The Changes in Physico-Chemical Compositions of 'Irwin' Mango Fruit after Postharvest Treatments under low Temperature Storage

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Abstract

The changes in physico-chemical compositions after postharvest ripening of mango fruit can effectively inhibit with 1-methylcyclopropene (1-MCP) application, chitosan coating and modified atmosphere packaging (MAP) under low temperature storage. 'Irwin' mango fruit were treated with 5 μL L^{-1} 1-MCP for 12 h, dipped with 0.5% chitosan coating, packed in polyethylene (PE) bags and untreated (control) thereafter stored at 10oC. Application of 1-MCP delayed firmness loss, titratable acidity (TA), inhibited increase of electrolyte leakage (EL) during storage. Moreover, 1-MCP prolonged storage life of mango for 32 days which was a 5 day extension or 19% when compared with the control. The PE bags treatment reduced weight loss in comparison with other treatments. Both 1-MCP and chitosan treatments delayed the increase of pH and all treatments reduced fruit decay. In addition, 10°C did lead to chilling injury (CI) symptoms in mango in any of the treatments. Therefore, 1-MCP application can inhibit ripening, maintain physico-chemical compositions, postharvest quality and prolong the storage life of mango during storage low temperature condition in order to expand marketability and the potential for export.

Keywords: 1-methylcyclopropene (1-MCP), chitosan, modified atmosphere packaging (MAP), quality, storage life

Introduction

Mango (*Mangifera indica* L.) is tropical fruit and contained vitamins, minerals and fiber which are essential to human health and export market (Jagtiani et al. 1988; Somsri et al. 2003). Mango is classified as climacteric fruit that shows rapid deterioration after harvest (Wang et al. 2006). The major causes of deterioration are moisture loss (transpiration), mechanical injury, pathological breakdown, elevated respiration and ethylene production (Wang et al. 2006; Planinsirichai and Trainoak, 2007). Additionally, desiccation of mango during transportation, storage and the shelf life period causes its shriveling and reduces the market value of the fruit (Rodov et al. 1997). In this regard, development of postharvest technology relates to quality maintenance and extending the postharvest life is essential for expanding export markets for mango fruit (Rodov et al. 1997; Zhong et al. 2006).

The application of 1-methylcyclopropene (1-MCP) is a feasible technology for ripening inhibition and quality maintenance of harvested fruit, resulting in expanded marketability (Zhong et al. 2006). 1-MCP is an ethylene action inhibitor that has a non-toxic mode of action, with negligible residue (Watkins 2006). In addition, chitosan has an edible coating made from the shells of crab, shrimp, and/or lobster and has been used for cosmetic,

health and agricultural proposes. The coating has also safe and prolongs storage life, reduces microbial growth and controls decay on many fruits such as litchi (Jiang et al. 2005; Vangnai et al. 2006), pummelo (Ratanachinakorn et al. 2005), sugar apple (Chunprasert et al. 2006), strawberry (Hernandez-Munoz et al. 2008) and mango (Abbasi et al. 2009). Furthermore, packaging technology is also used to maintain the postharvest quality of fresh products. For example, modified atmosphere packaging (MAP) is created when fruit are sealed in polyethylene (PE) bags with relatively low permeability to gases. Consequently as the fruit respires (Ding et al., 2002), the O_2 level decreases and the CO_2 level increases within the bags. Other volatiles such as acetaldehyde and ethanol can also accumulate inside the package (Meir et al., 1997; Ding et al., 2002; Cia et al., 2006). In addition, the optimum temperature for mature and half-mature mango storage has considered between 12-13 ºC (Mohammed and Brecht, 2002; Nunes, 2008). On the other hand, mango is highly sensitive to lower temperature storage with below 10-13ºC due to the development of chilling injury (CI) symptoms (Mohammed and Brecht, 2002; Nair and Singh, 2009). The visual symptoms of CI in mango fruit are expressed as dark scald-like peel discoloration, pitting or sunken lesions, uneven ripening, poor colour and flavor development and increased susceptibility to decay (Nair and Singh, 2009; Chaplin et al., 1991). However, The sensitivity of mango to temperature below 10ºC varies with the maturity of the fruit, the cultivar, and the duration and temperature of exposure (Mohammed and Brecht, 2002) and visual symptoms may not develop until the produce is return to higher temperatures (DeEll et al., 2000).

Therefore, the objective of this study was to evaluate the effects of 1-MCP treatment, chitosan coating and packaging (PE bags) on inhibited of the physico-chemical components, maintained postharvest quality and extended the storage life of 'Irwin' mango during storage at 10^{o}C without inducing CI symptoms or negatively affecting storage life.

Materials and Methods

Plant Material

'Irwin' mango fruit (*Mangifera indica* L.) at mature green stage harvested as the commercial maturity about 130 days after anthesis (DAA) from an orchard in Pintung, Taiwan ROC. The fruit were then transported to NPUST within 16 min at 25-28^{o}C. After grading for uniform size and shape, the fruit were assigned to treatments. Mango was treated with 5 µL L^{-1} 1-MCP, 0.5% chitosan, polyethylene (PE) plastic bags (30 µm thickness) and untreated (control). The quality of fruit was evaluated at 5 days intervals during storage.

Sample Preparation

1-MCP Treatment

Fruits were placed in a 137.2 L plastic container and fumigated with 5 µL L^{-1} 1-MCP for 12 h at 25^{o}C. The 1-MCP powder (Ansip, Lytone Enterprise, Inc, Taiwan) was placed inside a glass flask. An aliquot of distilled water was added onto the powder and a rubber septum was used to close the flask. The flask was then placed inside the container, and the once the powder was dissolved. The flask lid was removed immediately before completely sealing the container. Twelve hours later at a temperature of 25^{o}C, the lid of the container was opened and the fruit were then stored at 10oC for 30 days. This modified method followed the procedure used by Alves et al. (2004).

Chitosan Coating Method

The chitosan solution was prepared using the method of Jiang et al. (2005). The 0.5% or 5 g of chitosan powder (Chitosan from shrimp shells, Sigma Chemicals) was dissolved with 50 mL of glacial acetic acid and 900 ml distilled water, to prepare 1.0 L of 0.5% chitosan solutions. The pH of chitosan solution was adjusted to pH 5.0 with 1 M NaOH. Fruit were dipped in chitosan solution and then air-dried with a fan at 25^{o}C, and finally stored at 10^{o}C for 30 day.

Physical Analysis

Weight loss was determined as the difference between the initial and final weight of fruit in each replication. It was expressed as percent (%) using the following equation:

$$\%\text{Weight loss} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

Chemical Analysis

Fruit firmness was measured using a Shimadzu EZ test and a 0.5 mm-diameter plunger set to pierce 1 cm depth. Readings were taken in three positions of fruit area, averaged and recorded in newtons (N).

Titratable acidity (TA) and pH were measured from ten grams of mango pulp was homogenized with 100 ml of deionized water at speed 2 for 30 s with a homogenizer (model Heidolph DIAX 900). The homogenate was filtered using a Whatman No. 1 filter paper. Twenty five ml of solution was drawn from the filtrate in a titratable acid cup using a pipette. Titratable acidity (TA) and pH were measured using a Titrator Mettler Toledo model DL53 and expressed as a percentage (%) of citric acid following the procedure of Chen (2008).

Total soluble solids (TSS) was measured by direct readings of mango juice using a hand-held digital refractometer (Atago Pocket refractometer PAL-1) with results expressed in Brix. The measurement was taken in three positions of fruit area.

Starch content was measured from about 0.05 g of dried mango sample which was dried by using a Freeze Dryer FD-series was added to 5 mL of deionized water and shaken at 120 rpm, 30°C for 3 h. Then the solution was centrifuged at 12,000 x *g* for 10 min (25°C) and the residue retained. The residue was dried in precision ovens (Jih Her Tyan Scientific Co., Ltd., model HIPOINT OV, Taiwan) at 70°C for 12 h. Then, 1 mL of deionized water was added in a centrifuge tube and boiled in hot water bath for 15 min. After cooling, 1 mL of 9.2 N $HClO_4$ (perchloric acid) was added in a centrifuge tube and shaken at 150 rpm, for 15 min. After that the solution was centrifuged at 5000 x*g*, 25°C for 10 min. Then 20 µL of supernatants was added, plus 0.5 mL of 5% phenol and 2.5 mL of H_2SO_4 to each tube and left for 30 min. The solution was measured at a wavelength 490 nm following the procedure as modified from Dubois et al. (1956) and Sadasivam and Manickam (2005) with glucose as the standard. Starch was expressed as percent dry weight (%DW).

Fruit Electrolyte leakage (EL) measurement was modified using a modified method of Suwapanich and Haewsungcharern (2005), Fan and Sokorai (2005) and Dea et al. (2010). Twelve mesocarp tissue plugs (5 mm diameter, 10 mm length) were excised from fresh-cut slices using a No. 5 brass cork borer. The mesocarp plugs were cleaned of damaged cells by rinsing gently with 70 ml deionized water for 3 seconds then incubated in 30 ml solution of 0.7 M mannitol for 3 h (25°C). Thereafter, the electrical conductivity of the solution was measured by using a Conductivity meter (Suntex model SC-23000) as an initial reading. Total electrolytes were determined after freezing at -20°C, thawing, and re-warming to room temperature. EL was expressed as a percentage (%) of the conductivity of total tissue electrolytes and calculated from the following equation:

$$\%\ \text{EL} = \left(\frac{\text{Initial conductivity}}{\text{Total conductivity}}\right) \times 100$$

Fruit Decay

Fruit decay was scored on a scale 1-9 based on the incidence of anthracnose caused by *Colletotrichum gloeosporioides* and stem-end rots caused by *Lasioidplodia theobromae*, *Dothiorella* spp. and *Phomopsis mangiferae* infected fruit using the method of Silva et al. (2004) as 1 = absence of dark spots, skin color alterations and/or lesions, 2 = 1-3% very light dark spots, 3 = 4-6% of light dark spots, 4 = 7-10% of light dark spots, 5 = 11-25% of light dark spots and/or very light lesions, 6 = 26-40% of dark spots, skin color alterations and/or lesions, 7 = 41-60% of dark spots, severe lesions and skin color alterations, 8 = 61-75% of dark spots, severe lesions and skin color alterations and 9 = more than 75% of dark spots and very sever lesions.

Chilling Injury (CI) Symptoms

Chilling injury (CI) symptom in the fruit was assessed after storage by using Nair and Singh

(2009) method. The results were expressed using a rating scale from 0 to 4 as follows: 0 = no damage; 1 = very light damage; 2 = light damage; 3 = moderate damage and 4 = severe damage. Results were expressed as a CI index as per the equation below:

$$\text{CI index} = \frac{\text{CI level} \times \text{Number of fruit at the CI level}}{\text{Total number of fruit in the treatment}}$$

Storage Life

Storage life was determined as the time in days for fruit to completely ripened or reach the limit of acceptability and fruit appeared the symptom of anthracnose and stem-end rots. The fruit were considered ripened when their skin was completely yellow (ho<100). The limit of acceptability was determined by fruit appearance; fruit showing visible dehydration.

Statistical Analysis

All experiments were laid out using a completely randomized design (CRD). Three replicates per treatment were evaluated for fruit quality and storage life of the fruit. The data was analyzed using an Analysis of variance (ANOVA). Where possible, mean comparisons were made using the Duncan's multiple range tests (DMRT) at $p<0.05$. Statistical analysis was carried out using the SAS system.

Results and Discussion

Physical Changes

Weight loss of 'Irwin' mango fruit increased during storage and maintaining fruit in PE bags significantly delayed weight loss during storage (Figure 1A). Loss of fruit weight depends on the gas permeability of plastic film (Somboonkaew and Terry 2010). Modified atmosphere packaging (MAP) in low density polyethylene film held at 10°C markedly restricted water loss in papaya (Gonzalez-Aguilar et al. 2003), oranges (Porat et al. 2004) and carambolas (Ali et al. 2004).

Chemical Changes

Firmness of mango fruit tended to decrease during storage (Figure 1B) because enzymatically mediated degradative changes in the cell walls (Kays 1991). Fruit treated with 5 µL L^{-1} 1-MCP treatment (54.90%) was significantly higher firmness than 0.5% chitosan treatment and untreated (29.04 and 18.61 %, respectively) but did not significantly differ from the PE bags treatment (41.37%) after 15 d storage. Application of 1-MCP treatment maintained firmness until 15 d after storage, after that the fruit started to soften. The use of 1-MCP treated 'Kent' mango fruit for export to Europe or Japan by sea transportation thus decreasing the risk of over ripe fruit and lowering postharvest losses (Osuna-Garcia et al. 2009). The reduction of firmness in several fruits treated with 1-MCP and MA storage in sapodilla (Zhong et al. 2006), avocadoes (Meir et al. 1997), persimmons (Cia et al. 2006) apricots (Fan et al. 2000), mango (Alves et al. 2004; Wang et al. 2006; Penchaiya et al. 2006; Kramchote et al. 2008; Chaiprasart and Hansawasdi 2009; Castro et al. 2009), banana (Jansasithorn and Kanlayanarat 2006), and papaya (Manenoi et al. 2007).

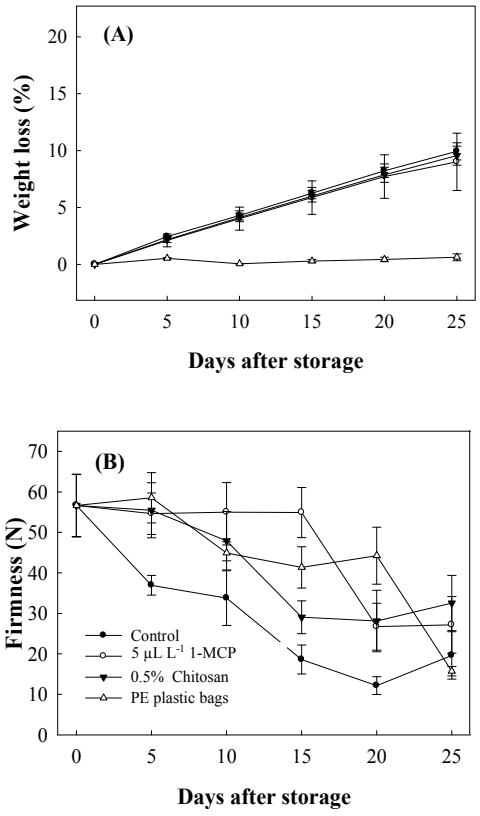

Figure 1 Changes in weight loss (A) and firmness (B) of 'Irwin' mango fruit treated with 1-MCP, chitosan and PE bags during storage at 10°C. Each value is the mean of three replications with SE bar.

The TA in mango fruit decreased during storage and 1-MCP application was delayed the increase of TA to 15 d after storage. TA decreased during storage may due to a reduction in the main organic acids consumption such as malic and citric acids or their conversion to sugars during respiratory metabolism (Alves et al. 2004; Etienne et al. 2013). Moreover, 1-MCP application maintained TA loss in apricot fruit (Fan et al. 2000), mango (Alves et al. 2004; Cocozza et al. 2004; Silva et al. 2004), and sapodilla (Zhong et al. 2006). However, Wang et al. (2006) reported that TA of mango did not change significantly after 1-MCP treatment. Zhong and Xia (2007) found that the application of 1-MCP and chitosan coating did not affect TA loss of Indian jujube fruit during storage.

The pH of mango fruit slightly changed in the initial stages of storage. In this investigation, the increase in pH of untreated fruit was higher than chitosan coating and PE bags but did not significantly differ in 1-MCP at 20 days after storage. The change in pH is due to the effect of the treatment on the biochemical condition of the fruit and a slower rate of respiration and metabolic activity. The increase in pH may due to the breakup of acids through respiration during storage (Abbasi et al. 2009). Moreover, application of PE packaging and chitosan coating were significantly delayed the increase of pH of mango during storage. Chitosan coating has used on fresh produce to maintain quality and extend shelf life (Abbasi et al. 2009). Whereas, MAP did not affect in terms of pH values in persimmon (Cia et al 2006) and bitter orange (Khazaei et al. 2011).

TSS of mango fruit increased until the end of storage. The change in TSS during fruit ripening may be attributed to an increase in the activity of enzymes responsible for the hydrolysis of starch to soluble sugars (Zhong et al. 2006). Application of 1-MCP, chitosan coating and PE bags did not affect the TSS in mango during storage. Cocozza et al. (2004) reported that 1-MCP had no affected on TSS in mango treated with 100 and 500 nL L^{-1} 1-MCP. Manganaris et al. (2007) reported that no differences in TSS content between the control and 1-MCP-treated plum fruit stored directly at 20^{o}C or at 5 or 0^{o}C for 10 days and subsequently transferred to 20^{o}C. Chitosan coating did not retard the increase in the TSS content in pummelo (Ratanachinakorn et al. 2005), sugar apple (Chunprasert et al. 2006) and strawberry (Hernandez-Munoz et al. 2008). These results agree with Khazaei et al. (2011) who reported no significant changes in TSS of bitter orange among normal and active MAP applications (P>0.05).

Starch content of mango fruit tended to decrease after storage and fruits treated with all treatments did not significantly different from the control. The decrease of starch content in fruits during storage was due to the conversion of starch to sugar, which the fruit's sweetness increased (Nunes 2008). Starch hydrolysis in the ripening mango has associated with amylase activity, which exhibits the properties of both α-amylase and β-amylase (Lizada 1993). However, the application of 1-MCP, chitosan coating and MAP treatments did not delay the decrease of starch content in mango fruit.

EL as membrane permeability of mango fruit increased during storage that related with fruit ripening (Figure 2A) because the cell wall in fruit increased the high activity degrading enzymes induce the fruit softening and increasing membrane permeability (Suwapanich and Haewsungcharern 2005). The EL of fruit that treated with 1-MCP application was lower than all the other treatments until 15 days after storage. Therefore, 1-MCP treatment inhibited the increase of EL.

Decay

Decay scale readings of mango fruit treated with 1-MCP, chitosan coating and PE bags after the end of storage (1) were significantly higher than control (5) (Figure 2B). These treatments which delayed the decay of fruit and diseases did not infect in the fruit but the control showed the infection of diseases in 11-25 % of light dark spots and/or very light lesions during storage at 10^{o}C. The results has accorded with Gonzalez-Aguilar et al. (2003) who reported that MAP reduced decay in papaya fruit during storage at 10^{o}C. The rates of product decay index were better in MAP treated nectarine fruits (Akbudak and Eris 2004). Sandhya (2010) who reported that an integrated strategy was developed to control postharvest decay of Embul banana by combining essential oils with MAP. Furthermore, Silva et al. (2004) who reported that 1-MCP treatment effectively maintained the external appearance for mango. Chitosan coating controlled

fruit decay in longan (Vangnai et al. 2006), litchi (Jiang et al. 2005) and strawberry (Hernandez-Munoz et al. 2008). The chitosan induces chitinase, a defense enzyme, which catalyzes the hydrolysis of chitin, a common component of fungal cell walls, thus chitosan prevented the growth of fungi on the fruit (Abbasi et al. 2009).

Chilling Injury (CI) Symptoms

CI symptoms did not appear in mango treated with 1-MCP application, chitosan coating, PE bags and untreated after 25 d storage at 10°C. Therefore, this mango cultivar did not sensitive to CI symptoms during storage under low temperature condition. This may because 'Irwin' mango is sub-tropical fruit that resistant to CI (Paull, 1998). Susceptibility to CI of fruit depended on time and temperature interactions, and genetic differences between cultivars (Holcroft and Mitcham, 1996). Moreover, an optimum storage of tropical fruit recommended at 8-12°C that fruit allowed ripening in this temperature without CI symptoms (Paull, 1998). CI symptoms developed in several mango cultivars during storage at 5-12°C, such as mango cv. Manila (Gutierrez et al., 1997), Tommy Atkins and Keitt cultivars (Pesis et al., 2000), and Kensington Pride cultivar (Nair and Singh, 2009).

Storage Life

Application of 1-MCP prolonged storage life of mango fruit more than 25 days after storage (Figure 3). The storage life of mango treated with 1-MCP extended to 32 days after storage, significantly longer than chitosan coating, PE bags and control (30, 30 and 27 d after storage, respectively). Moreover, no diseases on the fruit surface developed during this time period. The storage life of fruit that treated with the 1-MCP application (19%) compared with control has higher than the chitosan coating and MAP (11%). These results are similar with the studies of Penchaiya et al. (2006) and Jansasithorn and Kanlayanarat (2006), who reported that 1-MCP treatment prolonged the storage life of mango and banana to 15 and 20 days, respectively of storage at 20°C and Zhong and Xia (2007) who reported that Indian jujube fruit treated with 1-MCP and/or chitosan extended storage life at room temperature storage.

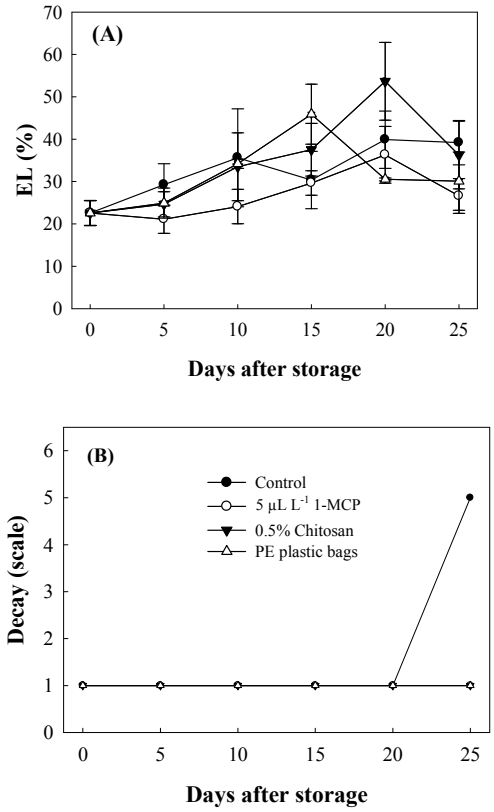

Figure 2 Changes in electrolyte leakage (A) and decay (B) of 'Irwin' mango fruit treated with 1-MCP, chitosan and PE bags during storage at 10°C. Each value is the mean of three replications with SE bar.

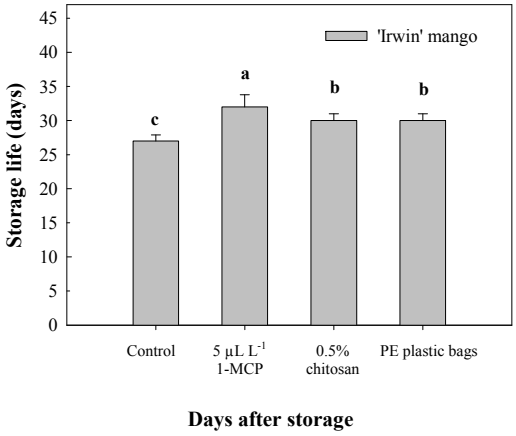

Figure 3 The storage life of 'Irwin' mango fruit treated with 1-MCP, chitosan and PE bags during storage at 10°C. Symbols labeled with the different letter are significantly different at the 95% ($P<0.05$) by DMRT.

Conclusions

Using 1-MCP application maintained firmness, TA and EL. Moreover, it also inhibited the increase of fruit decay and prolonged storage life at 32 days at 10°C. Both MAP and chitosan coating delayed weight loss, firmness loss, pH, prevented the fruit decay. However, this mango cultivar did not sensitive to CI symptoms during storage under low temperature condition. Therefore, using 1-MCP application can uses for ripening inhibition, maintenance of quality and to prolong storage life for postharvest handling in order to commercial market and export options.

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