Methods for Management of Ripening in Mango:
A Review of Literature

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1 Abstract

A review of the literature on methods for management of ripening in mango was conducted. Most of the recent research on this topic involves methods to delay ripening by modified atmosphere packaging using edible films or by inhibiting ethylene action through the use of 1-methylcyclopropene (1-MCP).

2 Introduction

To facilitate successful marketing of mangoes using conventional packaging and postharvest handling methods, mangoes destined for import into the USA are harvested at the mature green stage while still firm. The fruit are then ripened after they arrive in the USA by the wholesaler, retailer, or consumer (Kader and Mitcham, 2008). Kader and Mitcham note that sales of mangoes increase if ready-to-eat fruit are available at retail markets. One of the challenges to successful marketing of mangoes is their limited shelf-life (typically 14 to 28 days at the mature-green stage and up to a week at the ripe stage). Postharvest technology that would extend the shelf-life of mangoes without adversely affecting their quality at consumption would be of considerable value to the industry.

3 Factors Affecting Ripening

3.1 Temperature

Temperature management is the most critical factor in the management of ripening in mature-green mangoes. Paull and Chen (2004) indicate that holding the fruit in the temperature range of 20 to 23 °C (68.0 to 73.4 °F) provides the best appearance, palatability and decay control when ripening mangoes. Kader and Mitcham (2008) indicate that holding the fruit between 15.5 to 18°C (60 to 65°F) during ripening provides the most attractive skin color, however the flavor remains tart unless the fruit are held an additional 2-3 days at 21-24°C (70-75°F). If mangoes are held at 27-30°C (80-86°F) during ripening, the skin of the fruit becomes mottled and the fruit acquire a strong flavor. Ripening is retarded when mangoes are held above 30°C (86°F). Mature-green mangoes can be held at 10 to 13°C (50 to 55°F) for 14 to 28 days (Paull and Chen, 2004). Ripe mangoes can be held at 10 to 13°C (50 to 55°F) for up to one week.

Being a tropical fruit, mangoes are subject to chilling injury if held below 13°C (55°F) for mature green mangoes, and below 10°C (50 °F) for partially ripe mangoes (Kader and Mitcham, 2008). Ripe mangoes can be held in air storage at 10°C (50 °F) for a few days without chilling injury. Kader and Mitcham note that, in order to avoid the risk of chilling injury to the fruit, it would be preferable to hold mature-green mangoes or mangoes at the breaker stage in a controlled atmosphere chamber with 4% oxygen (with the balance of the atmosphere being nitrogen) and a temperature of 15°C (59°F) than in a normal air environment at 10°C (50 °F) when attempting to delay ripening. The humidity of the air in the ripening or storage facility should be in the 90 to 95% range to avoid fruit dehydration (shrivel).

3.2 Ethylene

Hatton et al (1965) reported that ripening and softening rates of Florida mango cultivars increased as temperature increased from 16 to 27C (60.3 to 80.6 F), but the best temperature range was 21 to 24C (69.8 to 75.2 F). Mangos ripened at 27C (80.6 F) and higher temperatures had strong flavors and molted skin (Soule and Harding, 1956; Hatton et al, 1965). Mangos produce relatively low levels of ethylene, but respond to exogenous ethylene applications. Campbell and Malo (1969) found that ripening of mature-green mangos was accelerated in response to ethylene released from 2-chloroethylphosphonic acid (ethephon). Exposure of Florida mango cultivars picked at the mature-green stage to 20-100 ppm ethylene for 24 hours results in faster and more uniform ripening at 21C (69.8 F) and 92-95% relative humidity (Barmore, 1974). Barmore and Mitchell (1977) reported that having ready-to-eat mangos with better color and aroma at retail stores increased sales. The benefits of ethylene-induced ripening were recently reported for 'Ataulfo' mangos (Montalvo et al, 2007).
The rate of ripening in mangoes can be accelerated by treating the fruit with ethylene at 100 ppm in a low (below 1%) carbon dioxide environment for a 12 to 24 hour period (Kader and Mitcham, 2008). The fruit will then ripen in 5 to 9 days, depending upon cultivar, if held at 18 to 22°C (65 to 72°F).

4 Management Techniques to Prolong Mango Storage Life

4.1 Background

Ben-Yehoshua et al. (2005) note that ripening and senescence rates in many climacteric fruits like mangoes, can be affected by control of the availability of O_2 and CO_2 to the fruit during respiration and that these two compounds can have a significant inhibitory effect on ability of ethylene to initiate ripening. Thus much of the research conducted on the development of techniques to facilitate the lengthening of storage life in mangoes has focused on methods that allow control of O_2, CO2, and/or ethylene.

4.2 Controlled Atmosphere Storage and Modified Atmosphere Packages

Based on studies with Florida mango cultivars, the optimal range of oxygen is 3 to 5% and carbon dioxide is 5 to10% in modified or controlled atmospheres (Bender et al, 1994, 1995, 2000, 2000a, 2000b; Hatton and Reeder, 1965; Kim et al, 2007; Spalding and Reeder,1974 and 1977; Yahia,2006). Yahia and Vasquez-Moreno (1993) found that mangos tolerate short exposures to insecticidal atmospheres with very low oxygen and elevated carbon dioxide. However, exposure of mature-green mangos to oxygen levels below 2% and/or carbon dioxide levels above 10% for longer than a few days may induce skin discoloration, grayish or pale flesh color, uneven ripening, and off-flavor development due to fermentative metabolism (accumulation of acetaldehyde and ethanol). Modified atmosphere packaging with or without ethylene absorbers can delay ripening and reduce water loss of mature-green mangos (Miller et al, 1983 and 1986; Yahia, 2006). However, if gas diffusion is restricted to the extent that undesirable levels of oxygen and carbon dioxide develop, the above-mentioned undesirable effects of low oxygen and elevated carbon dioxide will result.

Paull and Chen (2004) indicate that the storage life of mangoes can be extended by holding the fruit in an environment with 3 to 5% O_2 and 5 to 10% CO_2, at 7 to 9 °C (44.6 to 48.2 °F) and 90% relative humidity atmosphere. They note that mango cultivars respond differently to controlled atmosphere storage, and that ripening delays provided may be minor (several days) and not economically advantageous in all situations. The controlled atmosphere may be provided by a specially designed storage chamber during transportation and/or storage or by modified atmosphere packaging using polyethylene or other film bags, but that some types of bags can cause off-flavors or abnormal skin color in mangoes. Kader (2008) notes that holding mangoes in atmospheres below 2% O_2 or above 8% CO_2 may result in skin discoloration, grayish flesh color, and off-flavor development.

4.3 Edible Coatings

A number of studies have been conducted demonstrating that edible coatings can be used as a less costly modified atmosphere package to provide some control of ripening and lengthening of storage life. Baldwin (2005) has written a review on the use of edible coatings in fruits and vegetables to prolong shelf life and manage other postharvest factors. Baldwin notes that edible coatings can provide a suitable atmosphere for each fruit that has low O_2 and high CO_2 levels to reduce ripening rates in many climacteric fruits as long as the coating has been designed not to create an environment that causes anaerobic respiration. Many coatings have the added advantage of providing a moisture barrier that reduces dehydration in the fruit during storage. The availability and regulatory status of food coatings varies by country. Baldwin notes that materials classified as Generally Recognized As Safe (GRAS) are considered ‘edible’ by the US Food and Drug Administration. One advantage to the use of coatings in a fruit like mangoes, is that the skin is not normally consumed, possibly providing greater flexibility in the choice of coating materials.

Several studies have examined the performance of a fruit coating based upon carnauba wax or beeswax (e.g., Baldwin et al., 1999; Dhalla and Hanson, 1988; Dang et al., 2008; Feygenberg et al., 2005; Hoa et al., 2002; Hoa and Ducamp, 2008; Menezes et al., 1996). All studies show that wax coatings are effective at reducing water loss in mangoes during storage. Most of the studies observed that wax coatings were not effective in delaying the ripening of mangoes. A few studies (e.g., Dhalla and Hanson, 1988; Dang et al., 2008; Feygenberg et al., 2005) have observed a delay in ripening from a few to several days. Feygenberg et al. (2005) observed that the wax coated fruits did not develop any off-flavors, and were preferred over uncoated fruit by taste panelists.

A number of other coating materials have been studied for their ability to delay ripening in mangoes. Baldwin et al. (1999) observed a delayed in ripening of ’Tommy Atkins’ mangoes when coated with hydroxypropyl methylcellulose (a polysaccharide). Hoa et al. (2002) conducted a study on the effects of different coatings formulated from several materials including protein, carnauba wax, shellac, and cellulose on ‘Lirfa’ mangoes to determine their ability to delay fruit ripening and maintain fruit quality. They observed that coatings based upon hydroxypropyl methylcellulose and zein (a plant protein from maize) were most effective for delay of softening and color development and that these coatings were able to delay ripening of mature green fruit by several days. Mature green harvested mangoes coated with zein showed elevated levels of ethanol after storage, however their evaluation did not show significant differences in sensory panel ratings between of the zein coated fruit and the control fruit at the end of the storage period.

Carrillo-Lopez et al., (2000) observed ripening delays of several days in ‘Haden’ mangoes coated with “Semperfresh” (a mixture of esters of mono- and di- glycerides, sucrose, and carboxymethylcellulose). Dang et al. (2008) evaluated Semperfresh, and *Aloe vera* gel coatings on ‘Kensington Pride’ mangoes. They observed a few days ripening delay due to Semperfresh, and *Aloe vera* gel coatings, however these coatings also reduced the fruit aroma volatile development during ripening. Hoa and Ducamp (2008) observed ripening delays of about 3 days for ‘cat Hoa loc’ mangoes coated with Xedabio (a soybean lecithin-based coating). Malik and Singh (2005) observed that polyamine coatings delayed the ripening of ‘Kensington Pride’ mangoes by a few days without impairing fruit quality. Kittur et al. (2001) found that starch, cellulose, and chitosan-based coatings on ‘Alphonso’ mangoes were more effective in delaying ripening than Waxol. They also observed that chitosan-based coatings were effective in reducing fungal infections. A number of other studies (e.g., Srinivasa et al. 2002 and 2004; Wang et al., 2007; Zhu et al. 2008) have also observed that chitosan coatings can delay the ripening of mangoes by several days.

4.4 1-Methylcyclopropene (1-MCP)

The compound 1-methylcyclopropene (1-MCP) is an odorless gas that has a physical similarity to ethylene allowing it to bind to the ethylene receptors in fruits, thus inhibiting the normal action of ethylene and prolonging the storage life of fruit. Sozzi and Beaudry (2007) note that the majority of current usage for 1-MCP is as a supplement to proper postharvest temperature management or controlled atmosphere storage. A number of reviews on the postharvest uses of 1-MCP in produce have been written (e.g., Blankenship and Dole, 2003; Sozzi1 and Beaudry, 2007; Watkins, 2008), and Watkins and Miller (2009) have created a web site posting recent research studies on the use of 1-MCP in produce. The trade name SmartFresh™ (AgroFresh Inc.) is used for the commercial formulation of 1-MCP, and the product is registered for use up to 1 ppm (1000ppb) on mangoes in the USA and a number of other countries (Sozzi and Beaudry, 2007). The availability and registration of 1-MCP varies by country.

Watkins (2008) notes that the application of 1-MCP is best suited for a crop like apples, where the goal is to maintain the crunchy texture from harvest through to consumption. In fruits like mangoes, where the goal is to have a change in texture between harvest and consumption (i.e. the normal softening associated with ripening in these fruits), the use of 1-MCP is more challenging because the requirement is to delay, not inhibit, ripening. In these types of crops careful control of 1-MCP concentration and exposure time must be conducted, which can be challenging in commercial settings. The majority of 1-MCP research has been conducted on apples. In apples, many factors including cultivar, maturity, storage type (CA vs. air), storage temperature, time between harvest and 1-MCP application, packaging or bin materials, and preharvest cultural practices have been show to affect the performance of 1-MCP (Sozzi and Beaudry, 2007; and Watkins, 2008). It is likely that many of these factors would also affect the performance of 1-MCP in other crops including mangoes.

Several studies (e.g., Alves et al., 2004; Hofman et al., 2001; Jiang and Joyce, 2000; and Lalel et al., 2003; and Penchaiya et al., 2006) have shown that the number of days required to ripen mangoes can be delayed by up to several days through the use of 1-MCP. Study results are inconsistent regarding the level of 1-MCP concentration required to achieve the desired ripening delay. Alves et al. (2004) were successful in using low concentrations (30 and 120 ppb) of 1-MCP to delay ripening of ‘Tommy Atkins’ mangoes, while others (Hofman et al, 2001; Jiang and Joyce, 2000; and Lalel et al, 2003) required concentrations that are much higher (25 to 100 ppm) than is typically required for other crops in order to be effective. Wang et al. (2006) found, when applying 1-MCP using vacuum infiltration techniques, a 5-ppm concentration of 1-MCP provided an increase in shelf life of 8 to 12 days. Singh et al. (2007) compared 1-MCP treatments to silver nitrate, gibberellic acid, sodium metabisulphite, and ascorbic acid treatments on ‘Dashehari’ mangoes and found that the 1-MCP treatment was the most effective in delaying ripening. Cocozza et al. (2004) found that sensory judges detected no difference in aroma, color or firmness between untreated and 1-MCP treated 'Tommy Atkins' mangoes. However, Lalel et al. (2003) observed that 1-MCP treatment of ‘Kensington Pride’ mangoes suppressed the development of aromatic volatiles during ripening. Hofman et al. (2001) observed that 1-MCP doubled the decay incidence (stem rots) due to Colletotrichum spp. or Dothiorella spp. in mangoes when compared to untreated fruit.

4.5 Calcium Chloride Treatments

A number of studies have been conducted investigating a calcium chloride treatment for extending the storage life of mango (e.g., Tirmazi and Wills, 1981). The method of Esguerra and Bautista (1984) is often applied where the mangoes are submersed in a cold calcium chloride solution for 2 hours after harvest. In studies of ‘Julie’ (Mootoo, 1991) and ‘Willard’ (Suntharalingam, 1996) mangoes, treatments of 4% to 6% calcium chloride extended the shelf-life of the fruit by 5 to 7 days. Both Tirmazi and Wills (1981) and Suntharalingam (1996) observed skin injury to ‘Kensington Pride’ and ‘Willard’ mangoes, respectively, when treated with 8% calcium chloride solutions.

5 Conclusions

Postharvest management of mangoes is important to their successful marketing. The most critical factor affecting the postharvest shelf life of mangoes is their temperature management. The temperature range of 20 to 23 °C (68.0 to 73.4 °F) will result in fruit of the best appearance, palatability, and decay control when ripening mangoes. Mangoes can be held at 10 to 13°C (50 to 55°F) to extend their shelf life. Holding mangoes outside these temperature ranges will result in fruit with less than optimal quality, and can injure the fruit. The ripening rate can be accelerated by the treatment of mature-green mangoes with 100-ppm ethylene for 24 hours. Relative humidity of 90 to 95% should be maintained during all postharvest handling steps to minimize water loss and shriveling of mangoes.

Several methods have been evaluated to extend the shelf life of mangoes beyond that possible through postharvest temperature management. These methods generally rely on the control of the availability or action of O_2 and CO_2 and ethylene during ripening. Research studies of these techniques typically demonstrate a delay in ripening (and thus an extension of storage life) in the range of 2 to 10 days.

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