

A Review of Postharvest Treatments to Maintain Mango (*Mangifera Indica* L.) Quality

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ABSTRACT

Mango (*Mangifera indica* L.) is a popular fruit in the international market due to its excellent flavor, attractive fragrance, taste and nutritional properties. However, it is highly perishable since it ripens easily after harvest and it is susceptible to postharvest diseases causing severe losses during storage and transport. The paper reviews the literature on the most important postharvest treatments to alleviate this problem which include the use of fungicides, hot water treatment, vapor heat treatment, controlled atmosphere, irradiation, wax coatings and biological control. The use of fungicides, hot water treatment, irradiation, and wax coatings appear to be the most widely used postharvest treatments.

Key words: prochloraz, hot water and vapor treatment, controlled atmosphere, irradiation, wax coating, biological control

INTRODUCTION

Mango (*Mangifera indica* L.), widely referred to as the “King of Fruits”, originated from Southeast Asia especially Burma and Eastern India (Rathore *et al.*, 2007; Sivakumar *et al.*, 2011). It is a dicotyledonous plant belonging to the order Sapindales in the family Anacardiaceae (Sivakumar *et al.*, 2011). According to Baertels (1993) this popular fruit has been cultivated in India since 4,000 years ago and is the second most important tropical fruit behind banana.

Reports indicate that commercial mango production can be found in more than 87 countries around the world (Sivakumar *et al.*, 2011) with India, China, Thailand, Indonesia, Philippines, Pakistan, and Mexico as the major producing countries of the fruit (Tharanathan *et al.*, 2006). In terms of mango export, however, the top 10 leading countries are Mexico, India, Brazil, Pakistan, Netherlands, Peru, Ecuador, Thailand, Philippines, and the Ivory Coast (FAOSTAT – www.novagrim.com). Mango production is increasing outside the traditional geographical regions of mango cultivations such as in Central and South America, Australia, Southeast Asia, Hawaii, Egypt, Israel and South Africa, especially for export markets (Tharanathan *et al.*, 2006).

In the Philippines, mango is the third largest fruit export after banana and pineapple (Briones, 2013). Luzon is the largest mango producer with more than

half of its mango produce coming from the Ilocos Region. Export earnings from mango peaked in 2011 amounting to about 100 million US dollars. The widely grown variety is the “Carabao mango” which is considered as one of the best varieties. Cuaresma (2007) noted that due to this variety, the Philippines is included in the top 10 mango producing countries of the world.

Arauz (2000) reported that mango's popularity in the international market is due to its excellent flavor, attractive fragrance, beautiful color, taste and nutritional properties. The fruit is a good source of ascorbic acid, carotenoids and phenolic compounds, and other dietary antioxidants (bioactive compounds) (Talcott *et al.*, 2005; Djioua *et al.*, 2008).

However, mango is highly perishable since it easily ripens after harvest or during transport. Moreover, it is susceptible to some postharvest diseases which also cause a decline in its quality and consumer acceptability. This review will focus on the causes of loss of quality of mango and the widely used postharvest treatments to alleviate or solve it.

Causes of Quality Loss

Kader (2002) reported that the quality of mangoes depends largely on external and internal quality parameters. Consumer acceptance is higher for mangoes free from external damages including bruises, latex or sap injury, decay, uniform weight, color, and shape which are external quality attributes.

According to the U.S. National Mango Board (2010) the timing of harvest is important in order to provide the market place with superior quality fruits. This is because mangoes picked before their optimum maturity may develop inferior flavor and aroma, show increased susceptibility to chilling injury caused by low temperatures during transport, and have shortened shelf life (National Mango Board, 2010; Yahia, 1998).

During the harvesting, direct exposure of the harvested mangoes to sunlight results in higher flesh temperatures, which in turn accelerates metabolism and shortens potential shelf life. The National Mango Board (2010) warned that direct exposure of mangoes to sunlight increases respiration and water loss, resulting in short shelf life. Transport vehicles should be covered to protect the top layers of fruit from direct exposure to sunlight while in transit (Johnson and Hofman, 2009).

Yahia (1998) and Sivakumar *et al.* (2011) mentioned that loss of mango quality can be the result of harvesting fruit at improper maturity, mechanical damage caused during harvesting or improper field handling, sap burn, chilling injury, disease, and pest damage. Moreover, loss of fruit quality often occurs due to tight fruit packing, improper transport, and inadequate field handling. Sivakumar *et al.* (2011) also emphasized that postharvest diseases reduce mangoes fruit quality and result in severe losses. Latent infections such as anthracnose (caused by *Colletotrichum gloeosporioides*), Alternaria black spot (*Alternaria alternata*), and stem end rot (caused by *Lasiodiplodia theobromae* or *Dothiorella dominicana* or *Botryosphaeria spp.*) are the predominant postharvest diseases that cause severe postharvest losses and affect fruit quality during the supply chain. Fruit becomes susceptible to infection as it softens. During handing, packing and transportation operations, small openings in the skin or wounded areas on fruit surface become the ideal sites for these pathogens to gain entry to the fruit tissue (Johnson and Hofman, 2009; Jabbar *et al.*, 2011; Sivakumar *et al.*, 2011).

Regarding sap burn, Johnson and Hofman (2009) revealed that severing the stem from the fruit causes relatively large volumes of latex to spurt or ooze from the cut stem. The sap has low pH but has high oil content and can burn the surface of the fruit. The oil fraction contains terpinolene and resorcinol and is the fraction of the latex that causes the damage.

Harvested fruits should be transported to the packhouse as soon as possible, with no prolonged exposure to the sun. Rough handling and transport must be minimized. Road tracks from orchard to packhouse should be smooth, with transport vehicle tires correctly inflated, and with special suspensions to reduce vibration and damage.

The storage of the mango fruit is also a very important factor affecting the fruit quality. Abbasi *et al.* (2009) cited literatures indicating that the shelf life of mango varies among its varieties depending on storage conditions. It ranges from 4 to 8 days at room temperature and 2-3 weeks in cold storage at 13°C. This short period seriously limits the long distance commercial transport of this fruit. Usually after harvesting, the ripening process in mature green mango takes 9-12 days (Herianus *et al.*, 2003).

Cuaresma (2007) reported that the large-scale, long distance shipment of fresh mangoes from the Philippines is not yet feasible because the fruits ripen seven days after harvest. Because of this, exportable, good quality fruits barely reach 50% of the total harvest. Moreover, mango is susceptible to postharvest diseases such as anthracnose and stem-end-rot which causes considerable losses.

Postharvest Treatments

Johnson and Hofman (2009) reported that postharvest handling of mangoes is the last phase (from the tree to mouth) of an agribusiness venture. Postharvest handling or treatment is aimed to optimize quality and minimize premature ripening and fruit damage. They recommended that precise maintenance of fruit quality and the storage environment demand inputs at every stage from picking to the consumer.

The control of postharvest disease in mango is generally achieved through proper preharvest and postharvest management practices such as strict orchard hygiene management, application of fungicides and temperature management during storage and shipping (Johnson and Hofman, 2009; Sivakumar *et al.*, 2011).

Use of Fungicides

The most widely used pesticide for agricultural products in Europe, Australia, Asia, and South America is the fungicide prochloraz (Vinggaard *et al.*, 2006) with a molecular formula of $C_{15}H_{16}Cl_3N_5O_2$ (FAO, 2009). According to Vinggaard *et al.* (2006) postharvest treatment of mango with prochloraz is in the form of protectant spray. It is the only fungicide used for postharvest disease control in mangoes (Sivakumar *et al.*, 2011). In South Africa, prochloraz treatment is adopted in packhouses before wax (Citrashine™) application. For fruits intended for the local market, a 5-min dip in a heated (55°C) prochloraz at 900 $\mu\text{g mL}^{-1}$ is the most common practice (Prusky *et al.*, 1999).

The combination of fungicide and hot water treatment is a widely used

postharvest treatment. For example, in South Africa mango fruits for export are dipped for 20 sec at 25 °C in Prochloraz solution and followed by a 5 min hot water treatment (HWT) at 50 °C (Sivakumar *et al.*, 2011). Jabbar *et al.* (2011) cited studies showing that postharvest hot water dips with fungicides have been proven to be effective in protecting mango against postharvest pathogen infection and in extending storage life of mango fruit during overseas shipments.

Jabbar *et al.* (2011) found that pre-transport fungicide dip (Topsin-M @ 1 g/L) of mango fruits followed by hot water treatment at 48°C for 60 min, for fruit fly disinfestation, reduced the incidence of postharvest diseases during storage and transit. They also found that longer exposure time (45°C for 75 min, Iran protocol), although reduced the incidence of diseases, caused higher degree of hot water damage, compared with those subjected to shorter period at higher temperature (48°C for 60 min: China protocol).

Prusky *et al.* (1999) tested the efficacy of the hot water treatment over a range of temperatures from 48 to 64°C, in combination with prochloraz treatment and fruit waxing. Hot water brushing of fruits significantly reduced decay (infected area) development by *A. alternata*. But after storage for 3 weeks at 12°C and another week at 20°C, the reduction of disease incidence by hot water brushing and prochloraz treatment (900 mg ml⁻¹) was more effective than by hot water brushing alone. The hot water treatment for 15 sec improved color development and was more effective than the common, commercial 5-min dip treatment at 55°C.

Johnson and Hofman (2009) reviewed studies showing that hot water and fungicide application, hot water dips, or sprays over brushes, with or without fungicide, and fungicide sprays or dips, can eradicate quiescent fungal infections that have been established on and beneath the cuticle and within the pedicel prior to harvest.

Use of Hot Water Treatments

According to Esguerra and Bautista (2007), hot water treatment is the easiest heat treatment to employ which consists of submerging the commodity in a hot water tank at a specified time based on the commodity and the target pest. There are two methods of hot water dip treatment that have been used commercially as quarantine treatment: double dip treatment which has been used for papaya, and extended hot water immersion (46.1°C for 75-90min) which is currently used for mangoes.

Lurie (1998) mentioned that hot water was originally used for fungal control, but has been extended to disinfestation of insects. Hot water dips are effective for fungal pathogen control because fungal spores and latent infections are either on the surface or in the first few cell layers under the peel of the fruit or vegetable (Lurie, 1998). Many fruits and vegetables tolerate exposure to water temperatures of 50–60°C for up to 10 min, but shorter exposure at these temperatures can be enough to control many postharvest plant pathogens (Barkai-Golan and Phillips, 1991). Hot water dips for fruits require 90-min exposure to 46°C. Procedures have been developed to disinfest a number of subtropical and tropical fruits from various species of fruit fly. The times of immersion can be 1 h or more and temperatures are below 50°C, in contrast to many antifungal treatments which are four minutes at temperatures above 50°C (Lurie, 1998).

Prusky *et al.* (1999) reported that hot water bath improved the appearance of the fruit, but did not enhance total soluble solids or reduce acidity. Their results suggested that hot water treatment may be useful for reducing postharvest decay. It also improved general appearance of mango fruits as a result of removing the sap and dirt and of improved fine color and gloss.

Johnson and Hofman (2009) reviewed several literatures on the use of hot water treatment for mangoes. They noted that hot water immersion is environmentally safe and efficient for killing mango pests and has been intensively used to kill fruit fly eggs and larvae in the USA after ethylene dibromide was removed from the market as a chemical fumigant due to health concerns. Typical treatments include 46.1°C for 65 min for smaller fruits to 90 min for larger fruits. Smith (1992) revealed that immersing five Australian mango cultivars in 48°C water for 30 min killed eggs and larvae of *Bactrocera aquilonis*. Grové *et al.* (1997) found that treatment of several cultivars in hot water at 46.1°C for 90 min followed by refrigeration for 24 h did not damage fruit, although some cultivars showed severe lenticel damage.

There are also reports of negative effects of hot water treatment on mangoes. Shukla and Tandon (1985) showed that weevils in 'Alphonso' mangoes from India were not killed after immersion in water at 48–52°C for up to 90 min and 54–70°C for up to 5 min. Jacobi *et al.* (2001) also observed that hot water treatments can cause skin scalding, lenticel damage, cavities, white starchy areas in the flesh, and delayed ripening depending on cultivar, temperature, and duration. Immature fruits have low heat tolerance, and small fruits are damaged by heat more readily than large fruits. Hot water dips could also pose human health risks. An outbreak of *Salmonella enterica* that infected 72 patients from 13 USA states may have been due to contamination of hot-water-dipped mangoes from a single farm in Brazil (Sivapalasingam *et al.*, 2003).

Use of Modified or Controlled Atmosphere

The use of modified atmosphere (MA) or controlled atmosphere (CA) is now a standard procedure for mangoes in the U.S. The U.S. National Mango Board (2010) requires that packed and palletized mangoes should be cooled as rapidly as possible to their optimum shipping and storage temperature 12°C [54°F] for mature green mangoes. Lowering the temperature slows fruit metabolism including ripening, reduces water loss, and slows the initiation and spread of decay. Johnson and Hofman (2009) summarized the available studies on CA or MA regimes and noted that they have potential for disinfesting mangoes, but there has been less interest in the technology because heat treatments and irradiation are faster. Treatments are limited to regimes which do not adversely affect ripe fruit quality. Likewise, Abbasi *et al.* (2009) noted that application of MA or CA is not always compatible with mango. Although it can extend the shelf-life of mango, it is costly.

Ullah *et al.* (2011) reported that CA storage has been very successful with apples and pears but the response of mangoes to CA condition varies. Nakamura *et al.*, (2004) revealed that CA storage having 5-10% CO₂ is effective to suppress the respiration rate of ripe mangoes but another study revealed that CA comprised of 2% O₂ and 3% CO₂ is better for maintaining the aromatic compounds of ripen fruits (Lalel *et al.*, 2003). They reported that mangoes stored in CA comprising of

2% O₂ and 3% CO₂ resulted in significantly higher total aroma volatiles, monoterpenes, and sesquiterpenes compared with normal storage irrespective of storage period. CA storage did not significantly affect production of aldehydes while ketone was significantly higher in the fruit stored under normal atmosphere for 35 days, compared with CA storage.

Kader (2015) recommended the optimum temperature of 13°C (55°F) for mature green mangoes and 10°C (50°F) for partially ripe and ripe mangoes. The optimum relative humidity should be 90-95%. The CA should also have 35% O₂ and 58% CO₂. CA delays ripening and reduces respiration and ethylene production rates. Exposure to below 2% O₂ and or above 8% CO₂ may induce skin discoloration, grayish flesh color, and off-flavor development. Postharvest life is potential at 13°C (55°F) 24 weeks in air and 36 weeks in CA, depending on cultivar and maturity stage.

Leon *et al.* (2000) exposed Manila mangoes infested with *Anastrepha obliqua* to nine different controlled atmospheres (CA) containing combinations of 1, 3, or 5% O₂ and 30, 50, and 70% CO₂. Surviving larvae were enumerated after subjecting the mangoes to CA for 1 to 5 days. Selected compositional and physical parameters (weight loss, pH, titratable acidity, color, soluble solids, reducing sugars, and texture) were analyzed during post-treatment ripening. CA containing 1% O₂ and either 30 or 50% CO₂ effectively killed all larvae present in treated fruits and did not alter the composition or sensory characteristics of fully ripened mangoes. CAs containing 70% CO₂ were not only effective in disinfestation, but also affected compositional and sensory qualities of the fruits and induced the "spongy" texture defect in 65% of the fruits.

In an effort to establish a protocol for extending the shelf life of Philippine "Carabao" mango using controlled atmosphere container vans, Cuaresma (2007) proved that controlled atmosphere storage with preset levels of 6% CO₂, 4% O₂ and pulp temperature of 13°C delays the ripening process and extends the shelf life of Carabao mango for 28 days starting from loading. He also found that storage temperature without CA can also extend the shelf life of mango for 21 days starting from loading. Cuaresma (2007) was able to develop a protocol for Carabao mango storage in container van facilities which can be modified depending on the requirements of importing countries.

Use of Vapor Heat Treatment

Vapor heat treatment (VHT) involves heating the mango fruit with air saturated with water vapor at temperatures of 40–50°C to kill insect eggs and larvae. VHT involves heating air that is nearly saturated with moisture and passing the air stream across the fruit (Jacobi *et al.*, 2001). Hot air can be applied by placing fruits or vegetables in a heated chamber with a ventilating fan, or by applying forced hot air where the speed of air circulation is precisely controlled. Hot air, whether forced or not, heats more slowly than hot water immersion or forced vapor heat, although forced hot air will produce heat faster than a regular heating chamber. When the temperature of the mango fruit is at or below the dew point of air, condensation occurs on the fruit surface and rapidly heats the fruit by conductive energy transfer. The core of the fruit next to the seed is heated to c. 45°C for the required time before cooling. Fruits have to be sorted for size before

treatment because of different rates of attaining the required core temperature (Johnson and Hofman, 2009).

VHT is adopted for mangoes exported from Australia, Thailand, the Philippines, and Taiwan to the Japanese market (Sivakumar *et al.*, 2011). Jacobi *et al.* (2001) provided the VHT protocols approved for importation of mangoes into Japan from the Philippines, Taiwan, Thailand, Australia, and Mexico. The protocols indicated vapor temperature range from 43–47°C pulp core temperature for 10 min to 6 h; however, the most common treatment conditions are 46–47°C for 10–30 min. Sunagawa *et al.* (1987) reported that melon fruit fly (*Bactrocera cucurbitae* Coquillett) immatures in mangoes from Okinawa were killed at $44 \pm 0.3^\circ\text{C}$ core temperature for 3 h whereas Kuo *et al.* (1987) observed that Taiwanese mangoes infested with melon fly can be disinfested with vapor heat at 47.5°C until the center pulp is $>46.5^\circ\text{C}$ for 45 min.

In the Philippines, the recommended VHT for “Carabao” mango to be exported to Japan, Australia, USA, South Korea, and New Zealand consists of setting the chamber temperature at 47.5°C until the pulp temperature reaches 46°C which should be maintained for 10 min to ensure that fruit flies are killed and with relative humidity maintained at 90%. This is followed by air cooling and then by hydrocooling (Esguerra and Bautista, 2007).

Use of Irradiation Treatments

Esguerra and Bautista (2007) mentioned that the treatment objective in the use of irradiation as a phytosanitary measure is to prevent introduction and spread of regulated pests by way of mortality, aborted development, inability to reproduce, and inactivation. They added that the level of quarantine security required depends on the importing country. Australia and New Zealand Food Standards Code authorizes irradiation of tropical fruits including mango.

Sivakumar *et al.* (2010) reported that irradiation is recommended as quarantine or phytosanitary treatment. The purpose of irradiation is to kill or to sterilize microbes or insects by damaging their DNA. Based on their review of available literature for mangoes, they noted that the effectiveness of irradiation on mango fruit quality depends on irradiation dose, cultivar, and fruit maturity stage. Fruit damage or irradiation stress can be indicated by softening, uneven ripening, or surface damage on mango fruits. Fruits that are partially ripe may not be affected by irradiation. They cited studies showing that lower irradiation doses between 100 and 150 Gy affected the flavor, and doses higher than 750 Gy caused loss of ascorbic acid content in 'Irwin' and 'Sensation' mangoes.

Johnson and Hofman (2009) reviewed the use of irradiation on mangoes and observed that it involves γ rays (at <1000 Gy), X-rays, electrons, and microwaves. Radiation treatments have been developed for fruit flies in mangoes from Florida, Mexico, India, and Australia. Von Windeguth (1986) treated mangoes with 76 Gy and disinfested them of Caribbean fruit fly eggs and larvae. Bustos *et al.* (1992) observed that a dose of 60 Gy applied to third instar fruit fly larvae in the infested mango fruits sterilized this species and prevented the emergence of adults of the other three species. A dose of 250 Gy was required to prevent emergence of *C. capitata*. In fertility tests using emerged adults of *A. ludens* and *A. obliqua*, a dose of 30 Gy gave 45 and 27 % fertility, respectively. The adults of *A. serpentina* that

emerged died before reaching sexual maturity.

Bustos *et al.* (2004) recommended a generic dose of 150 Gy for control of Mexican fruit fly (*A. ludens*), the West Indian fruit fly (*A. obliqua*), the sapote fruit fly (*Anastrepha serpentina*), and the Mediterranean fruit fly (*C. capitata*) in mango. The international guidelines for the use of irradiation as a phytosanitary measure provided by the International Standards for Phytosanitary Measures (ISPM) (2003) are available. Very important is that the fruits are never exposed to radioactive materials and most modern treatment units use an electron beam process rather than a radioactive source for irradiation.

Use of Wax Coatings

Baldwin (1994) reported that one method to extend the postharvest shelf-life of fresh fruits and vegetables is the use of edible coatings. Such coatings are made of edible materials that are used to enrobe fresh produce and thereby providing a semi-permeable barrier to gases and water vapor. According to Abbasi *et al.* (2009) films and edible coatings have been used traditionally to improve appearance and to conserve food products; the most common examples of which are the wax coatings for fruits. Baldwin (1994) also noted that edible coatings are used to create a controlled internal atmosphere of fruit tissues and improve the mechanical handling properties, help maintain structural integrity, retain volatile flavor components, and carry additives such as antimicrobial agents and antioxidants.

Tripathi and Dubey (2004) indicated that the barrier characteristics to gas exchange for films and coatings are the subjects of much recent interest. Development of films with selective permeability characteristics, especially to O₂, CO₂ and ethylene allow some control of fruit respiration and can reduce growth of microorganisms. Baldwin (1994) noted that the development of the so-called “wax” coatings, which may or may not actually include a wax, emphasized the reduction of moisture loss due to the hydrophobic components such as waxes, oils, and resins. Coatings have long been used on citrus, apples (shellac and carnauba wax), tomatoes (mineral oil), and cucumbers (various waxes). However, these coatings are less studied for use on apricots, pineapples, bananas, cherries, dates, guavas, mangoes, melons, and nectarines or peaches (Baldwin, 1994).

Feygenberg *et al.* (2005) reported that coating fruits with wax maintains their postharvest quality by slowing down ripening and reducing water loss. Regular fruits are coated mainly with polyethylene-shellac- or carnauba-shellac-based waxes, but these waxes are not allowed. In mango cv. 'Tommy Atkins' the levels of AA and ethanol were much higher in fruits coated with NutraSeal (cellulose-based polysaccharides) than in those coated with carnauba wax – a difference that affects the fruit taste (Baldwin *et al.*, 1999). According to Feygenberg *et al.* (2005), it seems that the organic wax has a high potential to improve the quality of various biological fruits and to increase their storability and shelf life. The main distinguishing feature between the two wax coatings was that beeswax coated fruits had a lusterless look whereas those coated with carnauba wax were shiny. Both waxes were efficient in reducing water loss and maintaining fruit firmness and color without inducing off-flavors. These waxes probably gain their superiority because their formulas include no shellac, which blocks gas exchange; therefore

there is no accumulation of anaerobic metabolites. Moreover, the organic waxes were effective in reducing chilling injury symptoms in mango and avocado fruits.

According to the U.S. National Mango Board (2010) waxing mangoes, usually with carnauba-based formulations, improves their appearance by increasing the natural fruit gloss and reducing water loss, which causes mangoes to appear dull. Brushing during wax application helps to obtain uniform wax distribution on the fruit. If spraying is used during wax application, care must be taken to prevent wax inhalation by workers. Waxes must be applied according to label instructions.

Use of Biological Control

Sharma *et al.* (2009) noted that synthetic fungicides are primarily used to control postharvest diseases of fruits and vegetables. However, the trend around the world is shifting towards reduced use of fungicides on produce and thus, there is a strong public and scientific interest in safer and eco-friendly alternatives to reduce the high loss due to decay loss of harvested commodities. Furthermore, the increasing concern for health hazards and environmental pollution due to chemical use has necessitated the development of alternative strategies for the control of postharvest diseases of fruits and vegetables. Their review on the subject revealed that among the different biological approaches, use of the microbial antagonists like yeasts, fungi, and bacteria are quite promising and gaining popularity.

According to Sharma *et al.* (2009) there are two basic approaches for using the microbial antagonists for controlling the postharvest diseases of fruits and vegetables: (1) use of microorganisms which already exist on the produce itself, which can be promoted and managed, or (2) those that can be artificially introduced against postharvest pathogens. Several modes of action have been suggested to explain the biocontrol activity of microbial antagonists but researchers (e.g. Droby *et al.*, 1992; Jijakli *et al.*, 2001) still consider competition for nutrient and space between the pathogen and the antagonist as the major modes of action by which microbial agents control pathogens causing postharvest decay. In addition, others (e.g. El-Ghaouth *et al.*, 2004) consider the production of antibiotics (antibiosis), direct parasitism, and possibly induced resistance are other modes of action of the microbial antagonists by which they suppress the activity of postharvest pathogens on fruits and vegetables.

For mango, *Bacillus licheniformis* (Weigmann) Verhoeven and *Brevundimonas diminuta* (Leifson & Hugh) Segers are used to control Anthracnose (*Colletotrichum gloeosporioides*) and stem end rot (*Dothiorella gregaria* Sacc.). *Trichoderma viride* is also effective against stem-end rot (*Botryodiplodia theobromae*) (Sharma *et al.*, 2009). In general, microbial antagonists are applied in two different ways: preharvest and postharvest application. It commonly happens that pathogens infest the mango fruits in the field, and these latent infections become an important cause for the fruit decay during transport or storage of the fruits. Because of this preharvest application of microbial biocon culture is often effective to control postharvest decay of fruits and vegetables (Ippolito *et al.*, 2004). According to Sharma *et al.* (2009), the purpose of preharvest application is to pre-colonize the fruit surface with an antagonist immediately before harvest so that wounds inflicted during harvesting can be colonized by the antagonist before colonization by a pathogen.

However, this approach is not commercially viable due to poor survival of microbial antagonists in the field. On the other hand, postharvest application where microbial cultures are applied as postharvest sprays or as dips in an antagonist solution is an effective, practical, and useful method than preharvest application of microbial antagonists (Sharma *et al.*, 2009).

SUMMARY

Mango is in demand in the international market due to its excellent flavor, attractive fragrance, taste, and nutritional properties. However, it is highly perishable since it ripens easily after harvest and it is susceptible to postharvest diseases causing severe losses during storage and transport. The most important postharvest treatments to alleviate this problem include the use of fungicides particularly prochloraz, hot water treatment, vapor heat treatment, controlled atmosphere, irradiation, wax coatings, and biological control. The use of fungicides, hot water treatment, irradiation, and wax coatings are the most widely used postharvest treatments because these are effective, cheap, and easy to implement. In many countries, fungicides and hot water are used in combination to increase effectiveness in protecting mango against postharvest pathogen infection and in extending storage life of mango fruit during overseas shipments. The protocol for controlled atmosphere involving the storage in container van facilities developed for Philippine's "Carabao" mango has potential for improving the country's mango export industry.

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