12 (1) (2022) 216, https://doi.org/10.3390/agronomy12010216.
[27] B.A. Amiri, W. Acosta, W.S.U. Plant, Gray Mold, 2020, pp. 1–5.
[28] F. Naz, A. Tariq, C.A. Rauf, M.F. Abbas, E. Walsh, J. Luo, J.W. Bennett, First report of *Botrytis cinerea* causing gray mold disease of bell pepper (*Capsicum annuum*) fruit in Pakistan, Plant Dis. 102 (7) (2018) 1449, https://doi.org/10.1094/PDIS-10-17-1632-PDN.
[29] N. Tzortzakis, N. Alkan, C. Ziv, L. Korsten, Solanaceae and Cucurbitaceae Crops. In Postharvest Pathology of Fresh Horticultur-Al Produce, CRC Press, Boca Raton, FL, USA, 2019, pp. 303–338.
[30] Schouten S.P. (1991). Post-harvest diseases and disorders of fruits and vegetables: AL Snowdon (Editor). Wolfe Publishing Ltd., London 1990, 302 pp., £ 48.00, ISBN 0-7234-0941-5.
[31] R. Troncoso, C. Espinoza, A. Sánchez-Estrada, M.E. Tiznado, H.S. García, Analysis of the isothiocyanates present in cabbage leaves extract and their potential application to control *Alternaria* rot in bell peppers, Food Res. Int. 38 (6) (2005) 701–708, https://doi.org/10.1016/j.foodres.2005.02.004.
[32] M.M. Wall, C.L. Biles, *Alternaria* fruit rot of ripening Chile peppers, Phytopathology 83 (3) (1993) 324–328.
[33] E.E. Stinson, D.D. Bills, S.F. Osman, J. Siciliano, M.J. Ceponis, E.G. Heisler, Mycotoxin production by *Alternaria* species grown on apples, tomatoes, and blueberries, J. Agric. Food Chem. 28 (5) (1980) 960–963, https://doi.org/10.1021/jf60231a040.
[34] M. Frans, R. Moerkens, S. Van Gool, C. Sauviller, S. Van Laethem, S. Luca, J. Ceusters, Modelling greenhouse climate factors to constrain internal fruit rot (Fusarium spp.) in bell pepper, J. Plant Dis. Prot. 125 (4) (2018) 425–432, https://doi.org/10.1007/s41348-018-0159-3.
[35] M.A. Khan, A. Tariq, F. Naz, C.A. Rauf, Morpho-molecular characterization and pathogenicity of Fusarium species causing fruit rot of bell pepper, Mycopath 16 (2) (2020).
[36] Y. Yang, T. Cao, J. Yang, R.J. Howard, P.D. Kharbanda, S.E. Strelkov, Histopathology of internal fruit rot of sweet pepper caused by Fusarium lactis, J. Indian Dent. Assoc. 32 (1) (2010) 86–97, https://doi.org/10.1080/07060660903503681.
[37] M. Frans, R. Aerts, N. Ceusters, S. Luca, J. Ceusters, Possibilities of modified atmosphere packaging to prevent the occurrence of internal fruit rot in bell pepper fruit (*Capsicum annuum*) caused by Fusarium spp, Postharvest Biol. Technol. 178 (2021), 111545, https://doi.org/10.1016/j.postharvbio.2021.111545.
[38] J. He, Y. Ren, C. Chen, J. Liu, H. Liu, Y. Pei, Defense responses of salicylic acid in mango fruit against postharvest anthracnose, caused by Colletotrichum gloeosporioides and its possible mechanism, J. Food Saf. 37 (1) (2017) e12294, https://doi.org/10.1111/jfs.12294.
[39] M. Asghari, M.S. Aghdam, Impact of salicylic acid on post-harvest physiology of horticultural crops, Trends Food Sci. Technol. 21 (10) (2010) 502–509, https://doi.org/10.1016/j.tifs.2010.07.009.
[40] K.S. Thakur, K. Jyoti, S. Kumar, S. Gautum, Improvement of postharvest keeping quality of bell pepper (*Capsicum annuum L.*) fruits treated with different chemicals following cold storage, Int. J. Curr. Microbiol. Appl. Sci 6 (7) (2017) 2462–2475, https://doi.org/10.20546/ijcmas.2017.604.291.
[41] A. Dobón-Suárez, M.J. Giménez, M.E. García-Pastor, P.J. Zapata, Salicylic acid foliar application increases crop yield and quality parameters of green pepper fruit during postharvest storage, Agronomy 11 (11) (2021) 2263, https://doi.org/10.3390/agronomy11112263.
[42] F.A. Abdel-Rahman, E.Y. Khafagi, M.S. Soliman, T. Shoala, Y. Ahmed, Preharvest application of salicylic acid induces some resistant genes of sweet pepper against black mold disease, Eur. J. Plant Pathol. 159 (4) (2021) 755–768, https://doi.org/10.1007/s10658-020-02199-z.
[43] A.K. Pandey, P. Kumar, P. Singh, N.N. Tripathi, V.K. Bajpai, Essential oils: sources of antimicrobials and food preservatives, Front. Microbiol. 7 (2161) (2017), https://doi.org/10.3389/fmicb.2016.02161.
[44] E.M. Alexandre, T.R. Brandão, C.L. Silva, Assessment of the impact of hydrogen peroxide solutions on microbial loads and quality factors of red bell peppers, strawberries and watercress, Food Control 27 (2) (2012) 362–368, https://doi.org/10.1016/j.foodcont.2012.04.012.
[45] Y.A. Bayoumi, Improvement of postharvest keeping quality of white pepper fruits (*Capsicum annuum L.*) by hydrogen peroxide treatment under storage conditions, Acta Biol. Szeged. 52 (1) (2008) 7–15.
[46] Z.S. Ilić, R. Trajković, Y. Perzelan, S. Alkalai-Tuvia, E. Fallik, Influence of 1-methylcyclopropene (1-MCP) on postharvest storage quality in green bell pepper fruit, Food Bioprocess Technol. 5 (7) (2012) 2758–2767, https://doi.org/10.1007/s11947-011-0614-7.
[47] W.M. Aizat, J.A. Able, J.C. Stangoulis, A.J. Able, Characterisation of ethylene pathway components in non-climacteric *capsicum*, BMC Plant Biol. 13 (1) (2013) 1–14, https://doi.org/10.1186/1471-2229-13-191.
[48] M. Grzegorzewska, E. Badełek, A. Wrzodak, K. Fabiszewski, A. Ciecierska, Quality and storage ability of fresh-cut pepper treated by 1-methylcyclopropene, J. Hortic. Res. 28 (1) (2020) 101–110, https://doi.org/10.2478/johr-2020-0007.
[49] J.P. Fernández-Trujillo, J.M. Serrano, J.A. Martínez, Quality of red sweet pepper fruit treated with 1-MCP during a simulated post-harvest handling chain, Food Sci. Technol. Int. 15 (1) (2009) 23–30, https://doi.org/10.1177/1082013208100464.
[50] S. Cao, Z. Yang, Y. Zheng, Effect of 1-methylcyclopene on senescence and quality maintenance of green bell pepper fruit during storage at 20 C, Postharvest Biol. Technol. 70 (2012) 1–6, https://doi.org/10.1016/j.postharvbio.2012.03.005.
[51] X. Li, J. Yun, X. Fan, Y. Xing, Y. Tang, Effect of 1-methylcyclopropene and modified atmosphere packaging on chilling injury and antioxidative defensive mechanism of sweet pepper, Afr. J. Biotechnol. 10 (34) (2011) 6581–6589.
[52] M. Schirra, G. D'hallewin, S. Ben-Yehoshua, E. Fallik, Host–pathogen interactions modulated by heat treatment, Postharvest Biol. Technol. 21 (1) (2000) 71–85, https://doi.org/10.1016/S0925-5214(00)00166-6.

[53] R. Barkai-Golan, N. Paster, Mycotoxins in Fruits and Vegetables. Elsevier, 2011.
[54] X. Li, X. Zhu, N. Zhao, D. Fu, J. Li, W. Chen, W. Chen, Effects of hot water treatment on anthracnose disease in papaya fruit and its possible mechanism, Postharvest Biol. Technol. 86 (2013) 437–446, https://doi.org/10.1016/j.postharvbio.2013.07.037.
[55] H. Endo, K. Miyazaki, K. Ose, Y. Imahori, Hot water treatment to alleviate chilling injury and enhance ascorbate-glutathione cycle in sweet pepper fruit during postharvest cold storage, Sci. Hortic. 257 (2019), 108715, https://doi.org/10.1016/j.scienta.2019.108715.
[56] M. Sakaldas, K. Kaynas, Biochemical and quality parameters changes of green sweet bell peppers as affected by different postharvest treatments, Afr. J. Biotechnol. 9 (48) (2010) 8174–8181, https://doi.org/10.5897/AJB10.1021.
[57] Z.S. Ilić, R. Trajković, R. Pavlović, S. Alkalai-Tuvia, Y. Perzelan, E. Fallik, Effect of heat treatment and individual shrink packaging on quality and nutritional value of bell pepper stored at suboptimal temperature, Int. J. Food Sci. Technol. 47 (1) (2012) 83–90, https://doi.org/10.1111/j.1365-2621.2011.02810.x.
[58] E. Fallik, S. Grinberg, S. Alkalai, S. Lurie, The effectiveness of postharvest hot water dipping on the control of grey and black moulds in sweet red pepper (*Capsicum annuum*), Plant Pathol. 45 (4) (1996) 644–649, https://doi.org/10.1046/j.1365-3059.1996.d01-175.x.
[59] R.N.U. Rehman, A.U. Malik, A.S. Khan, M.U. Hasan, R. Anwar, S. Ali, M.W. Haider, Combined application of hot water treatment and methyl salicylate mitigates chilling injury in sweet pepper (*Capsicum annuum L.*) fruits, Sci. Hortic. 283 (2021), 110113, https://doi.org/10.1016/j.scienta.2021.110113.
[60] J.G. López-Velázquez, F. Delgado-Vargas, G. López-Ángulo, E. García-Armenta, M.E. López-López, L.E. Ayón-Reyna, M.O. Vega-García, Phenolic profile associated with chilling tolerance induced by the application of a hot water treatment in bell pepper fruit, J. Food Sci. 85 (7) (2020) 2080–2089, https://doi.org/10.1111/1750-3841.15310.
[61] L.A. Gabriela, L.V.J. Gerardo, V.G.M. Odín, B.A.W. Denisse, D.V. Francisco, A.R.L. Elena, L.L.M. Edith, Antioxidant enzymatic changes in bell pepper fruit associated with chilling injury tolerance induced by hot water, J. Food Biochem. 45 (11) (2021) e13966, https://doi.org/10.1111/jfbc.13966.
[62] G.A. González-Aguilar, L. Gayosso, R. Cruz, J. Fortiz, R. Báez, C.Y. Wang, Polyamines induced by hot water treatments reduce chilling injury and decay in pepper fruit, Postharvest Biol. Technol. 18 (1) (2000) 19–26, https://doi.org/10.1016/S0925-5214(99)00054-X.
[63] G.A. González-Aguilar, R. Cruz, R. Baez, C.Y. Wang, Storage quality of bell peppers pretreated with hot water and polyethylene packaging, J. Food Qual. 22 (3) (1999) 287–299, https://doi.org/10.1111/j.1745-4557.1999.tb00558.x.
[64] E. Fallik, S. Grinberg, S. Alkalai, O. Yekutieli, A. Wiseblum, R. Regev, E. Bar-Lev, A unique rapid hot water treatment to improve storage quality of sweet pepper, Postharvest Biol. Technol. 15 (1) (1999) 25–32, https://doi.org/10.1016/S0925-5214(98)00066-0.
[65] S.C. Riva, U.O. Opara, O.A. Fawole, Recent developments on postharvest application of edible coatings on stone fruit: a review, Sci. Hortic. 262 (2020), 109074, https://doi.org/10.1016/j.scienta.2019.109074.
[66] P. Raghav, N. Agarwal, M. Saini, Edible coating of fruits and vegetables: a review, Education 1 (2016) 2455–5630.
[67] T. Bourtoom, Edible films and coatings: characteristics and properties, Int. Food Res. J. 15 (3) (2008) 237–248.
[68] E.A. Baldwin, M.O. Nisperos-Carriedo, R.A. Baker, Edible coatings for lightly processed fruits and vegetables, Hortscience 30 (1) (1995) 35–38.
[69] E.A. Baldwin, Edible coatings for fresh fruits and vegetables: past, present, and future, Edible coatings and films to improve food quality 1 (1994) 25.
[70] R. Porta, G. Rossi-Marquez, L. Mariniello, A. Sorrentino, C.V.L. Giosafatto, M. Esposito, P. Di Pierro, Edible coating as packaging strategy to extend the shelf-life of fresh-cut fruits and vegetables, J. Biotechnol. Biomater. 3 (4) (2013) 1.
[71] H.E. Salama, M.S.A. Aziz, Development of active edible coating of alginate and aloe vera enriched with frankincense oil for retarding the senescence of green capsicums, LWT 145 (2021) 111341, https://doi.org/10.1016/j.lwt.2021.111341.
[72] K. Gholamipour Fard, S. Kamari, M. Ghasemnezhad, R.F. Ghazvini, Effect of chitosan coating on weight loss and postharvest quality of green pepper (Capsicum annuum L.) Fruits, in: VI International Postharvest Symposium 877, 2009, pp. 821–826, https://doi.org/10.17660/ActaHortic.2010.877.109.
[73] N. Taa, R. MA, L. Akter, Effect of edible coating on postharvest quality of bell pepper at ambient storage, Bull. Inst. Trop. Agric. Kyushu Univ. 41 (2018) 73–83, https://doi.org/10.11189/bita.41.73.
[74] N. Kumar, A. Ojha, A. Upadhyay, R. Singh, S. Kumar, Effect of active chitosan-pullulan composite edible coating enrich with pomegranate peel extract on the storage quality of green bell pepper, LWT 138 (2021) 110435, https://doi.org/10.1016/j.lwt.2020.110435.
[75] S. Kumar, K.S. Thakur, K. Jyoti, Evaluation of different edible coatings for quality retention and shelf life extension of bell pepper (*Capsicum annuum L.*), Plant Archives 19 (2) (2019) 1056–1062.
[76] A. Ali, Y.Z. Wei, M.A. Mustafa, Exploiting propolis as an antimicrobial edible coating to control post-harvest anthracnose of bell pepper, Packag. Technol. Sci. 28 (2) (2015) 173–179, https://doi.org/10.1002/pts.2088.
[77] Z.N. Correa-Pacheco, M.L. Corona-Rangel, S. Bautista-Baños, R.I. Ventura-Aguilar, Application of natural-based nanocoatings for extending the shelf life of green bell pepper fruit, J. Food Sci. 86 (1) (2021) 95–102, https://doi.org/10.1111/1750-3841.15542.
[78] J.G. Uresti-Porras, M. Cabrera-De-La Fuente, A. Benavides-Mendoza, E. Olivares-Sáenz, R.I. Cabrera, A. Juárez-Maldonado, Effect of graft and nano ZnO on nutraceutical and mineral content in bell pepper, Plants 10 (12) (2021) 2793, https://doi.org/10.3390/plants10122793.
[79] X. Hu, K. Saravanakumar, A. Sathiyaseelan, M.H. Wang, Chitosan nanoparticles as edible surface coating agent to preserve the fresh-cut bell pepper (*Capsicum annuum L.* var. grossum (L.) Sendt), Int. J. Biol. Macromol. 165 (2020) 948–957, https://doi.org/10.1016/j.ijbiomac.2020.09.176.
[80] G. Hernández-López, R.I. Ventura-Aguilar, Z.N. Correa-Pacheco, S. Bautista-Baños, L.L. Barrera-Necha, Nanostructured chitosan edible coating loaded with α-pinene for the preservation of the postharvest quality of *Capsicum annuum L.* and *Alternaria alternata* control, Int. J. Biol. Macromol. 165 (2020) 1881–1888, https://doi.org/10.1016/j.ijbiomac.2020.10.094.
[81] I. Batool, I. Hassan, S.Z.U. Hasan, T. Rafique, A. Saleem, T. Hussain, I. Ali, Qualitative and quantitative traits of sweet pepper as influenced by copper nanoparticles, Plant Cell Biotechnol. Mol. Biol. (2022) 31–40.
[82] A. Sathiyaseelan, K. Saravanakumar, A.V.A. Mariadoss, C. Ramachandran, X. Hu, D.H. Oh, M.H. Wang, Chitosan-tea tree oil nanoemulsion and calcium chloride tailored edible coating increase the shelf life of fresh cut red bell pepper, Prog. Org. Coating 151 (2021) 106010, https://doi.org/10.1016/j.porgcoat.2020.106010.
[83] N.D.L. Petito, J.M. Devens, D.Q. Falcão, F.M.L. Dantas, T.S. Passos, K.G.D.L. Araujo, Nanoencapsulation of red bell pepper carotenoids: comparison of encapsulating agents in an emulsion based system, Colorants 1 (2) (2022) 132–148, https://doi.org/10.3390/colorants1020009.
[84] S. Horvitz, M.J. Cantalejo, Application of ozone for the postharvest treatment of fruits and vegetables, Crit. Rev. Food Sci. Nutr. 54 (3) (2014) 312–339, https://doi.org/10.1080/10408398.2011.584353.
[85] S. Shezi, L.S. Magwaza, A. Mditshwa, S.Z. Tesfay, Changes in biochemistry of fresh produce in response to ozone postharvest treatment, Sci. Hortic. 269 (2020), 109397, https://doi.org/10.1016/j.scienta.2020.109397.
[86] R. Botondi, F. De Sanctis, N. Moscatelli, A.M. Vettraino, C. Catelli, F. Mencarelli, Ozone fumigation for safety and quality of wine grapes in postharvest dehydration, Food Chem. 188 (2015) 641–647, https://doi.org/10.1016/j.foodchem.2015.05.029.
[87] E.M.C. Alexandre, D.M. Santos-Pedro, T.R.S. Brandao, C.L.M. Silva, Influence of aqueous ozone, blanching and combined treatments on microbial load of red bell peppers, strawberries and watercress, J. Food Eng. 105 (2011) 277–282, https://doi.org/10.1016/j.jfoodeng.2011.02.032.
[88] L. Ketteringham, R. Gausseres, S.J. James, C. James, Application of aqueous ozone for treating pre-cut green peppers (*Capsicum annuum L.*), J. Food Eng. 76 (2006) 104–111, https://doi.org/10.1016/j.jfoodeng.2005.05.019.
[89] A. Alexopoulos, S. Plessas, S. Ceciu, V. Lazar, I. Mantzourani, C. Voidarou, E. Stavropoulou, E. Bezirtzoglou, Evaluation of ozone efficacy on the reduction of microbial population of fresh cut lettuce (Lactuca sativa) and green bell pepper (*Capsicum annuum*), Food Control 30 (2013) 491–496, https://doi.org/10.1016/j.foodcont.2012.09.018.
[90] M. Glowacz, R. Colgan, D. Rees, Influence of continuous exposure to gaseous ozone on the quality of red bell peppers, cucumbers and zucchini, Postharvest Biol. Technol. 99 (2015) 1–8, https://doi.org/10.1016/j.postharvbio.2014.06.015.
[91] S. Horvitz, M.J. Cantalejo, Effects of ozone and chlorine postharvest treatments on quality of fresh cut red bell peppers, Int. J. Food Sci. Technol. 47 (2012) 1935–1943, https://doi.org/10.1111/j.1365-2621.2012.03053.x.
[92] S. Horvitz, M.J. Cantalejo, Effects of aqueous ozone on quality of minimally processed red bell pepper, Acta Hortic. 858 (2010) 329–333, https://doi.org/10.17660/ActaHortic.2010.858.50.

[93] T. Özen, M.A. Koyuncu, D. Erbaş, Effect of ozone treatments on the removal of pesticide residues and postharvest quality in green pepper, J. Food Sci. Technol. 58 (6) (2021) 2186–2196, https://doi.org/10.1007/s13197-020-04729-3.
[94] P.J. Cullen, B.K. Tiwari, C.P. O'Donnell, K. Muthukumarappan, Modelling approaches to ozone processing of liquid foods, Trends Food Sci. Technol. 20 (3–4) (2009) 125–136, https://doi.org/10.1016/j.tifs.2009.01.049.
[95] J.G. Kim, A.E. Yousef, S. Dave, Application of ozone for enhancing the microbiological safety and quality of foods: a review, J. Food Protect. 62 (9) (1999) 1071–1087, https://doi.org/10.4315/0362-028X-62.9.1071.
[96] L. Carletti, R. Botondi, R. Moscetti, E. Stella, D. Monarca, M. Cecchini, R. Massantini, Use of ozone in sanitation and storage of fresh fruits and vegetables, J. Food Agric. Environ. 11 (3–4) (2013) 585–589.
[97] A.A.Z. Rodrigues, M.E.L.R. de Queiroz, L.R.D.A. Faroni, L.H.F. Prates, A.A. Neves, A.F. de Oliveira, L. Zambolim, The efficacy of washing strategies in the elimination of fungicide residues and the alterations on the quality of bell peppers, Food Res. Int. 147 (2021), 110579, https://doi.org/10.1016/j.foodres.2021.110579.
[98] V. Ummat, A.K. Singh, G.K. Sidhu, Effect of aqueous ozone on quality and shelf life of shredded green bell pepper (*Capsicum annuum*), J. Food Process. Preserv. 42 (10) (2018), https://doi.org/10.1111/jfpp.13718.
[99] N.A. Alwi, A. Ali, Dose-dependent effect of ozone fumigation on physiological characteristics, ascorbic acid content and disease development on bell pepper (*Capsicum annuum L.*) during storage, Food Bioprocess Technol. 8 (3) (2015) 558–566, https://doi.org/10.1007/s11947-014-1419-2.
[100] P. Adhikari, N. Paneru, K. Thapa, A. Dhakal, Effects of perforation mediated-modified atmospheric packaging (MAP) on shelf life and quality of calcium chloride treated bell pepper (*Capsicum annuum*), Asian J. Dairy Food Res. 39 (4) (2020) 354–358, https://doi.org/10.18805/ajdfr.DR-200.
[101] L. Leistner, G.W. Gould, Hurdle Technology: Combination Treatments for Food Stability, Safety and Quality, Kluwer Academic, New York, 2002.
[102] F. Devlieghere, M.I. Gil, J. Debevere, Modified atmosphere packaging (MAP), in: The Nutrition Handbook for Food Processors, 2002, pp. 342–370.
[103] H.P. Lwin, J. Lee, J. Lee, Perforated modified atmosphere packaging differentially affects the fruit quality attributes and targeted major metabolites in bell pepper cultivars stored at ambient temperature, Sci. Hortic. 301 (2022), 111131, https://doi.org/10.1016/j.scienta.2022.111131.
[104] C. Barbosa, T.B. Machado, M.R. Alves, M.B.P. Oliveira, Fresh-cut bell peppers in modified atmosphere packaging: improving shelf life to answer food security concerns, Molecules 25 (10) (2020) 2323, https://doi.org/10.3390/molecules25102323.
[105] I. Cerit, O. Demirkol, Effects of modified atmosphere packaging conditions and ethylene absorber on the quality of red bell pepper, J. Food Nutr. Res. 59 (1) (2020).
[106] K. Devgan, P. Kaur, N. Kumar, A. Kaur, Active modified atmosphere packaging of yellow bell pepper for retention of physico-chemical quality attributes, J. Food Sci. Technol. 56 (2) (2019) 878–888, https://doi.org/10.1007/s13197-018-3548-5.
[107] G.A. González-Aguilar, J.F. Ayala-Zavala, S. Ruiz-Cruz, E. Acedo-Félix, M.E. Dıaz-Cinco, Effect of temperature and modified atmosphere packaging on overall quality of fresh-cut bell peppers, LWT–Food Sci. Technol. 37 (8) (2004) 817–826, https://doi.org/10.1016/j.lwt.2004.03.007.
[108] L.A. Terry, D.C. Joyce, Elicitors of induced disease resistance in postharvest horticultural crops: a brief review, Postharvest Biol. Technol. 32 (1) (2004) 1–13, https://doi.org/10.1016/j.postharvbio.2003.09.016.
[109] L. Garcia-Mier, S.N. Jimenez-Garcia, R.G. Guevara-González, A.A. Feregrino-Perez, L.M. Contreras-Medina, I. Torres-Pacheco, Elicitor mixtures significantly increase bioactive compounds, antioxidant activity, and quality parameters in sweet bell pepper, J. Chem. 2015 (2015), https://doi.org/10.1155/2015/269296.
[110] S.N. Jimenez-Garcia, M.A. Vázquez-Cruz, R. Miranda-Lopez, L. Garcia-Mier, R.G. Guevara-González, A.A. Feregrino-Perez, Effect of elicitors as stimulating substances on sensory quality traits in color sweet bell pepper (*Capsicum annuum L.* cv. Fascinato and Orangela) grown under greenhouse conditions, Pol. J. Food Nutr. Sci. 68 (4) (2018).
[111] Cock, M.J A.E. Hajek, B.P. Hurley, M. Kenis, J.R. Garnas, S.J. Bush, M.J. Wingfield, Exotic biological control agents: a solution or contribution to arthropod invasions?, Biol. Invasions 18 (2016) 953–969, https://doi.org/10.1007/s10530-016-1075-8.
[112] M. Luo, H. Purdy, T.J. Avis, Compost bacteria provide antifungal activity against grey mold and *Alternaria* rot on bell pepper fruit, Botany 97 (3) (2019) 221–230, https://doi.org/10.1139/cjb-2018-0180.
[113] I. Vagelas, A. Papachatzis, H. Kalorizou, E. Wogiatzi, Biological control of *Botrytis* fruit rot (gray mold) on strawberry and red pepper fruits by olive oil mill wastewater, Biotechnol. Biotechnol. Equip. 23 (4) (2009) 1489–1491, https://doi.org/10.2478/V10133-009-0017-3.
[114] B. Bhusal, M.T. Mmbaga, Biological control of Phytophthora blight and growth promotion in sweet pepper by Bacillus species, Biol. Control 150 (2020) 104373, https://doi.org/10.1016/j.biocontrol.2020.104373.
[115] B. Yousuf, S. Wu, M.W. Siddiqui, Incorporating essential oils or compounds derived thereof into edible coatings: effect on quality and shelf life of fresh/fresh-cut produce, Trends Food Sci. Technol. 108 (2021) 245–257, https://doi.org/10.1016/j.tifs.2021.01.016.
[116] M. Sapper, A. Chiralt, Starch-based coatings for preservation of fruits and vegetables, Coatings 8 (5) (2018) 152, https://doi.org/10.3390/coatings8050152.
[117] E. Fallik, S. Grinberg, Hinokitiol: a natural substance that controls postharvest diseases in eggplant and pepper fruits, Postharvest Biol. Technol. 2 (2) (1992) 137–144, https://doi.org/10.1016/0925-5214(92)90016-I.
[118] N. Tzortzakis, A. Chrysargyris, D. Sivakumar, K. Loulakakis, Vapour or dipping applications of methyl jasmonate, vinegar and sage oil for pepper fruit sanitation towards grey mould, Postharvest Biol. Technol. 118 (2016) 120–127, https://doi.org/10.1016/j.postharvbio.2016.04.004.
[119] E.M. Mekawi, E.Y. Khafagi, F.A. Abdel-Rahman, Effect of pre-harvest application with some organic acids and plant oils on antioxidant properties and resistance to *Botrytis cinerea* in pepper fruits, Sci. Hortic. 257 (2019), 108736, https://doi.org/10.1016/j.scienta.2019.108736.
[120] S. Mohamed, N. T, P. Ding, J. Kadir, M. Ghazali H, Potential of UVC germicidal irradiation in suppressing crown rot disease, retaining postharvest quality and antioxidant capacity of Musa AAA "Berangan" during fruit ripening, Food Sci. Nutr. 5 (5) (2017) 967–980, https://doi.org/10.1002/fsn3.482.
[121] S. Promyou, S. Supapvanich, Effect of ultraviolet-C (UV-C) illumination on postharvest quality and bioactive compounds in yellow bell pepper fruit (*Capsicum annuum L.*) during storage, Afr. J. Agric. Res. 7 (28) (2012) 4084–4096, https://doi.org/10.5897/AJAR12.242.
[122] N. Castillejo, L. Martínez-Zamora, F. Artés-Hernández, Postharvest UV radiation enhanced biosynthesis of flavonoids and carotenes in bell peppers, Postharvest Biol. Technol. 184 (2022), 111774, https://doi.org/10.1016/j.postharvbio.2021.111774.
[123] A.R. Vicente, C. Pineda, L. Lemoine, P.M. Civello, G.A. Martinez, A.R. Chaves, UV-C treatments reduce decay, retain quality and alleviate chilling injury in pepper, Postharvest Biol. Technol. 35 (1) (2005) 69–78, https://doi.org/10.1016/j.postharvbio.2004.06.001.
[124] C. Liu, L. Cai, X. Han, T. Ying, Temporary effect of postharvest UV-C irradiation on gene expression profile in tomato fruit, Gene 486 (1–2) (2011) 56–64, https://doi.org/10.1016/j.gene.2011.07.001.
[125] L. Martínez-Zamora, N. Castillejo, F. Artés-Hernández, Postharvest UV-B and photoperiod with blue+ red LEDs as strategies to stimulate carotenogenesis in bell peppers, Appl. Sci. 11 (9) (2021) 3736, https://doi.org/10.3390/app11093736.
[126] N.A. Abbasi, S. Ashraf, I. Ali, S.J. Butt, Enhancing storage life of bell pepper by UV-C irradiation and edible coatings, Pakistan J. Agric. Sci. 52 (2) (2015).
[127] L. Alfaro, R. Soler-Segura, C. Jacquin, M. Juan, M.A. Elorrieta, J.L. Valenzuela, Yellow bell pepper fruit response to postharvest application of ultraviolet radiation, in: VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits-Ethical and Technological Issues 1194, 2016, pp. 815–822, https://doi.org/10.17660/ActaHortic.2018.1194.115.
[128] I.K. Yildirim, M. Pekmezci, Postharvest ultraviolet-C (UV-C) treatment reduces decay and maintains quality of bell peppers, Akademik Ziraat Dergisi 6 (2) (2017) 89–94, https://doi.org/10.29278/azd.371065.
[129] S. González-Casado, O. Martín-Belloso, P. Elez-Martínez, R. Soliva-Fortuny, Enhancing the carotenoid content of tomato fruit with pulsed electric field treatments: effects on respiratory activity and quality attributes, Postharvest Biol. Technol. 137 (2018) 113–118, https://doi.org/10.1016/j.postharvbio.2017.11.017.
[130] S. Toepfl, C. Siemer, G. Saldaña-Navarro, V. Heinz, Overview of pulsed electric fields processing for food, in: Emerging Technologies for Food Processing, 2014, pp. 93–114, https://doi.org/10.1016/B978-0-12-411479-1.00006-1. Academic Press.
[131] R. Soliva-Fortuny, M. Vendrell-Pacheco, O. Martín-Belloso, P. Elez-Martínez, Effect of pulsed electric fields on the antioxidant potential of apples stored at different temperatures, Postharvest Biol. Technol. 132 (2017) 195–201, https://doi.org/10.1016/j.postharvbio.2017.03.015.

[132] A. Wiktor, M. Nowacka, M. Dadan, K. Rybak, W. Lojkowski, T. Chudoba, D. Witrowa-Rajchert, The effect of pulsed electric field on drying kinetics, color, and microstructure of carrot, Dry. Technol. 34 (11) (2016) 1286–1296, https://doi.org/10.1080/07373937.2015.1105813.

[133] K. Rybak, A. Wiktor, D. Witrowa-Rajchert, O. Parniakov, M. Nowacka, The effect of traditional and non-thermal treatments on the bioactive compounds and sugars content of red bell pepper, Molecules 25 (18) (2020) 4287, https://doi.org/10.3390/molecules25184287.

[134] K. Rybak, A. Wiktor, D. Witrowa-Rajchert, O. Parniakov, M. Nowacka, The quality of red bell pepper subjected to freeze-drying preceded by traditional and novel pretreatment, Foods 10 (2) (2021) 226, https://doi.org/10.3390/foods10020226.

[135] B. Gómez, P.E. Munekata, M. Gavahian, F.J. Barba, F.J. Martí-Quijal, T. Bolumar, J.M. Lorenzo, Application of pulsed electric fields in meat and fish processing industries: an overview, Food Res. Int. 123 (2019) 95–105, https://doi.org/10.1016/j.foodres.2019.04.047.

[136] F. Babellahi, J. Paliwal, C. Erkinbaev, M.L. Amodio, M.M.A. Chaudhry, G. Colelli, Early detection of chilling injury in green bell peppers by hyperspectral imaging and chemometrics, Postharvest Biol. Technol. 162 (2020), 111100, https://doi.org/10.1016/j.postharvbio.2019.111100.

[137] E. Ropelewska, K. Sabanci, M.F. Aslan, The changes in bell pepper flesh as a result of lacto-fermentation evaluated using image features and machine learning, Foods 11 (19) (2022) 2956, https://doi.org/10.3390/foods11192956.

[138] K. Mohi-Alden, M. Omid, M.S. Firouz, A. Nasiri, A machine vision-intelligent modelling based technique for in-line bell pepper sorting, Info. Proc. Agri. (2022), https://doi.org/10.1016/j.inpa.2022.05.003.

[139] K. Mohi-Alden, M. Omid, M. Soltani Firouz, A. Nasiri, Design and evaluation of an intelligent sorting system for bell pepper using deep convolutional neural networks, J. Food Sci. 87 (1) (2022) 289–301, https://doi.org/10.1111/1750-3841.15995.

[140] B. Harel, Y. Parmet, Y. Edan, Maturity classification of sweet peppers using image datasets acquired in different times, Comput. Ind. 121 (2020), 103274, https://doi.org/10.1016/j.compind.2020.103274.