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Effect of molecular weights of chitosan coating on postharvest quality and physicochemical characteristics of mango fruit

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ABSTRACT

'Nam Dok Mai' mango is an important export fruit of Thailand. However, the quality of fruit is reduced after harvest. Therefore, it is necessary to develop a postharvest treatment to maintain the quality of 'Nam Dok Mai' mango after harvest. Chitosan solutions (high molecular weight (HM-CTS), medium molecular weight (MM-CTS), and low molecular weight (LM-CTS)) were applied as fruit coating for 'Nam Dok Mai' mango (*Mangifera indica* L.) and stored at 25 °C for 16 days. The film forming properties of chitosan were influenced by molecular weight and significantly impacted postharvest quality of mango fruit during storage. HM-CTS could delay mango fruit ripening and thus maintaining the highest value of titratable acidity, fruit firmness, and also resulting in a reduction of weight loss, ethylene production, and respiration rate of mango fruit. Moreover, HM-CTS coated fruit exhibited no incidences of disease throughout storage. DPPH inhibition and ascorbic acid content were maintained in coated fruit during storage. H_2O_2 content was inhibited by catalase and ascorbate peroxidase activities in HM-CTS coated fruit. These data indicated that the application of HM-CTS could be used to reduce deteriorative processes, maintain quality, and increase the shelf life of 'Nam Dok Mai' mango during postharvest storage.

1. Introduction

Mango (*Mangifera indica* L.) is a popular tropical fruit that is in high demand around the world (Kim, Brecht, & Talcott, 2007) because of its nutritional properties, attractive fragrance, aesthetic color, and excellent exotic flavour (Ulloa, Guatemala, Arriola, Escalona, & Díaz, 2009). However, mango is a climacteric fruit which quickly ripens and softens after harvest because of high ethylene synthesis, and in addition to accelerated ethylene synthesis, chilling injury can occur if mango is stored at temperatures under 13 °C for several days (Acosta et al., 2000). Moreover, anthracnose caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. is a major postharvest disease in mango where the pathogen can attack immature fruit (Dodd, Prusky, & Jeffries, 1997). These severe problems of postharvest mango cause reduction in the quality of fruit during storage, transport, and marketing period (Mitra & Baldwin, 1997). Fungicides are used to resolve the problem caused by anthracnose despite many countries having concerns over toxic residues and human health (Bautista-Banos et al., 2006). Thus, it is necessary to develop alternative postharvest technologies to better maintain overall mango fruit qualities during the export chain or market period.

Fruit coating is becoming one of the most popular methods to extend the commercial shelf-life of fruits by delaying ripening, water loss, and decay (Baldwin, Nisperos, Hagenmaier, & Baker, 1997). Coatings can lead to a change in the composition of the atmosphere surrounding the fruit which results in creating a modified atmosphere (MA) that can act as a barrier to gas exchange, especially for O_2, CO_2, and ethylene. Storage under MA allows for some controls of fruit softening and senescence. In addition, fruit coating can maintain fruit quality by slowing fungal development and improving appearance during transportation and storage (Amarante & Banks, 2001; Baldwin, 1994).

Chitosan (poly-β-(1,4)-D-glucosamine), a deacetylated form of chitin (poly-*N*-acetylglycosamine), has been widely used as fruit coating (Djioua et al., 2010; Ippolito, El-Ghaouth, Wisniewski, & Wilson, 2000; Jiang & Li, 2001; Rinaudo, 2006) due to its film-forming property, biocompatibility, and biodegradability (Shahidi,

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Arachchi, & Jeon, 1999). Chitosan coating can create MA (Baldwin, Nisperos, Shaw, & Burns, 1995) that decrease the response of fruit to environmental conditions by reducing gas exchange leading to retardant ripening, water loss, respiration rate, and ethylene production (Baldwin et al., 1997; Jitareerat, Paumchai, Kanlayanarat, & Sangchote, 2007). Chitosan can act as an exogenous elicitor inducing activities of several defense-related enzymes and accumulating special substances in some plants (Cabrera, Messiaen, Cambier, & Van, 2006; Trotel-Aziz, Couderchet, Vernet, & Aziz, 2006), which are known to participate in defense mechanisms and to prevent pathogen infections. The effects of chitosan coatings on the extension of storage life of many fruits were reported (Ampaichaichok, Rojsitthisak, & Seraypheap, 2014; Chien, Sheu, & Lin, 2007; Zhang & Quantick, 1998). It was found that coating 'Nam Dok Mai' mango fruit with 1% chitosan (Mw 350 kDa) could maintain ascorbic acid content, weight loss, peel color change, and total titratable acidity while reducing respiration rate and ethylene production. In addition, the treated fruit showed higher chitinase and β-l,3-glucanase activities than control fruit (Jitareerat et al., 2007).

To date, there are few reports on the effect of different molecular weights of chitosan coatings on fruit storage, especially in 'Nam Dok Mai' mango fruit. Therefore, the aims of this study are to develop a fruit coating for mango that improves fruit shelf life and quality, and to further investigate the effect of different molecular weights of chitosan on postharvest qualities and physicochemical characteristics of mango fruit during storage.

2. Materials and methods

2.1. Chitosan materials

Chitosan flakes prepared from shrimp shells were obtained from A.N. Lab, Thailand. Chitosan properties were analyzed for molecular weight (Gel Permeation Chromatography (GPC, Water 600E, Waters Corp., USA)), solubility (Robert, 1992), moisture content (AOAC International, 2000), deacetylation degree (Muzzarelli & Rocchetti, 1985), and viscosity (Brookfield Viscometer, model DV-II+, Japan). Chitosan materials were divided into three different molecular weight groups: high molecular weight chitosan (HM-CTS: 360 kDa), medium molecular weight chitosan (MM-CTS: 270 kDa), and low molecular weight chitosan (LM-CTS: 40 kDa). One percent (w/v) chitosan solution was prepared in 0.5% (v/v) acetic acid; the solution was then stirred at 25 °C overnight. After stirring, the solution was amended with 0.1% (w/v) tween® 80 and stirred at room temperature for 30 min before treatment.

2.2. Plant materials and treatments

Mature green mango (*Mangifera indica* L. cv Nam Dok Mai) fruit were harvested 90–100 days after fruit set from a commercial orchard in Nakornratchasrima province, Thailand. Afterwards, fruit were selected for their uniformity in size, color, shape, and as well as lack of blemishes and disease symptoms. The 160 fruits were separated into 4 replications for each treatment. Fruit were dipped for 1 min into a solution of 1% (w/v) HM-CTS, MM-CTS, and LM-CTS. The control fruit were dipped in 0.5% acetic acid containing 0.1% tween® 80. After treatment, fruit were air-dried for 30 min and stored at room temperature (25 ± 2 °C). Every 4 days, 32 fruits were randomly sampled until day 16.

2.3. Scanning electron microscopy (SEM) analysis

Thickness and surface properties of chitosan coating film were measured by using a scanning electron microscope (FEI Quanta 250 ESEM, Netherlands) with voltage set at 10 kV.

2.4. Respiration rate and ethylene production

Fruit from each treatment were weighed and placed in 2.4 L jars fitted with a rubber septum for 1 h at 25 °C. One mL sample of the internal atmosphere was extracted and injected into a gas chromatograph equipped with a thermal conductivity detector (GC-RIA, Shimadzu, Kyoto, Japan) for carbon dioxide. The column temperature for carbon dioxide was at 50 °C and helium was used as the carrier gas. The respiration rate measured by CO_2 production was expressed in mg CO_2 kg^{-1} h^{-1}.

For ethylene, one mL sample was analyzed using a gas chromatograph (GC-14, Shimadzu, Kyoto, Japan) equipped with a flame ionization detector held at 80 °C using nitrogen as the carrier gas. Ethylene levels were determined and expressed as μL kg^{-1} h^{-1}.

2.5. Peel color

Mango peel color was determined by using colorimeter (Color Reader CR-10, Konica Minolta Sensing, Inc., Japan). Lightness (L) and hue angle value were measured for peel color change. The measurement was taken from three equatorial regions of the fruit peel (blossom end, middle, and stem end).

2.6. Fruit firmness

Pulp firmness was evaluated by using a handheld penetrometer (Hardness tester FHM-1, Takemura, Japan) on the same three regions as for the peel color measurement. Firmness was recorded as kg-force in Newtons (N).

2.7. Percentage of weight loss

Weight loss was calculated as percentage loss from initial weight. Fruit were weighed regularly to determine weight loss using formula as described by AOAC (1984).

2.8. Titratable acidity (TA)

The titratable acidity analysis method was applied from AOAC (1984). One hundred mL of distilled water was mixed with 10 g of sliced mango pulp by vortex for 1 min and filtered. Ten mL of filtrate was titrated with 0.1 N NaOH. Filtrate was added with 1% phenolphthalein indicator; then titrated until the end point. The TA (%) was calculated as follows:

$$TA(\%) = \frac{NaOH(mL) \times 0.1NaOH(N) \times 0.07 \times 100}{10g}$$

2.9. Total soluble solids content (TSS)

Mango juice was used to measure total soluble solids with a hand refractometer (N-1E, Japan), and TSS was expressed as °Brix.

2.10. H_2O_2 content

One gram of mango pulp was ground with liquid nitrogen then 10 mL of 50 mM phosphate buffer (pH 6.5) containing 1 mM hydroxylamine at 0 °C was added. The mixture was centrifuged at 8000 × g for 25 min; 1 mL supernatant was added with 1 mL of 0.3% titanium sulphate in 20% H_2SO_4 (v/v) and then centrifuged again at 8000 × g for 15 min. The H_2O_2 content was measured at 410 nm by