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Pre-storage putrescine treatment maintains quality and prolongs postharvest life of *Musa acuminata* L.

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Abstract: The study was carried out to determine the effect of putrescine on quality and postharvest life of *Musa acuminata* L. during storage. The fruits were dipped at different concentrations of putrescine (0.5, 1 and 2 mM for 30 min) and distilled water as 'control'. Changes in fruit quality attributes such as weight loss, firmness, skin color (L*, hue angle), total soluble solids (TSS), titratable acidity (TA), pH, ascorbic acid, polyphenol oxidase (PPO) and polygalacturonase (PG) enzymatic activity were calculated at harvest and after 5, 10, 15 and 20 days of storage at 0±1°C, 80-85% relative humidity. Weight loss, fruit softening, skin color changes, TSS, pH, the activity of PPO and PG increased during fruit ripening but the rate of changes was significantly slowed in putrescine treated fruits. Moreover, putrescine application maintained higher levels of TA, ascorbic acid and reduced the loss of sensory acceptability and decay incidence compared to control. In conclusion, the postharvest dip treatment of putrescine could be an effective means for extending the storage life of *Musa acuminata* L.

1. Introduction

Banana (*Musa* spp.) is a climacteric fruit; therefore, ripening process is induced by ethylene production via ACC (1-aminocyclopropane 1-carboxylic acid) biosynthesis. The rate of respiration is followed by reaching a threshold level of ethylene within the cells of fruit then rises rapidly to a peak and subsequently falls as ripening progress. During fruit softening, starch is turned to sugars, the peel color changes to yellow and fruit flavor develop by losing its astringency (Pathak *et al*., 2003).

Polyamines as natural compounds suppress ethylene synthesis by inhibition of ethylene biosynthesis enzymes activities (Lee *et al.*, 1997). They are present ubiquitously in plant organs. The main polyamines are putrescine (1, 4-diaminobutane), spermidine (*N*-3-aminopropyl-1, 4-diaminobutane), and spermine [bis (*N*-3-aminopropyl)-1, 4-diaminobutane] which are essential in plant growth, differentiation and stress responses (Valero and Serrano, 2010). They are known to improve the storage life of fruits by inhibiting ethylene production and delaying the ripening process, respectively.

Polyamines and ethylene have opposite impacts on fruit ripening and senescence. Thus, a balance between them is crucial to enhance and retard the fruit ripening process. In general, polyamines level declines throughout fruit senescence along with accelerating ethylene synthesis (Valero *et al*., 2002).

Much researches have indicated the positive effects of pre and postharvest polyamines application on retarding fruit softening in mango (Malik *et al*., 2003) and pear (Franco-Mora *et al*., 2005), reducing weight loss in apricot (Martinez-Romero *et al*., 2002), inhibition of ethylene production in peach (Zokaee Khosroshahi and Esna-Ashari, 2008), delaying ripening process in nectarine (Torrigiani *et al*., 2004) and peach (Bregoli *et al.*, 2002), and maintaining TA at higher levels, diminishing the increase in TSS, and declining color change in plum (Khan *et al*., 2008).

Thus, the present study was carried out to evaluate the application of putrescine for extending quality and storage life of *Musa acuminata* L.

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2. Materials and Methods

Mature green bananas (*Musa acuminata* L.) were harvested from a commercial orchard in Minab, Iran, and then transported to the laboratory for experiments. Fruits uniform in size and color, without any noticeable defects, were selected and dipped in putrescine solution at different concentrations (0.5, 1 and 2 mM for 30 min) and distilled water as 'control'.

Then all of treated and untreated fruits were stored at 13°C and 80-85% relative humidity. Then, some physico-chemical attributes were measured at harvest and after 5, 10, 15 and 20 days of cold storage.

Quality parameters evaluation

Fruit weight was recorded just after harvest and after the different sampling dates and then expressed as percentage of weight loss relative to the initial weight (Soto-Zamora *et al*., 2005).

Fruit firmness was measured using a FG-5020 penetrometer (Lutron Electronic Enterprise Co.) of 5 mm in diameter at 2 equatorial points and was expressed as newton (N).

Color was determined at opposite sides of each fruit from each replicate with a Minolta Chromameter CR400; the following parameters were considered: L* (0= black; 100= white), a* (green to red) and b* (blue to yellow) then expressed as L* and hue angle (h°)= arctan (b* a^{*-1}) (Ozdemir, 2016).

Total Soluble solids (TSS) content was assessed by a digital refractometer (Atago N1, Japan) at 20˚C and expressed as a percent. Titratable Acidity (TA) was estimated by titrating 5 ml of diluted juice against 0.1 N NaOH using phenolphthalein as an indicator and was expressed as percent malic acid (%). The pH of fruit juice was measured using a MTT65 (Japan) pH meter calibrated by pH 4 and 7 buffer solutions.

Ascorbic acid assessment

Ascorbic acid content was estimated using the methods of Marisa and Wall (2006).

Polyphenol oxidase (PPO) and Polygalactronase (PG) activities measurement

PPO and PG were assessed using the procedure of Marquez Cardozo *et al.* (2015) and Zhu *et al.* (2015) respectively.

Decay incidence and sensory acceptability determination

Fruit deteriorations were measured on individual fruit by visual observations. From each fruit 5 slices were obtained and fruits decay was recorded using the following formula: A/B ×100 in which A is the number of decayed fruit slices and B the initial number of all fruit slices.

The fruits were rated by a panel of 10 judges on the basis of color, texture, taste and flavor and overall acceptability (as 1-2 unusable, 3-4 unsalable, 5-6 salable, 7-8 good, 9-10 very good).

Statistical analysis

To estimate storability of fruit, a factorial design completely randomized was carried out in three replications. All data were analyzed using SAS software package 9.4 for windows and mean comparisons were conducted using Duncan's multiple range tests.

3. Results and Discussion

Weight loss and firmness

Weight loss percentage increased in all the treatments along the storage. However, all putrescine concentrations demonstrated significantly lower weight loss than control. Fruits treated with 2 mM putrescine exhibited the lowest weight loss amongst the putrescine concentrations during storage while highest weight loss was registered by control (Fig. 1 A). The effect of putrescine on reducing weight loss

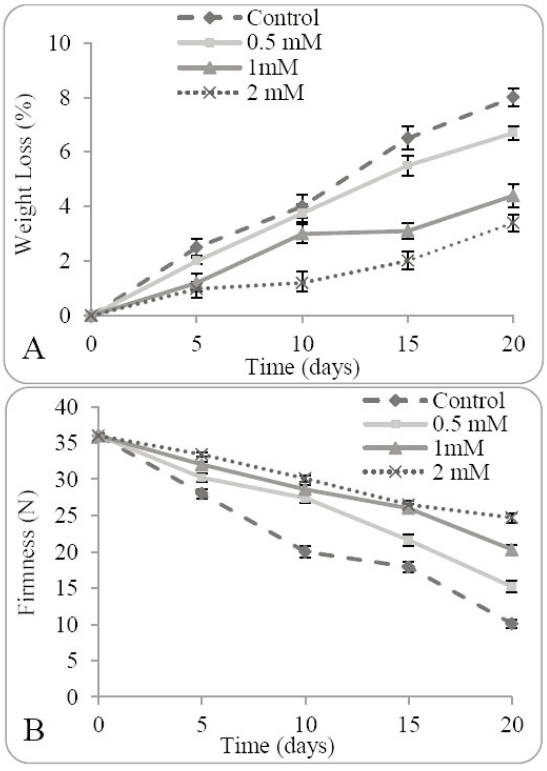

Fig. 1 - The effect of putrescine at different concentrations (0.5, 1 and 2 mM) on weight loss (A) and firmness (B) of *Musa acuminata* L. during storage.

may be ascribed to conjugation of polyamines to the cell membrane phospholipids that result in cell membrane integrity (Mirdehghan and Rahimi, 2016). Similar results have been reported in apricot (Enas *et al.*, 2010).

As shown in figure 1B irrespective of treatments, fruit firmness decreased significantly over storage but putrescine treated fruits were observed firmer, and especially 2 mM putrescine treatments was more effective than others in keeping the firmness. It is suggested that polyamines maintain fruit firmness by their cross-linkage to the pectin substances carboxyl groups in the cell wall and lead to rigidification of cell wall; consequently cell wall degrading enzymes activities of pectin methyl esterase (PME), pectin esterase (PE) and polygalactouronase (PG) are decreased (Valero *et al*., 2002). The results are in line with peach (Bregoli *et al*., 2002).

Color changes

Skin color alteration from green to yellow is a predominant index used for evaluating the stage of ripening in banana (Gomes *et al.*, 2013). As the storage time progressed, fruit color changed as a result of chlorophyll degradation along with carotenoid synthesis. However, putrescine treated fruits showed higher L* and hue angle than control (Fig. 2 A and B).

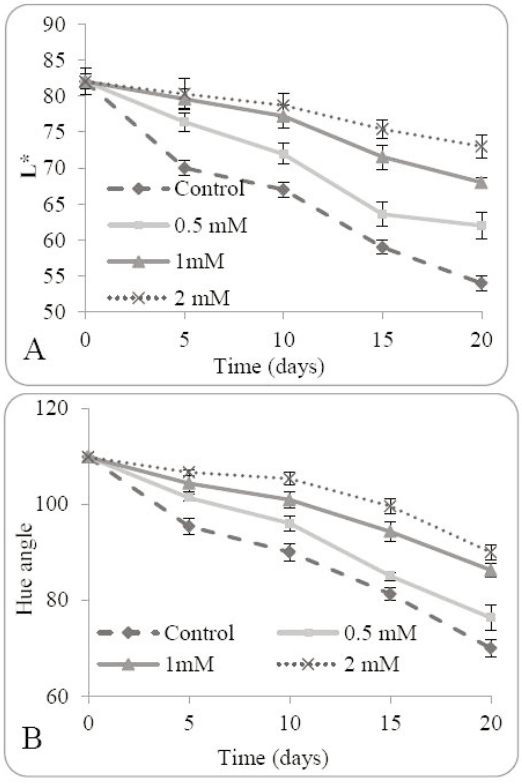

Fig. 2 - The effect of putrescine at different concentrations (0.5, 1 and 2 mM) on L* (A) and hue angle (B) of *Musa acuminata* L. during storage.

Delayed color changes can be associated to the effect of putrescine as anti-senescence by reducing ethylene production and subsequently delaying fruit ripening as well as senescence (Drake and Chen, 2000). Similar results have been observed in apricot (Martinez-Romero *et al*., 2002).

Total soluble solids (TSS), titratable acidity (TA) and pH

TSS content and TA increased along the storage period while pH demonstrated reverse trend in all treated and untreated fruits (Fig. 3 A, B and C). Lower

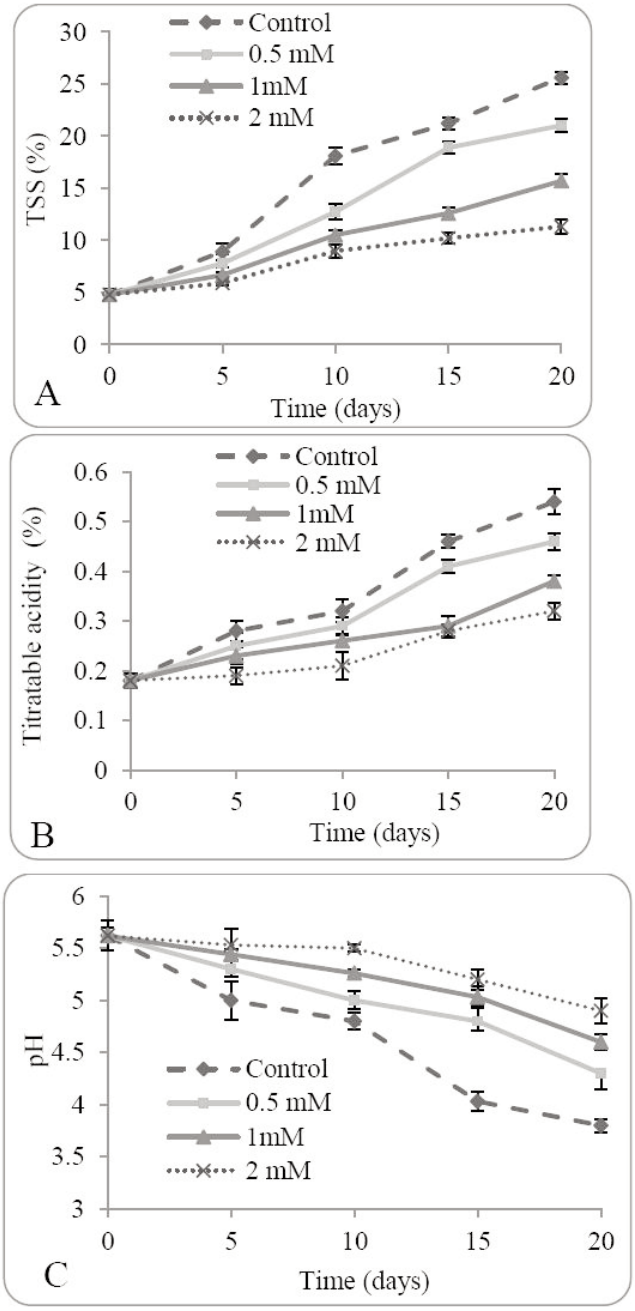

Fig. 3 - The effect of putrescine at different concentrations (0.5, 1 and 2 mM) on TSS (A), TA (B) and pH (C) of *Musa acuminata* L. during storage.

values of TSS, TA and higher value of pH content were observed in putrescine treated fruits compared to control (Fig. 3). That is ascribed to the role of putrescine on delaying fruit ripening process by reducing ethylene production and respiration rate in fruit (Valero *et al*., 2002). The results are in agreement with those observed in mango (Malik and Singh, 2006).

Ascorbic acid

The content of ascorbic acid was significantly influenced by putrescine. The value of ascorbic acid was higher in treated fruits than control throughout the storage (Fig. 4). It is possible that putrescine inhibits ascorbic acid oxidation by decreasing ascorbate oxidase activity and consequently maintaining ascorbic acid (Ishaq *et al*., 2009). This result is in line with the finding of Davarynejad *et al.* (2013).

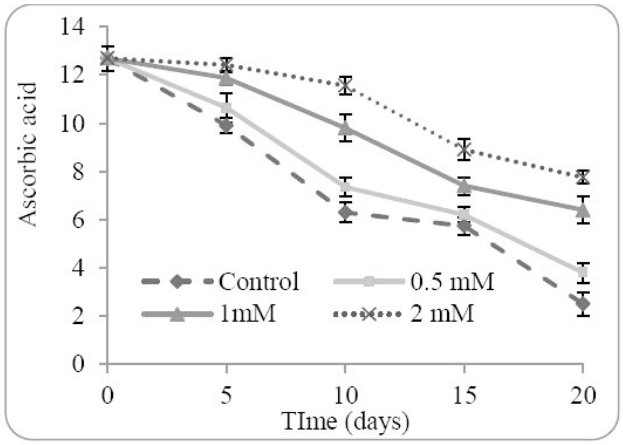

Fig. 4 - The effect of putrescine at different concentrations (0.5, 1 and 2 mM) on ascorbic acid of *Musa acuminata* L. during storage.

Enzymatic activity of polyphenol oxidase (PPO)

Irrespective of treatments, the activity of PPO increased during ripening process and it was significantly higher in control than treated fruits (Figure 5 A). This trend may be attributed to the role of putrescine on reducing polyphenol oxidase activity (Koushesh saba *et al*., 2012). Previously, it has been observed in kiwifruit (Jhalegari *et al*., 2012).

Polygalacturonase (PG) activity

PG is known as an important enzyme on fruit softening, whereas, a reduction in PG activity results in a delay in fruit softening and consequently an increase in the storage life (Jhalegari *et al*., 2012). In this study, the activity of PG increased during the storage. As shown in figure 5 B, untreated fruits demonstrated the highest values of PG activity (1.74 mmol kg^{-1} s^{-1} on the 20th day of storage). Fruits treated with 2 mM exhibited the lowest PG activity, followed by putrescine at 1 and 0.5 mM respectively. This trend is associated to declining fruit firmness and increasing fruit softening by the loss of membrane integrity (Sitrit and Bennett, 1998).

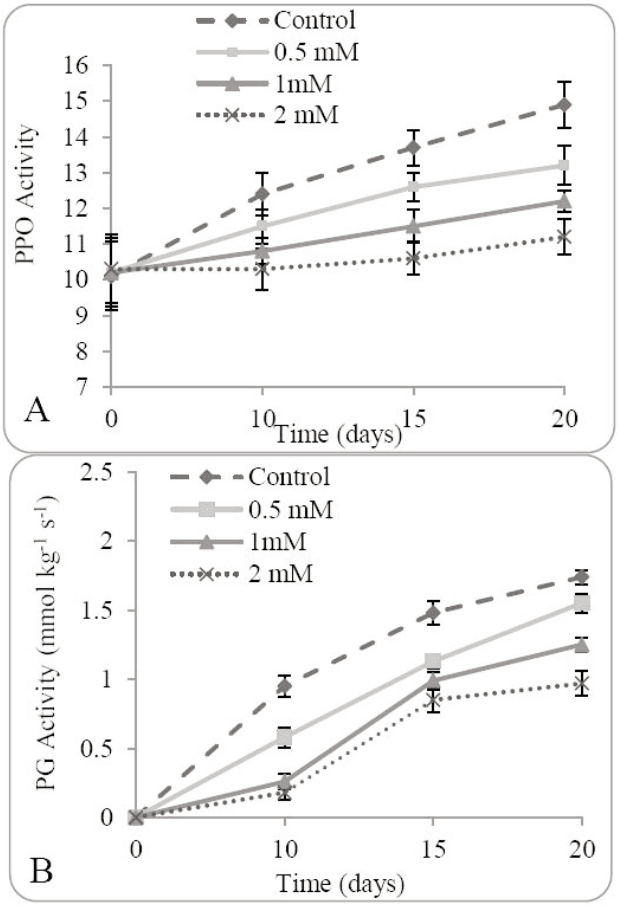

Fig. 5 - The effect of putrescine at different concentrations (0.5, 1 and 2 mM) PPO (A) and PG (B) activities of *Musa acuminata* L. during storage.

Decay incidence and sensory acceptability

The highest rate of fruit decay percent was observed in control while all three concentrations of putrescine reduced the decay development significantly during storage; in particular, the fruits dipped in 2 mM putrescine showed the lowest decay incidence in comparison to others (Fig. 6 A). While time passed, sensor acceptability declined. However, fruit treated by putrescine exhibited higher scores of sensor acceptability compared to control at the end storage (Fig. 6 B).

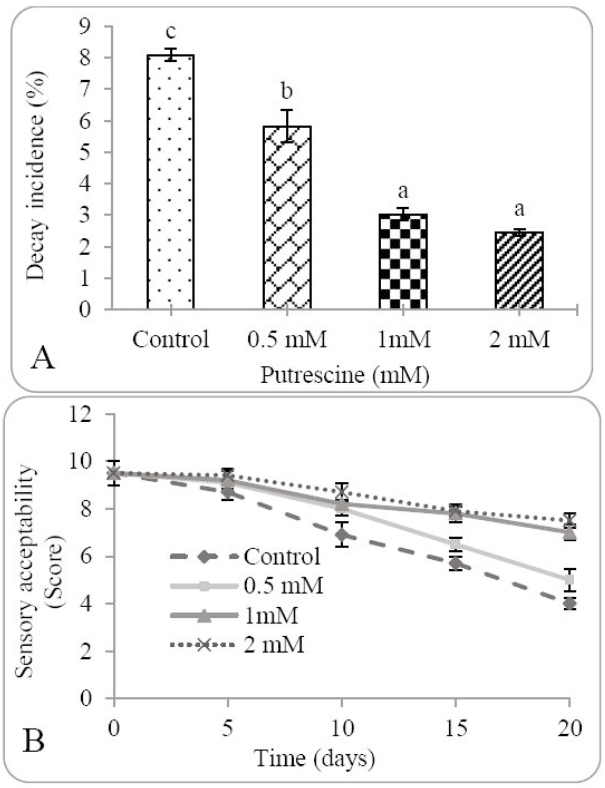

Fig. 6 - The effect of putrescine at different concentrations (0.5, 1 and 2 mM) on decay incidence (A) and sensory acceptability (B) of *Musa acuminata* L. during storage.

4. Conclusions

The effect of putrescine treatment at different concentrations (0.5, 1 and 2 mM for 30 min) was investigated to improve and extend storage life of banana (*Musa acuminata* L.). Application of putrescine maintained fruit quality attributes such as firmness, color, TSS, TA, pH and sensory acceptability. In addition, the reduction of weight loss, PPO, PG, and decay incidence were observed in putrescin treated fruits compared to control. Thus, the postharvest dip treatment of putrescine may be an effective tool for prolonging the storage life of *Musa acuminata* L.

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