Food Research 8 (2) : 322 - 332 (April 2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

MINI REVIEW

Recent advances for postharvest protection and preservation of mango fruit: a review

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Article history:
Received: 21 March 2022
Received in revised form: 24 April 2022
Accepted: 7 October 2022
Available Online: 6 April 2024

Keywords:
Tropical fruit,
Customer acceptability,
Fruit damage,
Postharvest handle,
Fruit commercialization

DOI:
https://doi.org/10.26656/fr.2017.8(2).105

Abstract

Mango fruit is one of the most important cultivars in the world. In postharvest handling, mango fruit can be affected by pathogens. Some of the phytopathogens that severely attack mango fruit are the fungal *Colletotrichum*, *Aspergillus*, *Alternaria* and *Botrytis*. The presence of these pathogens can generate postharvest losses between 5-30% of mango production. Fungicides are used to control these microorganisms. To reduce and eradicate its use in post-harvest, methods that are not harmful to the consumer have been developed and are classified into chemical, physical and biological methods. The selection of a postharvest method depends on its ability to adapt to an established process and its ability to extend its shelf life. Different post-harvest methods have been applied to mango fruit, including cold storage, hydrothermal treatment, UV, edible coatings and 1-MCP. The result with the application of these methods has been efficient but increases with the application of synergies between different postharvest methods. This review presents a compilation and recent advances of the different postharvest control methods that have been applied individually or in synergy in mango fruits to control and/or prevent the attack of pathogens and preserve the quality parameters to extend the shelf life of the fruit.

1. Introduction

Internationally, the mango fruit stands out among other fruits for its exquisite sweet flavor, its production in the last 10 years has been increasing due to its high demand (Statistica, 2021). This is a crop that, once harvested, accelerates its ripening by increasing its respiration rate and ethylene production. This causes rapid deterioration of the fruit, with the presence and incidence of phytopathogenic agents, mainly *Colletotrichum*, *Aspergillus*, *Alternaria* and *Botrytis* (Zakawa *et al*., 2020). During the post-harvest period of mango, different physical, chemical and biological methods are used to inhibit or reduce the presence of fungal agents, as well as a combination of these different methods. Therefore, the objective of this review is to collect relevant information on the different postharvest control methods that have been applied individually or in synergy in mango fruits to control and/or prevent the attack of pathogens and preserve the quality parameters to extend the shelf life of the fruit.

2. Mango production and marketing

Mango is a tropical fruit appreciable for its fresh and sweet flavor (Zakawa *et al.,* 2020). The mango fruit is produced around the world, specifically in countries with a tropical climate. The global production volume of mangos in 2019 was 55.85 million metric tons, which represented an increase of 37.0% in the last 10 years. The principal, producing countries in the world include India, China, Thailand, Indonesia, Pakistan and Mexico. Specifically, India leading as the principal producer supplying more than 50.0% of mango fruit in the world (Statistica, 2021). About the exportation of this tropical fruit, in 2020 the principal mango exporters were Thailand, Mexico and Peru. The flow of commercialization is different for each country, Thailand exported 18.91% to China and Hong Kong, Mexico exported 11.8% to the United States of America and Canada, while Peru exported to Spain, Germany and the Netherlands. In this sense, the potential consumers of mango around the world are China (25.0%), the United States of America (19.5%) and the Netherlands (10.2%) (Tridge, 2021).

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

3. Postharvest losses and mango diseases

Mango is a climacteric fruit that after harvest increases its respiration rate and ethylene production, promoting the development of the fruit's characteristics such as color, flavor and texture. The accelerated development of these parameters reduces the fruit quality at storage and generated postharvest losses by phytopathogenic fungi. These microorganisms are the cause of different postharvest diseases such as anthracnose and stem-end rot that generate damage to the fruit tissue. The phytopathogenic that attack mango fruit has been identified are the genus *Alternaria* (Luria *et al.*, 2014), *Aspergillus, Botrytis* (Zakawa *et al.*, 2020), *Colletotrichum* (Xu *et al.*, 2017), *Fusarium* (Kausar *et al.*, 2021) and *Lasiodiplodia* (Montecalvo *et al.*, 2019).

Colletotrichum species have been identified as the causal agent of anthracnose on mango fruit. It has been reported as one of the most aggressive pathogens that attack the different varieties of mango fruit from Indonesia (Benatar *et al.*, 2021), Australia (Giblin *et al.*, 2018), China (Mo *et al.*, 2018), México (Tovar-Pedraza *et al.*, 2019), Philippines (Dela Cueva *et al.*, 2021) and Egypt (Ismail and El-Ganainy, 2022). *Colletotrichum* could be in a latent phase during preharvest, the beginning of the disease symptoms appears on the postharvest, generating dark spots and tissue putrefaction. The different *Colletotrichum* species associated to anthracnose include *Colletotrichum siamense*, *C. tropicale, C. asiaunum* (Tovar-Pedraza *et al.*, 2019), *C. scovillei* (Wu *et al.*, 2020), *C. plurivorum* (Lu *et al.*, 2022), *C. theobromicola* (Dela Cueva *et al.*, 2021) and *C. gloeosporioides* (Uddin *et al.*, 2018). It is estimated that 30% of postharvest losses in mango fruit are caused by the infection of *Colletotrichum*.

The pathogen *Alternaria alternata* develops the postharvest disease called stem-end rot in mango fruit (Galsurker *et al.,* 2020). This disease is characterized by the development of circular depressions, and subsequent black spots. The incidence of these pathogens has been reported in countries such as China (Li *et al.*, 2018), Israel (Galsurker *et al.*, 2020) and Egypt (Ammar *et al.*, 2022). The *Aspergillus* species *flavus*, *fumigatus* and *niger*, cause postharvest losses of up to 10%. Its incidence can be present after 4 days of storage, with the development of mycelial growth and rotting on the fruit surface.

Other phytopathogens have been identified in mangoes such as *Lasiodiplodia theobromae, Penicillum chrysoenum* and *Rhizopus stolonifera* (Rajmane and Korekar, 2016). The high incidence of postharvest diseases on mango fruit demands the search for postharvest technologies to decrease the negative effects of these phytopathogens and consequently prolong the shelf life of the fruits (Gutiérrez-Martínez *et al.,* 2014).

4. Postharvest disease control methods

Postharvest attack by pathogens causes serious damage and loss of fruit. Fungicides have been the most widely used postharvest method in the world to control diseases in crops. These chemicals are considered toxic to the consumer and the environment (Mamane *et al.,* 2015). Different alternatives have been developed to replace them and have been classified as physical, chemical and biological. This review presents a recompilation of the recent postharvest control methods applied individually and in synergy to mango fruit to extend shelf life, preserve quality parameters and reduce pathogen infection.

5. Chemical control methods

5.1 1-Methylcyclopropane

The application of 1-methylcyclopropane (1-MCP) in mango fruits has been used as a ripening suppressant. This compound is an analog of the phytohormone ethylene and acts as a receptor blocker, increasing the shelf life of fruits (Ortiz-Franco *et al.,* 2016). Ethylene synthesis promotes the accelerated softening of the fruits by the synthesis of cell wall degrading enzymes. Pectinesterase (PE) and polygalacturonase (PG) are the enzymes responsible for this effect. Li, Li, Sun *et al.* (2020) reported that the postharvest application of 1-MCP in mango fruits cv. "Tainong" delay the ethylene synthesis and respiration reducing the synthesis of cell wall enzymes and fruit softening after 10 d of storage. In a similar study by these authors, treatment with 1-MCP delayed ethylene synthesis and respiration in mango fruits for 16 days stored at 25°C. To understand the mechanism of action of 1-MCP to control ethylene biosynthesis, molecular identification of the ETR family was realized. Molecular analysis indicated that 1-MCP suppressed the ethylene receptor genes, MiETR1 and MiERS1, part of the ETR receptor family. This suppression delays ethylene biosynthesis and prolongs fruit shelf life (Li, Shuai, Sun *et al.,* 2020).

For the control of pathogens, Osuna-García *et al.* (2007) reported that the application of 1-MCP in "Keitt" mango fruits failed to control the symptoms of anthracnose, concluding that 1-MCP does not have antifungal action. Xu *et al.* (2017) evaluated the antifungal effect of the application of 1-MCP, the results indicated an accumulation of Reactive Oxygen Species "ROS" and mitochondrial degradation in the mycelium and spores of the fungus *C. gloeosporioides* and consequently inhibition of germination and growth of the pathogen.

https://doi.org/10.26656/fr.2017.8(2).105

5.2 Nitric oxide

Nitric oxide (NO) is a signaling molecule in plants with physiological functions. Postharvest is applied as an exogenous agent to the control of pathogens (Kang *et al.,* 2016). This effect was confirmed by Hu *et al.* (2014), these authors reported a 30.0% reduction of anthracnose in mango fruits with exposure to NO. Also, the application of NO induced the synthesis of defence enzymes such as phenylalanine ammonia-lyase (PAL), chitinase (CHI), b-1,3-glucanase (GLU), and polyphenol oxidase (PPO). Later, Ren *et al.* (2020) reported NO generates the accumulation of antifungal compounds such as lignin, total phenols, anthocyanin, and flavonoids that protect the fruits. To understand the effect of exogenous NO application, peach fruit were analyzed and identified differentially accumulated proteins using a transcriptome analysis. The results showed an increase in the abundance of proteins involved in energy and metabolism (30.7%), the response to stress and defence (25.0%), and ripening and senescence (5.7%). In this sense, these increases in protein abundance indicate that NO could protect the fruit in stressful situations such as the attack of pathogens (Kang *et al.,* 2016).

6. Physical control methods

6.1 Cold storage

Storage at low temperatures is a postharvest method used for the preservation of fruits (Brizzolara *et al.,* 2020). Tropical or subtropical fruits are cold-sensitive, on mango fruit the optimum storage temperature is between 10 and 12.5°C. Low-temperature storage is a postharvest method used for the conservation of fruits (Brizzolara *et al.,* 2020). Tropical or subtropical fruits are sensitive to cold, the optimal storage temperature in mango fruit ranges between 10 and 12.5°C (Osuna-García, 2015). Pathogen infection can be prevented and controlled with the application of cold storage. For *C. gloeosporioides*, the optimal temperature for growth and sporulation is between 25-30°C. Sangeetha and Rawal (2009) reduced the mango storage temperature to 15°C and the results showed complete inhibition of the pathogen. "Shally" mango fruits are reported to be a variety resistant to storage at low temperatures (5-12°C) and anthracnose infection was minimal. On the other hand, the "Keitt" mango was sensitive to exposure to cold storage (5°C) and showed symptoms of chilling injury. After two days of cold storage, the transcriptomic analysis revealed an increase in gene expression involved in the plant's stress response. This effect was related to the presence of cell death around the discolored lenticels in the mango fruit peel. At the end of storage, the fruits showed cuticular opening and consequently decomposition possibly due to fungal penetration (Sivankalyani *et al.,* 2016).

6.2 Hot water treatment

Hot water treatment (HWT) is a postharvest requirement for the export of mango fruit to the United States of America. HWT has been efficient in controlling pests and pathogens, reducing cold injuries, and extending fruit quality during storage (Lurie and Pedreschi, 2014). In mango cv. "Carabao" HWT (53°C, 20 mins) inhibited anthracnose by 49-53% and stem-end rot (SER) by 48-61% (Alvindia and Acda, 2015). An increase in temperature to 55°C and immersion for 10 min, controlled 70.0% of SER, concerning untreated fruits (Montecalvo *et al.,* 2019). For the pathogen *Alternaria alternata,* Luria *et al.* (2014) reported a decrease in incidence between 60-80% with the application of HWT in different mango varieties. In "Shelly" mango fruits, the application of HWT extended shelf life up to 4 weeks in cold storage. A proteomic profile revealed that hydrothermal treatment increases the expression of genes that contribute to the preservation of its quality and control of damage by pathogens. RNA-seq analysis was used for the identification and characterization of the expressed genes. The expressed genes were classified into three groups associated with a response to HWT. The expressed genes were found to the associated with pathogen defense mechanisms, chlorophyll degradation, photosynthesis, cell defense and regulation, and flavonoid metabolism (Luria *et al.,* 2014).

6.3 Ultraviolet radiation

Ultraviolet (UV) radiation is widely used on fruits as a postharvest disinfectant method. Different studies have confirmed that the application of UV can stimulate the defense mechanism of the fruit, acting as an elicitor in the synthesis of enzymes and bioactive compounds. Srepong *et al.* (2013) confirmed this effect in mango fruits, where UV radiation decreased the attack of *C. gloeosporioides*. This postharvest alternative induced the synthesis of pathogenic enzymes, including PAL, CHI, GLU and peroxidase (POD). Antifungal compounds such as phenolic compounds increased as an elicitor effect in the mango peel. For the control of *Botryosphaeria dothidea*, the application of UV (2.5 kJ/m^2) controlled 36.4% of the microorganism. The UV irradiation of the "Chokanan" mango increased by 45.0% the expression of the proteins involved in the stress and defence mechanism of the fruit. As a consequence of irradiation, the fruits were able to extend their shelf life by 15 days (George *et al.,* 2016). The UV method is applied in the previous stage of fruit storage to keep the presence of pathogens under control. After this, efficient postharvest practices are required to preserve the quality

https://doi.org/10.26656/fr.2017.8(2).105

of the fruit and be free of pathogens until it reaches the consumer.

6.4 Active modified atmospheres

The active atmosphere consists of modifying the gas concentration in a packaged product, with the reduction of O_2 gas or its replacement by some other gas such as Nitrogen (N_2) or Argon (Ar) (Kargwal *et al.,* 2020). For Keitt mango fruits, the author Hailu (2016) reported an extension of the shelf life, for more than 6 weeks when the fruits are packed in an airtight plastic bag. The conditions used were storage at 7°C and atmospheric conditions in the packaging of 10% CO_2 + 6% O_2 + 84% N_2. Ntsoane *et al.* (2020) evaluated the optimal gas compositions for storage of 'Shelly' mango fruit, and the best conditions to preserve the quality were 5-8% O_2, 5-9% CO_2, and 86-91% N_2 stored at 13°C for 4 weeks. The increase in the concentration of CO_2 is not favorable for the development of pathogens, this affects enzymatic and biochemical processes that cause stress and generates a reduction in the development of these microorganisms.

6.5 Passive modified atmospheres

The application of the edible coating on fruits reduces gas exchange between the environment and the fruit. The physical barrier of the edible coating reduces the respiratory rate and the production of ethylene, promoting extending the shelf life of fruit (Mshora *et al.,* 2021). The major materials used in edible coatings are polysaccharides as gums, starches, chitosan, and pectin considered natural and viable compounds for their commercial use (Abd El-gawad *et al.,* 2019; Shah and Hashmi, 2020; Hmmam *et al.,* 2021). Specifically, in mango fruit, different edible coatings have been applied to preserve quality parameters and control diseases (Table 1). Edible coatings are currently used as an encapsulation matrix for the incorporation of compounds with biological activity, this generates a synergistic effect that can increase the preservation of quality parameters and the control of diseases (Suryadi *et al.,* 2020; Ochoa-Velasco *et al.,* 2021).

7. Biological control method

7.1 Antagonists

The antagonists are biological agents that can be applied pre- and post-harvest. Antagonists include yeast and bacteria with the capacity to compete for nutrients and space and promote the synthesis of antifungal compounds that attack the infectious pathogen (Aguirre-Güitrón *et al.,* 2019; Konsue *et al.,* 2020). Yeasts such as *Meyerozyma caribbica* and *Torulaspora indica* have been applied to control of anthracnose incidence in mango fruit. Aguirre-Güitrón *et al.* (2019) and Konsue *et al.* (2020) reported a range of control above 40.0% with the applications of these yeasts. Bacteria *B. subtilis* and *P. fluorescens* reduced anthracnose between 42.0% and 43.0% after 10 days of storage. A similar effect was reported with the application of the marine bacterium *Stenotrophomonas rhizophila* (Reyes-Perez *et al.,* 2019). *In vivo* application of *Bacillus siamensis* treatment on mango fruit reduced the anthracnose index after 9 d of storage. RNA-seq analysis indicates an increase in disease-resistance genes influenced by *B. siamensis* treatment (Jiang *et al.,* 2022). Antagonists are bioagents that are not considered hazardous to human health and the environment; however, different abiotic factors can interfere with their effectiveness in postharvest control.

7.2 Extracts and essential oils

Essential oils (EOs) are secondary metabolites produced by plants that have shown antifungal activity against pathogens, including those that attack mango fruit (Mesa *et al.,* 2019). Thymol essential oil applied to mango fruits in concentrations of 0.075% and 0.1% completely controlled the development of *C.*

Table 1. Edible coatings applied to mango fruit to control postharvest diseases.

Edible coating formulation	Fruit Variety	References
Chitosan (1%)	Nam Dok Mai	Jongsri *et al.* (2017)
Pectin / ChiNP (2%)	Elephant	Ngo *et al.* (2021)
Chitosan / *Aloe vera* (1%)	White Chaunsa	Shah *et al.* (2020)
ChiNP/Piper betle leaf extract (3:1 v/v)	Manalagi	Suryadi *et al.* (2020)
Nano-Silica (1%) / Chitosan (2%)	Tommy Atkins	Kassem *et al.* (2022)
Arabic gum (10%) / chitosan (1%)	Arumanis	Handojo *et al.* (2022)
High amylose corn/ carvacrol (1125 mg/L) / thymol (375 mg/L)	Ataulfo	Ochoa-Velasco *et al.* (2021)
Corn starch/ tobacco extract (10%)	Harumanis	Amilia *et al.* (2020)
Beeswax (1:3 w/v) / basil oil (600 µL/L)	Willard	Kargwal *et al.* (2020)
HPMC / Beewax (40%)	Palmer	Silva *et al.* (2021)
HPMC / Beewax (4:1)	Namdokmai Sithong	Klangmuang and Sothornvit, (2018)
Sodium alginate (2%)	Langra	Ehteshami *et al.* (2022)

ChiNP: Chitosan nanoparticles, HPMC: hydroxypropyl methylcellulose

https://doi.org/10.26656/fr.2017.8(2).105

gloeosporioides (Chillet *et al.,* 2020). The same effect was reported by Kalupahana *et al.* (2020) with the application of AE of *Cinnamomum zeylanicum* (Cinnamon) and *Syzygium aromaticum* (Clove). Kaffir lime essential oil (immature) at 1500 ppm was reduced above 60.0% anthracnose and, based on chromatographic analysis, the major compounds in the extract were beta-pinene, limonene and beta-citronellol (Chit-aree *et al.,* 2021). To control *A. niger* in mangoes, the application of 500 µL/L of *R. officinalis* reduced the incidence of *A. niger* by 82.0% compared to the untreated control (Javadpour *et al.,* 2018). *Moringa oleifera* leaf extracts were used to control *Botrytis cinerea* and *A. flavus* phytopathogens present in mango fruit, their application was efficient by controlling both pathogens above 75.0% (Zakawa *et al.,* 2020). EOs continue to show promising results for the control of a wide spectrum of pathogens, and research on these compounds is increasing.

8. Postharvest control methods synergies

The efficiency in the application of each postharvest alternative is affected by different factors such as the cultivar, application conditions, pathogen species and resistance and its mechanism of action and/or control. Each control alternative has a specific mechanism of action to attack fruit pathogens and protect the fruits. The mechanisms of action are classified into three effects antifungal, ripening suppressor and elicitor (Figure 1). The antifungal effect consists of a direct attack on the structure and/or vital functions of the pathogen by the presence of antifungal compounds (Alvindia and Mangoba, 2020; Shah and Hashmi, 2020). Ripening suppressors delay fruit metabolic processes such as ethylene production and respiration rate to avoid the signaling that promotes the initiation of infection by the pathogen (Sivankalyani *et al.,* 2016; Xu *et al.,* 2017). The elicitor effect is the activation of the induced defense system that reinforces the internal protection of the fruit with the synthesis of pathogenicity proteins (PR) and phenols and phytoalexins compounds (Gutiérrez-Martínez *et al.,* 2017; Ren *et al.,* 2017).

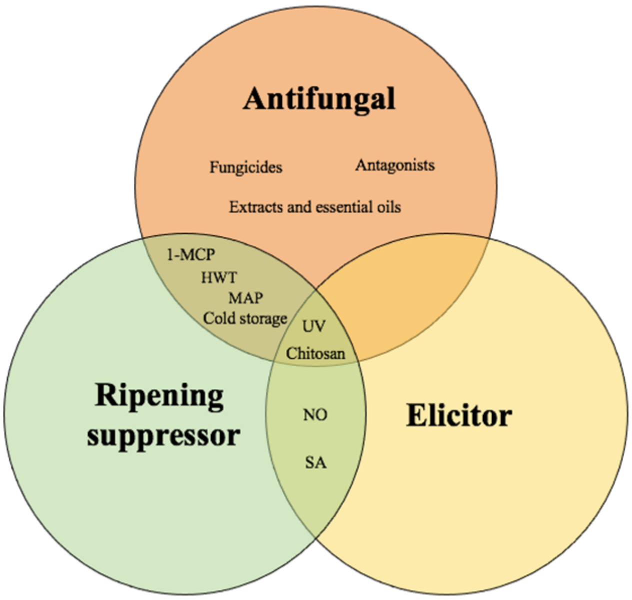

Figure 1. Action mechanisms of postharvest methods to preservation and protection of mango fruit. HWT: hot water treatment, MAP: passive modified atmospheres, UV: ultraviolet radiation, NO: nitric oxide, SA: salicylic acid.

Few postharvest alternatives promote all three effects to control pathogen attacks (Shah and Hashmi, 2020; Ngo *et al.,* 2021). To reinforce protection against infection by pathogens, different postharvest alternatives have been applied in synergy. Among the postharvest alternatives that are most used to generate synergies are edible coatings, which can encapsulate ingredients with antifungal potential. Edible coatings such as chitosan, hydroxypropylmethylcellulose, carboxymethylcellulose, sodium alginate, gums, and pectins have been incorporated with ingredients such as lacto-fermented antifungal substances, spirulina (Ranjith *et al.,* 2022), metal nanoparticles (Hmmam *et al.,* 2021), peel extract (Kumar *et al.,* 2021), and essential oils such as ginger (Klangmuang and Sothornvit, 2018), thyme (Shah and Hashmi, 2020), *Mentha* (de Oliveira *et al.,* 2020), cinnamon (Yu *et al.,* 2021) and oregano (Sánchez-Tamayo *et al.,* 2021) generating efficient results in the control of postharvest diseases and extending the shelf life of mango fruits.

Furthermore, edible coatings are combined with physical alternatives such as 1-MCP (Makka *et al.,* 2019), HWT (Khalil *et al.,* 2022) and cold storage (Shah and Hashmi, 2020). Specifically, cold storage is the postharvest alternative that performs synergy with most physical, chemical, and biological alternatives, it is pre-established as a storage condition that prolongs the useful life during the commercialization of the fruit. An analysis of the results of different reports in which different synergies have been applied to mango fruits showed a control effect on the development of postharvest diseases greater than 60% and more efficient than the individual application of each alternative (Table 2). This may indicate that the applied synergies may be combining action mechanisms to control pathogen infection and preserve fruit quality.

9. Quality parameters

The preservation of the quality parameters in the fruits is a determining factor for the acceptability of the consumer. Physicochemical parameters such as firmness, weight loss, color, pH, acidity and soluble solids reflect the quality of the fruit during postharvest storage. For marketing purposes, the quality and shelf life of the fruit

Table 2. Synergistic application of postharvest methods to mango fruit diseases control.

Synergistic methods	Concentrations	Individual disease control	Synergic disease control	Pathogen	References
Chitosan + Spermidine	1%	85%	87%	*C. gloeosporioides*	Jongsri *et al.* (2017)
	0.1 ppm	11%			
Chitosan Nano Particle + *Piper betle* leaf extract	5:1 v/v	60%	99%	*C. gloeosporioides*	Suryadi *et al.* (2020)
		60%			
Chitosan + *Aloe vera*	1%	65%	75%	Visible disease symptoms	Shah *et al.* (2020)
	1:1 v/v	-			
Hot water treatment + Chitosan	55°C for 5 mins	30%	87%	Visible disease symptoms	Khalil *et al.* (2022)
	1%	87%			
Hot water treatment + Azoxystrobin	55°C for 10 mins	61%	93%	*L. theobromae*	Montecalvo *et al.* (2019)
	175 ppm	17%			
Hot water treatment + Polyethylene	55°C for 1 min	53.3%	73.3%	Visible disease symptoms	Mustari *et al.* (2020)
	-	62.2%			
Hot water treatment + UV-C	65°C for 15 s	64%	41%	*B. dothidea*	Terao *et al.* (2018)
	2.5 kJ/m^2	36.4%			
Hot water treatment + Ethanol	50°C for 60 s	100%	100%	*Pestalotia mangiferae*	Gutiérrez-Martínez *et al.* (2012)
	300 ml/L	100%			
Chlorine dioxide + Yeast *D. hansenii*	3 mgL	20%	100%	*C. gloeosporioides*	Reyes-Perez *et al.* (2019)
	15 µL 1.0×10^6 cells/mL	-			
Yeast *M. pulcherrima* + Salicylic acid + Calcium chloride	1.0×10^8 CFU/mL	42.3%	58%	*C. gloeosporioides*	Shao *et al.* (2019)
	50 mg/L	29%			
	1 g/L	17.3%			
Ozone water + UV-C	400 mg/h	80%	100%	Visible disease symptoms	More *et al.* (2019)
	210 to 280 nm	80%			

Table 3. Effect of postharvest methods on the shelf life of mango fruit

Postharvest methods	Conditions	Shelf life days	References
Rosmarinus officinalis	500 µL/l	15 days	Javadpour *et al.* (2018)
Artemisia persica essential oils	1000 µL/l		
UV-C	2.5 kJ/m^2	15 days*	Terao *et al.* (2018)
Hot water treatment	55°C/ 10min	21 days*	Montecalvo *et al.* (2019)
Oxygen	5-8%	28 days*	Ntsoane *et al.* (2020)
Carbon dioxide	5-9%		
Nitrogen	86-91%		
Chitosan coating	1.0%	33 days*	Shah *et al.* (2020)
Polythene wrapping	-	18 days	Mustari *et al.* (2020)
Aloe vera coating	-	21 days	
Beeswax	3.0%	21 days*	Mshora *et al.* (2021)
M. oleifera oil-based coating	1.5%	12 days	Silva *et al.* (2021)
1-MCP	1500 ppm	45 days*	Fayek *et al.* (2022)

*Cold storage

must be extended for as long as possible, to ensure that it reaches its destination market free of damage (Javadpour *et al.,* 2018; Mustari *et al.,* 2020). The shelf life of mango fruit is 8-10 days when stored at room temperature. According to different investigations, the application of postharvest control methods reduces the incidence of diseases and can preserve quality parameters to extend the shelf life of mango fruit (Table 3).

10. Future trends

The different postharvest methods applied to the mango fruit have helped to reduce the incidence of diseases and extend its shelf life. In this review, we present some of the recent synergies between different postharvest methods that have been applied to mango fruit. The results of these synergies showed a potentiated

https://doi.org/10.26656/fr.2017.8(2).105

control effect by the combination of the mode of action of each method, increasing the preservation and protection of the fruit. The search for new synergies must continue to provide a broad spectrum of protection alternatives that could be applied in postharvest marketing.

To understand the response effect of the application of postharvest methods in the fruit, in the last decade proteomic techniques have been a useful tool. In mango, the changes in gene expression have been analyzed after exposure to cold storage, HWT, and UV, and the results showed an increase in the expression of the proteins involved in the stress and defense mechanism of the fruit. Future trends should be focused on evaluating the response effect of the different postharvest methods applied individually and in synergy to understand the control effect and the changes in protein expression that are generated.

11. Conclusion

Research on postharvest control methods applied to mango fruit has increased the incidence of infectious pathogens that limit their quality and shorten their shelf life for marketing. This review provides updated information on the control effect of postharvest methods applied individually and in synergies to the fruit. The results obtained are efficient and promising in reducing the incidence of infectious pathogens. Likewise, the implementation of omics techniques has helped to understand the mode of action involved in the control effect and thus have sustainable agricultural products. It is important to have updated information that indicates the current postharvest situation of the fruit and that shows where future research is heading and to be able to reinforce or improve it.

Conflict of interest

The authors declare no conflict of interest.

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