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Effects of putrescine treatment on the quality attributes and antioxidant activities of 'Nam Dok Mai No.4' mango fruit during storage

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ABSTRACT

This research is aimed at investigating the benefits of the exogenous application of putrescine on the postharvest quality and antioxidant activities of 'Nam Dok Mai No.4' mango. Mangoes harvested at commercial maturity were dipped into 1, 2, and 4 mmol/L putrescine (PUT) for 20 min while distilled water was used as the control. Treated fruit were stored at 14 °C for 9 days and then transferred to storage at 25 °C for 9 days. The 2 mmol/L PUT proved to be the most effective in keeping mango fruit quality intact during fruit ripening. Fruit hardness and titratable acidity (TA) were observed to be higher in treated fruit. The PUT treatment also caused a reduction in weight loss and soluble solids content (SSC). Moreover, 2 mmol/L PUT treated fruit exhibited the maximum superoxide dismutase (SOD), catalase (CAT), guaiacol peroxidase (GPOX), ascorbate peroxidase (APX) and glutathione reductase (GR) activities and total antioxidant contents of fruit during storage. These findings suggest that exogenous application of 2 mmol/L PUT could be an effective treatment for prolonging the storage life and enhancing antioxidant activities of 'Nam Dok Mai No.4' mango after harvest.

1. Introduction

Mango *(Mangifera indica* L.) is one of the most popular fruits in both the domestic and international markets because of its attractive aroma and great taste. Furthermore, with regard to nutrition, mango is appreciated for its rich mineral and vitamin content, including vitamin C, vitamin A, carotenoid and polyphenolic compounds (Masibo and He, 2008). It is well known that mango is a climacteric fruit which ripens quickly and has a short postharvest life, a major hurdle in prolonging its supply period in the international market (Ding et al., 2007). Various methods have been used to extend shelf life of mango fruit such as modified atmosphere packaging (Kumpoun and Uthaibutra, 2010), cold-shock treatment (Zhao et al., 2006), hot water treatment (Yimyong et al., 2011) and application of polyamines (Razzaq et al., 2014, Jongsri et al., 2017). Interestingly, a safe and potentially effective method for maintaining the storage life and quality of mango is the application of polyamines.

Polycationic nature of polyamines, small organic metabolites, causes them to interact with negatively charged molecules such as phospholipids, protein, and nucleic acid which leads to antioxidant properties and the ability to protect cell from abiotic stresses (Kusano et al., 2008). Polyamines are growth regulators associated with numerous metabolic processes in plants including fruit maturation, fruit ripening, fruit softening, and fruit senescence (Gill and Tuteja, 2010a). Exogenous putrescine (PUT) has been reported to inhibit ethylene production, delay fruit ripening, and maintain fruit hardness in Kiwi fruit (Petkou et al., 2003). Polyamine treatments have also been found to reduce weight loss and maintain hardness in apricot (Davarynejad et al., 2013).

During fruit ripening, excessive production and accumulation of reactive oxygen species (ROSs) cause oxidative damage and consequently reduce antioxidant ability to eliminate ROSs such as superoxide, hydroxyl radical, and hydrogen peroxide. If not scavenged, ROSs rapidly react with various molecules including DNA and proteins, resulting in membrane lipid peroxidation and ultimately causing cell death (Blokhina et al., 2003). The formation of ROSs is scavenged by the stimulation of antioxidant defense enzymes, e.g., superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), peroxidase (POX), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), guaiacol peroxidase (GPOX), and glutathione reductase (GR) (Gill and Tuteja, 2010b). Polyamines also play a role in non-enzymatic and enzymatic antioxidant systems (Gupta et al., 2013). It has been found that PUT treatment increased DPPH scavenging capacity and phenolic compounds in 'Lasgerdi' and 'Shahrodi' apricots (Davarynejad et al., 2013). Moreover, SOD, CAT and POX exhibited higher activities in 'Bagheri' and 'Asgarabadi' apricots (Saba et al., 2012) and 'Samar Bahisht Chaunsa' mango (Razzaq et al., 2014). However, information on the association of PUT treatment, non-

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Table 1
Effect of putrescine treatments on weight loss, firmness, SSC and TA of mango after storage at 14 °C and shelf life at 25 °C.

Storage and shelf life periods	Putrescine treatment	Weight loss (%)	Firmness (N)	SSC (°Brix)	TA (%)
0	Control	0 g	8.77 ± 0.07 a	9.28 ± 0.23 h	2.39 ± 0.06 a
	1 mmol/L	0 g	8.75 ± 0.06 a	9.38 ± 0.20 h	2.28 ± 0.10 a
	2 mmol/L	0 g	8.84 ± 0.05 a	9.38 ± 0.21 h	2.45 ± 0.02 a
	4 mmol/L	0 g	8.78 ± 0.05 a	9.16 ± 0.18 h	2.38 ± 0.08 a
9	Control	4.65 ± 0.22 e	8.72 ± 0.04 a	13.49 ± 0.34 g	1.40 ± 0.04 b
	1 mmol/L	4.52 ± 0.25 ef	8.73 ± 0.05 a	13.57 ± 0.32 g	1.45 ± 0.06 b
	2 mmol/L	3.73 ± 0.20 f	8.73 ± 0.05 a	13.33 ± 0.47 g	1.48 ± 0.05 b
	4 mmol/L	4.36 ± 0.17 ef	8.70 ± 0.04 a	13.33 ± 0.72 g	1.35 ± 0.03 bc
9 + 3	Control	5.99 ± 0.26 d	8.72 ± 0.22 c	16.91 ± 0.09 abc	1.12 ± 0.09 de
	1 mmol/L	5.81 ± 0.35 d	8.81 ± 0.25 bc	16.80 ± 0.31 abc	1.24 ± 0.07 cd
	2 mmol/L	4.84 ± 0.22 e	8.11 ± 0.08 b	14.76 ± 0.58 ef	1.46 ± 0.02 b
	4 mmol/L	5.65 ± 0.26 d	7.27 ± 0.20 d	17.79 ± 0.22 a	1.07 ± 0.06 e
9 + 6	Control	7.78 ± 0.30 bc	6.49 ± 0.13 fg	17.75 ± 0.19 a	0.18 ± 0.02g
	1 mmol/L	7.46 ± 0.39 c	6.78 ± 0.07 ef	16.23 ± 0.23 cd	0.26 ± 0.02 fg
	2 mmol/L	6.10 ± 0.41 d	7.00 ± 0.07 de	15.58 ± 0.19 de	0.35 ± 0.01 f
	4 mmol/L	7.32 ± 0.31 c	6.30 ± 0.22 g	17.23 ± 0.15 ab	0.16 ± 0.02 g
9 + 9	Control	9.93 ± 0.30 a	5.69 ± 0.15 f	17.75 ± 0.19 a	0.12 ± 0.01 h
	1 mmol/L	9.61 ± 0.45 a	5.60 ± 0.13 f	17.76 ± 0.31a	0.12 ± 0.01h
	2 mmol/L	8.49 ± 0.27 b	6.21 ± 0.08 g	16.53 ± 0.36 bc	0.17 ± 0.00 g
	4 mmol/L	9.57 ± 0.37 a	5.77 ± 0.11 f	17.70 ± 0.21 a	0.11 ± 0.01h

[a]Means in a column followed by a different letter for the same storage period were significantly different at p = 0.05 by Duncan's Multiple Range Test while ns showed no significance. Data are accompanied by standard errors of the means (n = 4).

enzymatic and enzymatic antioxidant systems, and hydrogen peroxide content in mango was lacking. Therefore, the aim of this work was to investigate the postharvest roles of PUT on quality attributes and antioxidant enzyme activities including SOD, CAT, GPOX, APX, and GR as well as free radical scavenging capacity and hydrogen peroxide content of mango cultivar 'Nam Dok Mai No.4' after cold storage and further shelf life at 25 °C.

2. Materials and methods

2.1. Plant materials and fruit treatment

Mango fruit (*Mangifera indica* L. cv. 'Nam dokmai No.4') were harvested 90–100 days after fruit set which is the physiologically mature stage (the weight range is 350–450 g and average soluble solids content is 9.3 ± 0.4°Brix) from Saichon Commercial Orchard in Nakhon Ratchasima province, Northeast, Thailand. Afterward, mangoes were selected based on uniformity of size, color, and disease-free. Then, fruit were immediately transported to the laboratory. Before the application of treatments (day 0), 32 mangoes were sampled to monitor fruit characteristics. After which, mangoes were randomly distributed into 4 replicate groups of 160 fruit each. Fruit were immersed for 20 min in 1, 2, and 4 mmol/L putrescine (PUT) while distilled water was used as the control. All solution contained tween-20 (0.2%) to improve the absorption of the polyamine, and mangoes were left to dry before storage. In order to simulate the storage and exporting procedure of the commercial production of mango fruit, all of the control and treated fruit were stored at 14 °C and 90 ± 5% relative humidity for 9 days, and after which, fruit were transferred to 25 ± 1 °C and 65 ± 5% relative humidity and randomly sampled at 3, 6, and 9 days of shelf life at 25 °C (room temperature). The mesocarp were collected, frozen in liquid nitrogen, and stored at −80 °C for analysis of enzyme activities and total protein.

2.2. Fruit quality measurements

2.2.1. Weight loss

In order to evaluate any weight loss during the storage period, the same samples were consistently measured. The weight loss was calculated by AOAC (1984) as the following equation:

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

2.2.2. Fruit hardness

Fruit hardness was determined at 3 points on the mango (blossom end, middle and stem end of the fruit) by using a penetrometer (Hardness tester FHM-1, Takemura, Japan) with a 12 mm cylindrical probe at a test speed of 1 mm/s. Results were expressed as force in Newtons (N) (Chancharoenrit, 2002).

2.2.3. Soluble solids content (SSC)

The soluble solids content was measured with a hand-held refractometer (Atago N-1E, Atogo Co., Japan) and reported as °Brix.

2.2.4. Titratable acidity (TA)

Titratable acidity (TA) method was applied from AOAC (1984). One hundred mL of distilled water was mixed with 10 g of sliced mango pulp. Afterward, the macerate was filtered and titrated with 0.1 mol/L NaOH using phenolphthalein as the indicator. The reading for TA was expressed as a percentage of citric acid and was calculated as follows:

$$\%\text{TA} = \frac{\text{NaOH (mL.)} \times 0.1 \quad \text{NaOH (mol/L)} \times 0.07}{10\text{g}} \times 100$$

2.2.5. Peel color

Peel color of mango was measured by using colorimeter (Konica Minolta Sensing, Inc., Japan) as Lightness (L) and hue angle value. The measurement was made from three equatorial positions of the mango peel (blossom end, middle and stem end).

2.3. Enzyme extraction and antioxidant enzyme activity assay

The activity of SOD, CAT, GPOX, APX, and GR was measured using 1 g of endogenous sample homogenized in 50 mmol/L potassium phosphate buffer (pH 7.0) containing 4% (w/v) polyvinylpyrrolidone, 4 mmol/L dithiothreitol, and 1 mmol/L phenylmethylsulfonyl. The homogenate was centrifuged at 10000*g* for 15 min at 4 °C, and the supernatant was used to assay for antioxidant enzyme activities.

2.3.1. SOD determination

SOD activity was analyzed using the method of McCord and