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Effects of 1-methylcyclopropene and chitosan on the fruit shelf-life and qualities of two different ripening stages of 'Cavendish' banana

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Abstract: Our previous research with chitosan leads us to conclude that 2.5% chitosan can be promptly used as a fruit coating. However, to be used as a fruit coating for climacteric fruits, the effect of ethylene trapped under chitosan coating on ripening needs to be blocked. 1- methylcyclopropene (1-MCP) is known as an anti-ethylene and it can be applied in combination with chitosan. This research which was conducted during September-October 2013 was aimed at studying the effects of 1-MCP and its combination with 2.5% chitosan in prolonging fruit shelf-life and maintaining fruit qualities of two different ripening stages of 'Cavendish' banana. A completely randomized design of two factors was used. The first factor was 1-MCP gassing (control and 1-MCP), and the second one was chitosan (control and 2.5% chitosan). 1-MCP gas was developed by diluting 0.5 g 1-MCP powder into 30 ml of water. The results showed that the fruits of early and late stages responded differently to treatments of chitosan, 1-MCP, and their combination. (1) At early stage, the chitosan-coated fruit showed slow color development and fruit quality deterioration, whereas at late stage, the chitosan-coating accelerated ripening by a quick decrease of fruit firmness, decrease of soluble solid content and increase of acidity. (2) In general, 1-MCP lengthened shelf-life of banana fruits by slowing fruit quality deterioration, and its effect was accentuated when applied in combination with chitosan. (3) The effect of combined application of chitosan and 1-MCP was best if it was applied at fruit yellowing stage (stage V), because at early stage (stage III) the combined application resulted in imperfect fruit color development.

Keywords: Banana, Coating, 1-MCP, Chitosan, Ripening

1. Introduction

'Cavendish' banana is a world-wide banana cultivar. It is commonly exported at a green stage, wrapped in a vacuum polyethylene bag inside a cartoon pack. Once it reaches its destination, it will receive an ethylene gassing to promote ripening, and be distributed to local markets at stage III (greenish-yellow). Once the bananas are put in selling, the ripening cannot be stopped and the fruits quickly reach stage VII at 3-4 days storage, a fruit stage of the end of economical values.

Its short shelf-life is believed due to its high respiration and ethylene production rates. Attempts that have been conducted to lengthen its shelf-life are usually focused on decreasing its respiration through applications of fruit coatings (Widodo et al., 2010; Zulferiyenni and Widodo, 2010a and 2010b), and on slowing its ripening through applications of anti-ethylene (Jiang et al. 1999; Blankenship and Dole, 2003; Pelayo et al., 2003; Suprayatmi et al., 2005; Zhang et al., 2006).

As an edible coating that is able to prolong fruit shelf-life (Han et al., 2004), chitosan was reported also to control changes in physiological, microbiological, and physicochemical aspects of food products (Kittur et al., 1998). Our previous research attempted to decrease banana respiration (Widodo et al., 2010) and to extend other fruits shelf-life (Widodo and Zulferiyenni. 2008; Widodo et al., 2007; Widodo et al., 2010 and 2013; Zulferiyenni and Widodo, 2010a and 2010b) has recommended that 2.5% chitosan can be used as fruit coating materials for both non-climacteric and climacteric typed fruits.

Different from application to non-climacteric fruit, application of chitosan to ‘Cavendish’ banana as climacteric fruits caused softening its flesh, even though the shelf-life was extended and the color of its skin remained unchanged (Widodo et al., 2010). It seemed that ethylene blocked inside chitosan was not readily diffused out and caused further ripening. Therefore, it was thought that application of chitosan to climacteric fruits should be accompanied with other anti-ethylene substances.

1-methylchyclopropane (1-MCP) is one of anti-ethylene that has a special mode of action to block responses of ethylene so that ripening signals cannot be generated (Blankenship and Dole, 2003; Pelayo *et al.*, 2003), and therefore, fruit ripening is prevented or delayed. Numerous reports on the effect of 1-MCP to various plants, such as fruits (Jeong et al*.*, 2002; Basseto et al., 2005; Suprayatmi et al., 2005; Watkins and Nock, 2005; Manenoi et al., 2007; Cantin et al., 2011; Guo et al., 2011), vegetables (Fan and Mattheis, 2000; Forney et al., 2003), and even ornamental plants (Raffeiner et al., 2009; Kongsuwan et al., 2012) are available. To our knowledge, however, there have been no reports on combining both chitosan and 1-MCP as single application to ‘Cavendish’ banana to extend the shelf-life of the banana without affecting the quality.

Therefore, the objectives of this study were to evaluate the effectiveness of use of combined 1-MCP and 2.5% chitosan on fruit in extending the shelf-life and qualities of two different ripening stages (stages III and V) of ‘Cavendish’ banana fruits.

2. Materials and Methods

This research was conducted in the Horticultural Postharvest, Department of Agrotechnology, Faculty of Agriculture, University of Lampung, Indonesia during September-October 2013. The samples of ‘Cavendish’ banana fruit of stages III (early) and V (late) were received directly as fresh harvests from PT Nusantara Tropical Farm (PT NTF), Way Jepara, East Lampung, Indonesia.

Treatments were arranged in a 2 x 2 factorial design of a completely randomized design with two replications. The replications were applied to each experimental unit consisting of one cluster fruit of two fingers each. The treatments and design were assigned to the Cavendish of stages III (greenish-yellow; early) and V (perfectly yellow with green tip and greenish-yellow peduncle; late) separately but at the same time. The first factor was 1-MCP treatment consisting of control (without 1-MCP; M0) and 1-MCP gassing (M1) developed by diluting 0.5 gram 1-MCP in 30 mL of water. Gassing was applied 24 hours to fruits in a 82 L of air-tight plastic chamber. The second factor was chitosan coating consisting of control (without chitosan; K0) and 2.5% chitosan (K1). The chitosan was diluted in 0.5% acetic acid (Widodo et al., 2010). Treated fruits were then placed in a storing room of room temperature of 28 ± 1 ºC.

The variables observed were fruit weight loss, soluble solid content (ºBrix), free acidity, and firmness. ºBrix was analyzed with an Atago N-1E hand refractometer, free acidity was analyzed by a titration with 0.1N NaOH and phenolphthalein as an indicator, and fruit firmness was analyzed with a penetrometer type FHM-5, Takemura Electric Work, Ltd., Japan. Variables were observed in every two days up to ten observations, otherwise the treatment was ended when the fruit showed a decrease quality as browning spots (stage VII). The data were then graphed with best fitted correlations.

3. Results and Discussion

Naturally, the stage changes of ‘Cavendish’ banana fruits correlates well with ripening which can be easily observed by skin color changes. Except ‘Cavendish’ banana fruits receiving no treatment (control, C0M0) which was stopped at 5 days storage, those receiving other treatments reached more than 5 days storage (Figure 1).

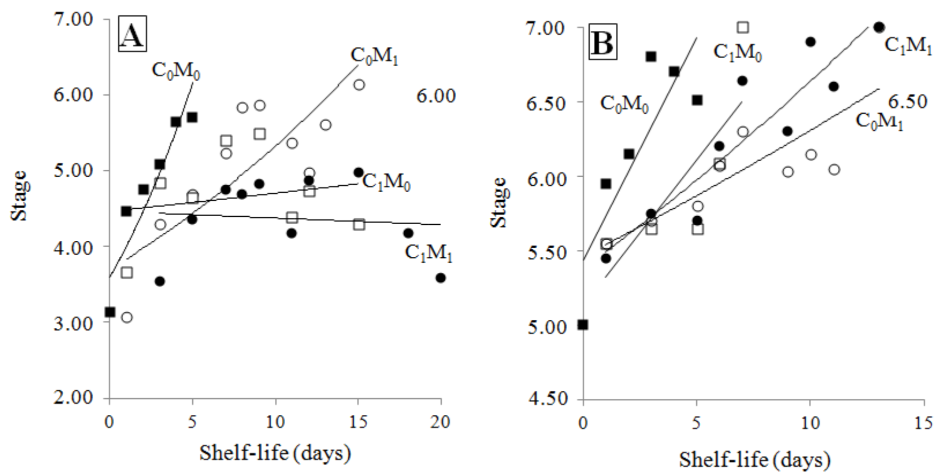

Figure 1. *Changes of ‘Cavendish’ banana stage at early (A) and late (B) stages on different treatment combinations of chitosan and 1-MCP during storage.C0 = without chitosan, C1 = 2.5% chitosan, M0 = without 1-MCP, M1 = 0.5 g 1-MCP/30 mL of water.*

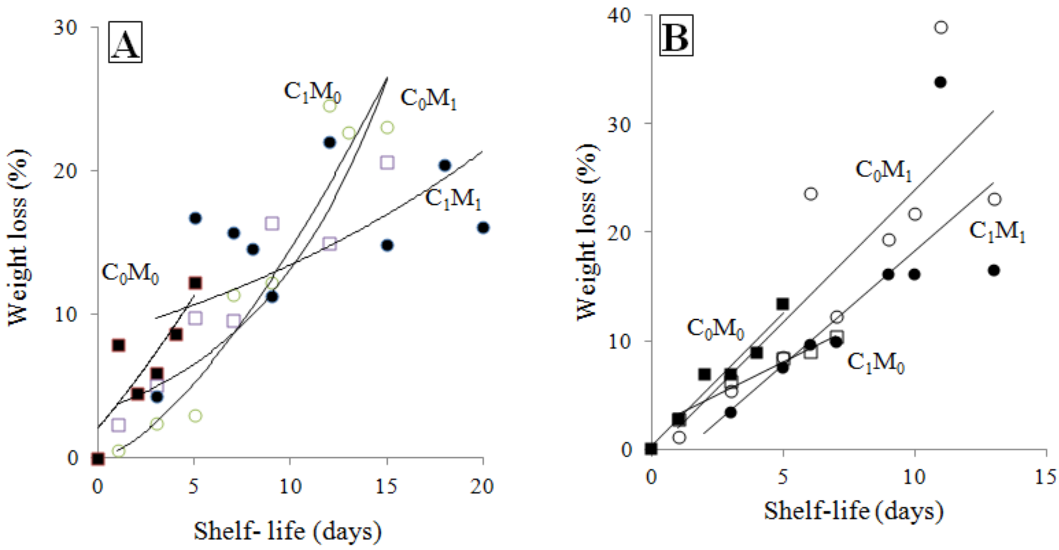

Figure 2. *Changes of fruit weight loss of 'Cavendish' banana at early (A) and late (B) stages on different treatment combinations of chitosan and 1-MCP during storage. C0 = without chitosan, C1 = 2.5% chitosan, M0 = without 1-MCP, M1 = 0.5 g 1-MCP/30 mL of water.*

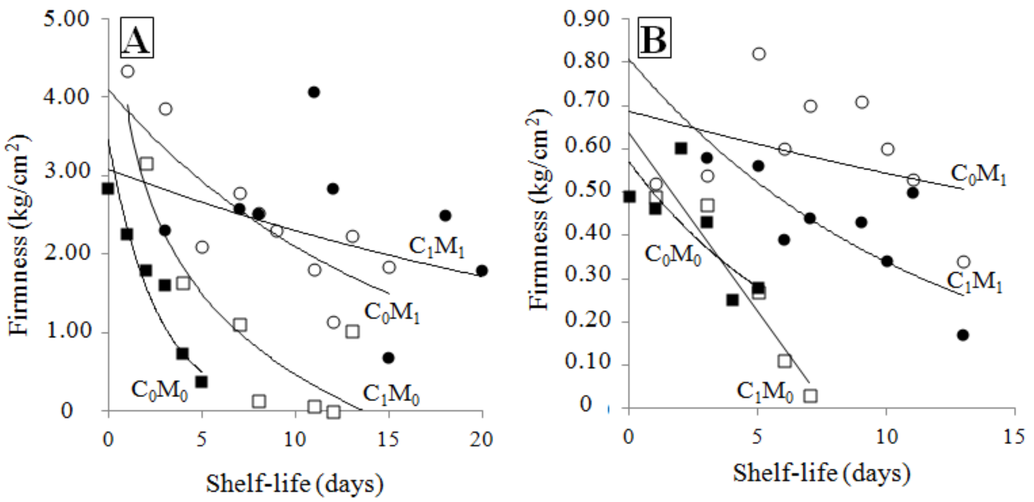

Figure 3. *Changes of fruit firmness of 'Cavendish' banana at early (A) and late (B) stages on different treatment combinations of chitosan and 1-MCP during storage. C0 = without chitosan, C1 = 2.5% chitosan, M0 = without 1-MCP, M1 = 0.5 g 1-MCP/30 mL of water.*

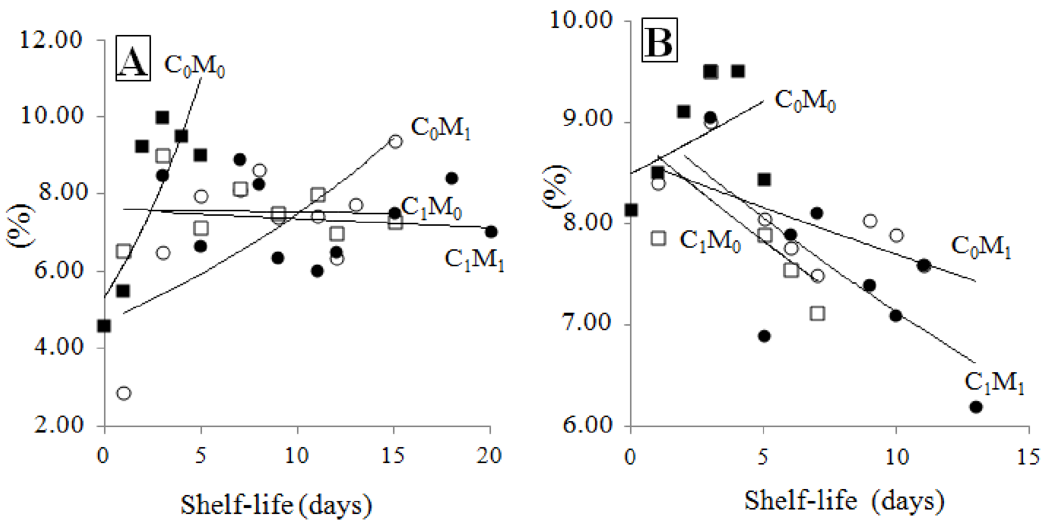

Figure 4. *Changes of soluble solid content (ºBrix) of 'Cavendish' banana at early (A) and late (B) stages on different treatment combinations of chitosan and 1-MCP during storage. C0 = without chitosan, C1 = 2.5% chitosan, M0 = without 1-MCP, M1 = 0.5 g 1-MCP/30 mL of water.*

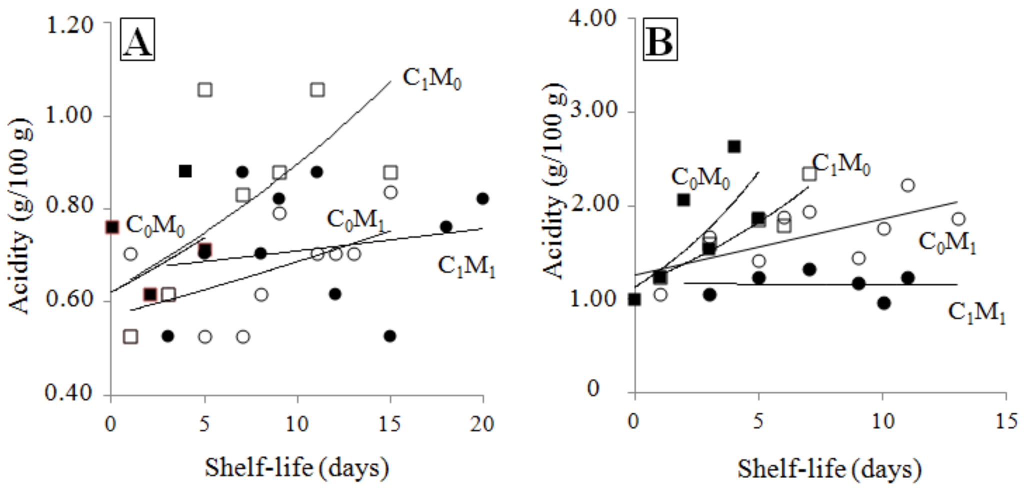

Figure 5. *Changes of free acid content of 'Cavendish' banana at early (A) and late (B) stages on different treatment combinations of chitosan and 1-MCP during storage. C0 = without chitosan, C1 = 2.5% chitosan, M0 = without 1-MCP, M1 = 0.5 g 1-MCP/30 mL of water.*

Regardless of treatments applied and fruit stages, the control fruits deteriorated quickly by having the shortest shelf-life (Figure 1) and quick decreases of fruit qualities (Figures 2-5), so that the observation was stopped at 5 days storage. The control fruits of both early and late stages developed browning as brown spots on their skin and their flesh was soften at 5 days storage.

The fruits of early and late stages responded differently to treatments of chitosan, 1-MCP, and their combination. Chitosan as a fruit coating is known to be beneficial to fruit through two modes of action. Firstly, chitosan, just as other coatings, plays as a physical barrier to transpired water (Gennadios and Weller, 1990), so that chitosan-coated fruits usually have a lower fruit weight loss than control (Figure 2). Secondly, chitosan develops a modified atmosphere inside coating by restricting O_2 consumption so that respiration and ethylene production decrease. Consequently, at early storage chitosan-coated fruit showed slow color development (Figure 1) and slow fruit quality deterioration (Figures 3-5). However, the physiological responses to chitosan depend on several factors, such as skin thickness (Widodo et al., 2010), natural characters of the skin that affect coating effectiveness (Widodo and Zulferiyenni, 2008; Widodo et al., 2013), and natural waxing on the fruit skin (Widodo et al., 2013).

Regardless of banana stages, chitosan-coated (C1M0) banana fruits showed lower fruit weight loss than control (C0M0) (Figure 2). However, chitosan seemed to accelerate ripening when applied to banana fruits of late stage because the fruit firmness of chitosan-coated banana of late stage decreased so low that the observation was terminated at 7 days storage (Figure 3B) which was 7 days earlier than banana of early stage (Figure 3A). This quick decrease of firmness of early banana stage (Figure 3A) did not mean that the stage (color development) progressed as its stage was unchanged significantly (Figure 1A). Its unchanged stage should not be interpreted that the skin color was unchanged but the skin color developed into dully brownish yellowing color, which was unacceptable yellowing color of 'Cavendish' banana.

The response of the late stage 'Cavendish' to chitosan was different to the early stage. As stated previously that the chitosan-treated banana was soften (Figure 3A) but the skin color developed abnormally (Figure 1A), the chitosan-treated late stage of 'Cavendish' was soften quickly (Figure 3B), almost 7 days quicker than the early stage, and developed a normal yellowing 'Cavendish' banana as the stage progressed (Figure 1B). This accelerated ripening was also correlated with the decrease of soluble solid content (Figure 4B) and the increase of acidity (Figure 5B), both were quicker than those of early stage (Figures 4A and 5A).

Generally, 1-MCP treated bananas showed slower rate of fruit softness compared to control and chitosan treatments (Figure 3), as also observed in bananas by Zhang et al. (2006) and Suprayatmi et al. (2005), and in other fruits by Moretti et al. (2002) and Fan and Mattheis (2000). The effect of 1-MCP was accentuated when applied in combination with chitosan. However, the fruits of early and late stages responded differently to treatment combinations of chitosan and 1-MCP.

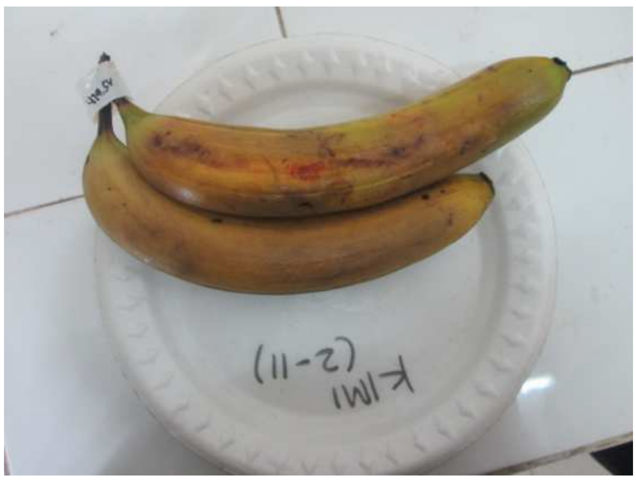

Figure 6. *Stage (color) of chitosan and 1-MCP-treated 'Cavendish' banana of early stage at 20 days storage.*

In the early stage, while the observations on untreated bananas (C0M0) were stopped at 5 days storage (Figures 1-5) and the shelf-life of chitosan-treated (C0M0) and 1-MCP-treated banana (C0M1) reached 15 days storage, no stage changes occurring in the treatment combination of chitosan and 1-MCP (C1M1) (Figure 1A). The observations on C1M1-treated 'Cavendish' were actually stopped at 20 days storage because it developed abnormal brownish yellowing color (Figure 6), eventhough the fruit firmness changed a little (Figure 3A) with slowest rate than other treatments. Pelayo et al. (2003) also concluded that the efficacy of 1-MCP in delaying ripening of partially ripened bananas is too inconsistent for commercial application. The treatments influenced differently in the late stage.

In the late stage, while the observations on untreated bananas (C0M0) were also stopped at 5 days storage (Figures 1-5) and the shelf-life of chitosan-treated (C0M0) reached 7 days storage, the 1-MCP-treated bananas persisted until 14 days storage. The chitosan and 1-MCP-treatment combination (C1M1) affected better as it caused a lower fruit weight loss that the 1-MCP alone (Figure 2B). However, the ripening process of C1M1-treated banana fruit continued during storage as indicated by the continuing increase of stage (Figure 1B) and decrease of fruit firmness (Figure 3B). This is understandable as 1-MCP works in disturbing response to ethylene (Blankenship and Dole, 2003), so that even though the ripening is slowed down at early periods (Toan et al., 2009 and 2011; Cetinbas and Konyuncu, 2011), the ripening is then reinitiated as newly produced ethylene finds newly developed ethylene receptors. So that stopping this reinitiated ripening is becoming important. To stop this ripening process, other anti-ethylene which is capable to stop ethylene production may be applied. Amino-ethoxy-vinyl-glycine (AVG) may be a potent anti-ethylene applied in a combination with chitosan. Greene and Schupp (2004) and Yildiz et al. (2012) reported that AVG hindered fruit ripening and consequently lengthened fruit shelf-life.

4. Conclusions

The results showed that the fruits of early and late stages responded differently to treatments of chitosan, 1-MCP, and their combination. (1) At early stage, the chitosan-coated fruit showed slow color development and fruit quality deterioration, whereas at late stage, the chitosan-coating accelerated ripening by a quick decrease of fruit firmness, decrease of soluble solid content and increase of acidity. (2) In general, 1-MCP lengthened shelf-life of banana fruits by slowing fruit quality deterioration, and its effect was accentuated when applied in combination with chitosan. (3) The effect of combined application of chitosan and 1-MCP was best if it was applied at fruit yellowing stage (stage V), because at early stage (stage III) the combined application resulted in imperfect fruit color development.

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