CHAPTER 5

Effects of Sodium Hypochlorite and Wax Coating on Fruit Decay and Visual Appearance of Fresh Vietnamese Longan Fruit cv. Long

5.1 Abstract

This research was designed to study the effects of sodium hypochlorite (SH) and bees-carnauba mixed wax (MW) on the prevention of fruit decay and the maintenance of visual appearance in fresh Vietnamese longan fruit cv. Long. The experiments were carried out by soaking fruits in 100, 150 and 200 ppm SH solutions for 2 min. After drying, soaked fruits were coated in 6% MW for 30 seconds, and stored at 5±1ºC for 30 days. Untreated fruits were used as control. Pericarp browning; pericarp color; pericarp pH; total microorganisms; percentage of fruit decay and weight loss; eating quality; and total soluble solids (TSS) content were monitored during the storage period. The results showed that 200 ppm SH in combination with 6% MW treated fruits did not decay throughout 25 days in storage, and kept visual appearance which was indicated by the lowest browning index, high lightness (L* value) and yellowness (b* value) of fruit pericarp, as well as low pericarp pH for 20 days in storage. Moreover, this treatment maintained low total microorganism levels, low weight loss, high eating quality score, and the TSS content of the longan fruit remained unchanged.

5.2 Introduction

Longan fruit (*Dimocarpus longan* Lour.) is one of the many kinds of specialty fruits of Vietnam and has high economic value (Huyen and Thuy, 2011). Longan fruit has a very short postharvest life of 3 to 4 days under ambient temperatures due to desiccation, rotting and browning (Tongdee, 2001; Jiang *et al*., 2002; Apai, 2010). Pericarp browning of fresh fruit results from phenolic compounds oxidized by endogenous polyphenol oxidase (PPO) and pigment formation. Longan fruits are very susceptible to postharvest decay as a result of both bacterial and fungal infections, including yeasts

(Jiang *et al*., 2002). The high sugar and moisture content in longan fruits induce various decay organisms to rot the fruit rapidly. Fruit rot usually follows skin browning (Apai, 2010). Recently published works indicate that the shelf life of 'Long' longan fruits could be extended by carbendazim dipping (Hoan *et al*., 2001), SO_2 fumigation (Thuy and Duyen, 2011), and sodium metabisulfite soaking (Hai *et al*., 2011). SO_2 can reduce browning symptoms due to reducing PPO activity, and it also acts as a bleaching agent (Wu *et al*., 1999; Tongdee, 2001). Carbendazim and SO_2 play an important role in decay and fungal growth inhibition (Hoan *et al*., 2001; Tongdee, 2001). However, there were many reports on the negative effects of the toxic residue of SO_2 and carbendazim in humans, and other reactions with sensitive individuals. Alternative treatments for SO_2 and carbendazim treatments on longan fruit cv. Long have also been studied such as chitosan coating (Huyen and Thuy, 2011). The results showed that shelf-life can be prolonged with good quality for 20 days, however, the percentage of fruit decay is very high (11.4%). Thus there is a need to develop effective and safe methods not only to replace SO_2 and carbendazim treatments but also to reduce fruit decay of fresh 'Long' longan fruit. An alternative method is the use of sodium hypochlorite soaking in combination with bees-carnauba mixed wax coating. Sodium hypochlorite (SH) solution, commonly known as bleach or liquid bleach, is frequently used as a disinfectant or a bleaching agent. SH has been approved for use (registered) by the US Environmental Protection Agency (Suslow, 2000). The US Government regulations (21 CFR Part 178) allow food processing equipment and food contact surfaces to be sanitized with solutions containing bleach, if the solutions do not exceed 200 parts per million (ppm) available chlorine. Chlorine has no residual affect (Sawyer, 1978). Many researchers have routinely used SH for surface sanitation and sterilization of fruits and vegetables (Hong and Gross, 1998). SH was included in treatment due to its fungicidal property (Cerioni e*t al*., 2009). The primary uses of chlorine have been to inactivate or destroy pathogenic bacteria, fungi, viruses, cysts, and other propagules of microoganisms associated with seed, cutting, irrigation water, farm or horticultural implements and equipment (Suslow, 2000). Khunpon *et al*. (2011) concluded that dipping in 0.001-0.05% sodium chlorite for 10 min has the potential to reduce exocarp browning in longan fruits cv. Daw by reducing the activity of PPO as well as maintaining total phenolic content during storage at ambient condition for 48 h. In a previous experiment (Hai *et al*., 2014), found that 6% bees-carnauba mixed wax (MW)

is the best treatment to maintain the postharvest quality of longan fruit cv. Long. However, the percentage of fruit decay was high (9.4%) after 25 days in storage.

The main purpose of this study was to investigate the effects of SH soaking in combination with MW coating on the prevention of fruit decay and the maintenance of visual appearance in fresh 'Long' longan fruit during storage at low temperatures.

5.3 Material and Methods

5.3.1 Plant Materials

Mature 'Long' longan fruits (at harvesting date about from 185 to 190 days after full bloom) of a commercial orchard in harvesting crop of 2014 in Hung Yen Province, Vietnam were harvested, transported, individually cut and selected at the same time as the fruits mentioned in Chapter 4, and were used for this research.

5.3.2 Studying Methods

The optimal and feasible concentrations of SH (100, 150 and 200 ppm) were selected after preliminary tests. The best treatment of 6% MW was selected in the Chapter 3, and made according to the method of Hai *ei al.* (2014).

The fruits were first soaked in 100, 150 and 200 ppm SH solutions for 2 min, and dried for 1 h at room temperature. Then the soaked fruits were coated with 6% MW for 30 seconds at room temperature; while the control fruits were not soaked and coated. The soaked and coated fruits were dried for 8 h and 1 kg per bag of longan fruit were packaged in polypropylene bags (305 x 457 mm in size, and 0.035 mm thick with 4 holes of 0.8 cm^2 per hole). The fruits were then stored at 5±1ºC in a cold room and sampled/analyzed at 5 day intervals. Each treatment had three replications.

A completely randomized design was used for the experiment. Four treatments were applied to the longan fruit as following:

SH_0 = non-treated fruit (control)

SH_1 = fruit was soaked in 100 ppm SH for 2 min and air dried before coated with 6% MW

SH_2 = fruit was soaked in 150 ppm SH for 2 min and air dried before coated with 6% MW

SH_3 = fruit was soaked in 200 ppm SH for 2 min and air dried before coated with 6% MW

The data collection methods used for this research in terms of observing changes in the fruits visual appearance; measurement of the fruit pericarp color and total soluble solids content; an assessment of the percentage of fruit decay and weight loss; determination of pericarp pH; evaluation of storage life; and the statistical analysis, were all similar to the methods described in Chapter 3 and Chapter 4.

The total microorganism populations on fruit surface were determined according to the method of Whangchai *et al*. (2006). For each sampled of fruit, 300 g of fruit was extracted by immersing in 2,700 ml sterile distilled water and shaking 180 rpm for 30 min at room temperature. Afterward, 1 ml sample suspension was spread over a potato dextrose agar (PDA) medium. The PDA plates were incubated at 25°C for 72 h and the survival of microorganisms was expressed as the mean number of colony forming units (CFU ml^{-1}).

Eating quality was assessed by a trained panel of seven researchers, on a hedonic scale of 1 to 9 based on fruit favor and sweetness. At each withdrawal, 30 fruits were randomly selected and rated for quality on the scale of 1 = poor, 5 = acceptable and 9 = excellent (Whangchai *et al*., 2006).

5.4 Results and Discussion

5.4.1 Change in visual appearance expressed as browning index (BI)

Changes in BI of treated and control longan fruits cv. Long are shown in the Figure 5.1. Fruits with BI above 2.0 (more than 25% pericarp browning area) were considered as unacceptable for marketing purposes. Overall, the BI of treated and control fruits tended to increase with increasing storage time. Whangchai *et al*. (2006) reported that pericarp browning in longan fruit increased with increasing of storage period. Exocarp browning of longan fruit represented by a browning index increased with increasing storage time (Khunpon *et al*., 2011). The control fruits and SH_1 treatment had BI higher than 2.0 and

were not acceptable by day 10 in storage. Our result is in accordance with the reported data on BI of untreated longan fruits (Jaitrong, 2006; Apai, 2010; Hai *et al*., 2011 and 2014). After 20 days in storage, there was significant difference in BI between treatments as well as control fruits ($P \leq 0.05$), and while the BI of SH_2 treatment was 2.6, the SH_3 treatment had the lowest BI (1.9). After 25 days in storage the BI of SH_3 treatment was higher than 2.0 and fruits also were not acceptable. The results of this study concluded that 200 ppm SH soaking in combination with 6% MW coating shows the best pericarp color and the longest storage life of longan fruit cv. Long for 20 days. This result is consistent with the reported data on BI of treated longan fruit pericarp cv. Long (Hai *et al*., 2011 and 2014). Browning of longan fruits results from the oxidation of phenolic compounds by endogenous polyphenol oxidase (PPO) (Jiang *et al*., 2002). PPO is activated by moisture loss from the fruit (Su and Yang, 1996). Khunpon *et al*. (2011) found that sodium chlorite treatments significantly decreased the activity of PPO as compared to the control group, and 0.01 and 0.05% sodium chlorite significantly reduced PPO activity more than other treatments at 12-48 h ($P \leq 0.05$). Apai (2009) demonstrated that water loss from the longan pericarp was significantly positively correlated with pericarp browning index. Coating the fruit with wax could prevent moisture loss (Hagenmaier and Shaw, 1992; Kolattukudy, 2003; Thirupathi *et al*., 2006; Hu *et al*., 2011; Shahid and Abbasi, 2011). Hai *et al*. (2014) concluded that 6% MW coating is the best treatment to prevent pericarp browning in 'Long' longan fruit. SH solution is frequently used as a bleaching agent (Suslow, 2000). The temperature at 5ºC was most suitable for storage and delayed browning in longan fruits due to less severe chilling injury (Apai, 2009). Khunpon *et al*. (2011) found that sodium chlorite at a concentration of 0.01% is the most effective treatment in reducing exocarp browning of longan fruit cv. Daw.

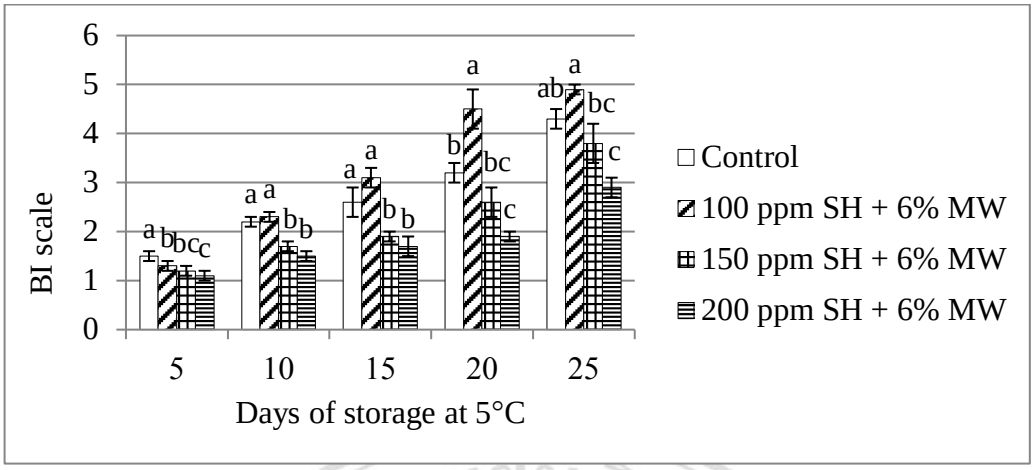

Figure 5.1 Change in BI of longan fruit pericarp either treated or not, during the storage period at 5ºC.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significant differences ($P \leq 0.05$).

5.4.2 Change in pericarp color expressed as L* (lightness) and b* (yellowness) values

Fruit pericarp color including L* and b* values is one of the most important factors of visual appearance to attract consumers. As shown in Figure 5.2, the L* values of treated and control fruits tended to decrease with increasing of storage time, and higher L* values were found in SH_3 treatment during the storage period. Khunpon *et al*. (2011) reported that L* values gradually decrease with increasing storage time, but dipping in 0.001-0.05% sodium chlorite significantly delayed the decrease in these values, indicating that sodium chlorite could maintain lightness of longan exocarp. By day 20 in storage the L* value of SH_3 treatment was 51.6 and it significantly differed from those of other treatments and control fruits ($P \leq 0.05$). Our result is in accordance with the reported data on L* values of treated longan fruits cv. Long (Hai *et al*., 2011 and 2014), but higher than the finding of Huyen and Thuy (2011) who found that L* values of longan fruit cv. Long of the best treatment (2% chitosan coating) after 20 days in storage was 44.3. This result demonstrates that 200 ppm SH soaking in combination with 6% MW coating significantly maintained the lightness of color on longan pericarp cv. Long. Apai (2010) showed that L* value is negatively correlated with the browning index. The results in this research also showed that high L* values correlate with low browning indexes (Figures 5.1 and Figure 5.2).

Figure 5.3 indicates the changes in b* values of treated and control fruits during the storage period. After 20 days in storage the b* value of treated samples and control fruits was significantly different, and it ranged from 22.6 to 30.5. After 25 days in storage the b* values of SH_2 and SH_3 treatments were similar, and the b* values of SH_1 treatment and control fruits were not different ($P \leq 0.05$). Generally, the b* values of treated and control fruits decreased, and SH_3 treatment maintained the highest b* values during the storage period. The b* values gradually decreased with increasing storage time, but dipping in 0.001-0.05% sodium chlorite significantly delayed the decrease in b* values, indicating that sodium chlorite could maintain yellowness of longan exocarp (Khunpon *et al*., 2011). This study indicates that low b* values correlated with high browning index (Figure 5.1 and Figure 5.3). As seen in Figure 5.3, the b* value of SH_3 treatment after 20 days in storage was 30.5. Our result was higher than the reported data on b* values which ranged from 18.3 to 27.4) of treated longan fruits cv. Long after 20 days in storage of Huyen and Thuy (2011) and Hai *et al*. (2011 and 2014). This result demonstrates the effectiveness of SH soaking in association with MW coating in maintaining the yellowness of longan fruit pericarp by inhibiting the pericarp browning and preventing water loss from pericarp as described by Shi (1990), Kolattukudy (2003), Thirupathi *et al*. (2006), Shahid and Abbasi (2011), and Hai *et al*. (2014). Kumar *et al*. (2012) concluded that treatment of dipping in 0.2% SH solution at 52°C for 4 min was the most effective combination to retain the attractive color of the 'Shahi' and 'China' litchi fruits.

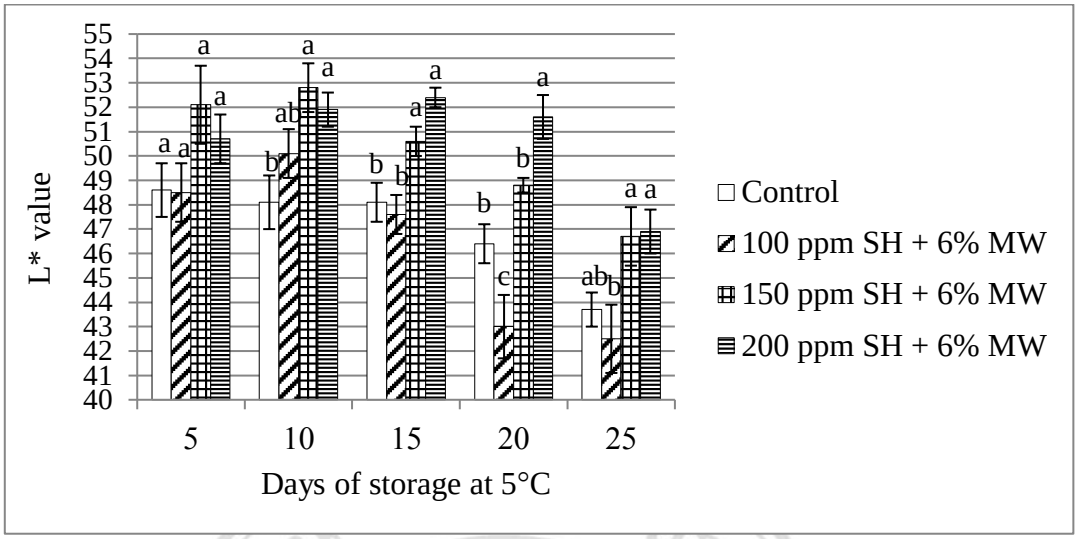

Figure 5.2 Change in L* values of treated and control longan fruits during storage at 5°C.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significant differences ($P \leq 0.05$).

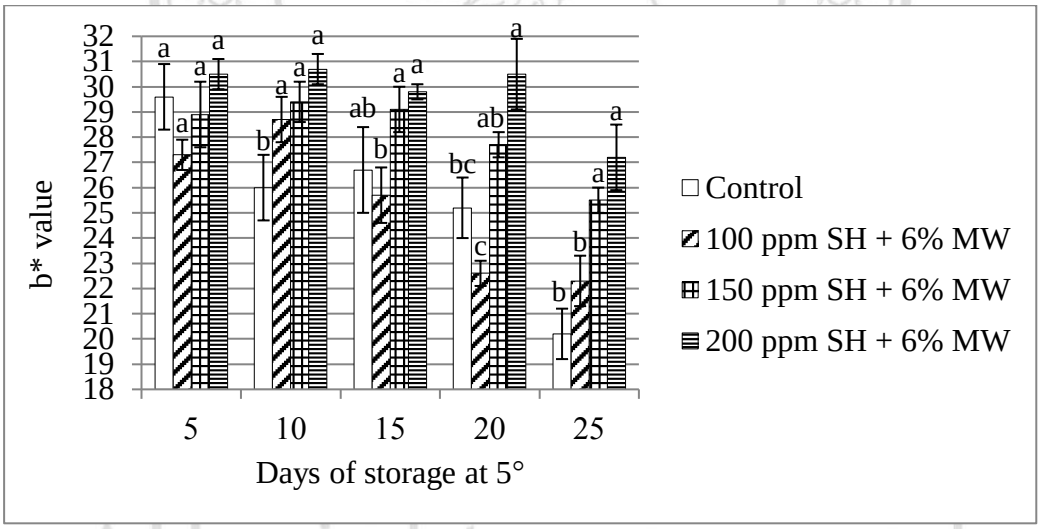

Figure 5.3 Change in b* values of treated and control longan fruits during storage at 5°C.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significant differences ($P \leq 0.05$).

5.4.3 Change in pericarp pH and weight loss

The pericarp pH of treated and control fruits during the storage period were measured and results are shown in the Figure 5.4. By day 5 and 10 in storage pericarp pH of

control fruits was similar with those of SH_1 and SH_2 treatments, and it significantly differed from pericarp pH of SH_3 treatment ($P \leq 0.05$). After 20 and 25 days in storage, the pericarp pH of treated and control fruits was significantly different, and the pH value ranged from 5.1 to 5.7 and 5.3 to 5.7 respectively. Our results are close to the findings of Apai *et al*. (2009) and Hai *et al*. (2014) who found that 1.2% chitosan dissolved in 1% citric acid and 6% MW coating maintain the lowest pericarp pH of 5.0 in longan fruit cv. Daw and cv. Long respectively after storage period. As shown in Figure 4, the pericarp pH of treated and control fruits tended to increase with increasing storage time, the control fruits maintained higher pericarp pH than treated fruits and the SH_3 treatment had the lowest pericarp pH during the storage period. This study indicates that low pericarp pH correlated with low browning index (Figures 5.1 and Figure 5.4). Apai (2010) demonstrated that the browning index of longan fruits decreases as pericarp pH decreases. Water loss from the pericarp causes an increase pericarp pH value (Apai, 2009). Wax coating can retard water loss (Mac Guire and Hallman, 1995; Baldwin *et al*., 1997; Hu *et al*., 2011). The pH optimum for maximum PPO activity in longan fruit is 6.5 (Jiang, 1999). Enzymatic browning occurs as a result of the oxidation by PPO (Jiang *et al*., 2002; Yoruk and Marshall, 2003). Caro and Joas (2005) and Joast *et al*. (2005) found that pericarp browning effects could be postponed by reducing pericarp pH. Low pH retards browning by minimizing the activity of PPO.

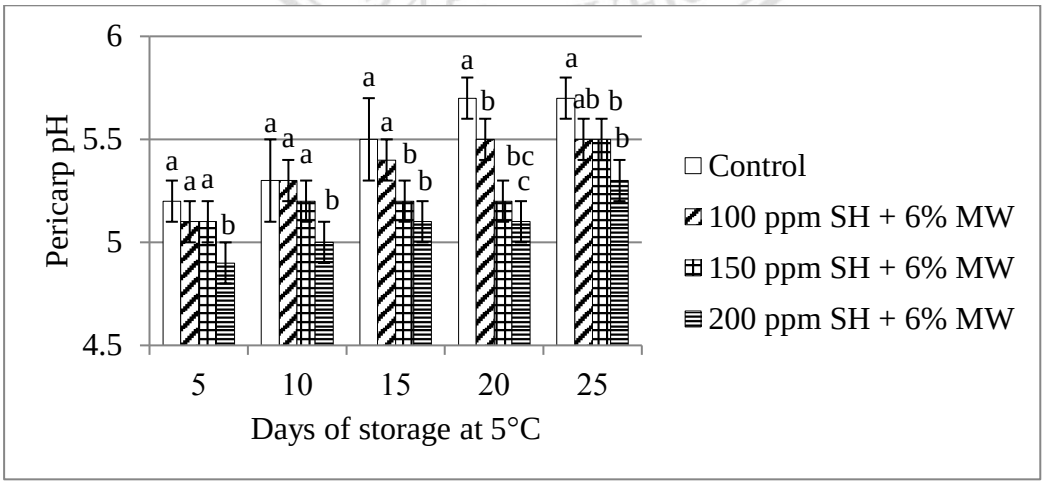

Figure 5.4 Change in pericarp pH of treated and control fruits during storage period at 5ºC.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significantly different ($P \leq 0.05$).

The weight loss of stored longan fruits cv. Long is shown in the Figure 5.5. There was marked difference in weight loss between treated and control fruits during the storage period ($P \leq 0.05$). At the first 5 days in storage, the percentage of weight loss in control fruits was 3.3%, and it reached 6.3 and 9.2% by day 20 and 25 respectively. In contrast, the weight loss of treated fruits was not different ($P \leq 0.05$), it ranged from 0.6 to 0.7% by day 5 in storage, and reached from from 3.8 to 4.4% by day 25 in storage. Our results are consistent with the results of Hai *et al*. (2014) who found that the best treatment of MW coating has the lowest weight loss (4.6% by day 25 in storage), but lower than the findings of Hoan *et al*. (2001) who reported that the percentage of weight loss of longan fruit cv. Long was approximately 10% after 20 days in storage. Our results are also in accordance with the reported data on weight loss of longan fruit (Jiang and Li, 2001; Sodchit *et al*., 2008; Huyen and Thuy, 2011). As seen in Figure 5.5, the weight loss of treated and control fruits tended to increase with increasing storage time, and the control fruits had higher weight loss than treated fruits during the storage period. These results justify the conclusion that SH in association with MW coating used in this study has the best effectiveness on reducing the weight loss in longan fruit cv. Long during the storage period. This study shows that high weight loss correlated with high browning index and high pericarp pH (Figures 5.1, Figure 5.4, and Figure 5.5). The purpose of the wax coating was to reduce the weight loss in fruits and vegetables (Thirupathi *et al*., 2006). Shahid and Abbasi (2011) reported that weight loss means the amount of water lost from fruits and vegetables and it is related to the shelf life of the produce. Use of two different waxes reduced water loss from longan fruit cv. Tongbi over 2 days at ambient temperature (Shi, 1990). Carnauba wax coating significantly reduced water loss compared to uncoated mango fruits (Baldwin *et al*., 1999). Sta-Fresh 2952 wax (60g/l) was more effective in alleviating weight loss in pineapple fruits (Hu *et al*., 2011). Shahid and Abbasi (2011) reported that 5% bees wax showed the minimum weight loss in sweet orange fruits cv. Blood red at room temperature storage. Waxing tomato fruits allow delaying in weight loss (Torres *et al*., 2009). Waxing of Xiang Sui and Pien Pu pears reduced weight loss at all storage temperatures (Sornsrivichai *et al*., 1990).

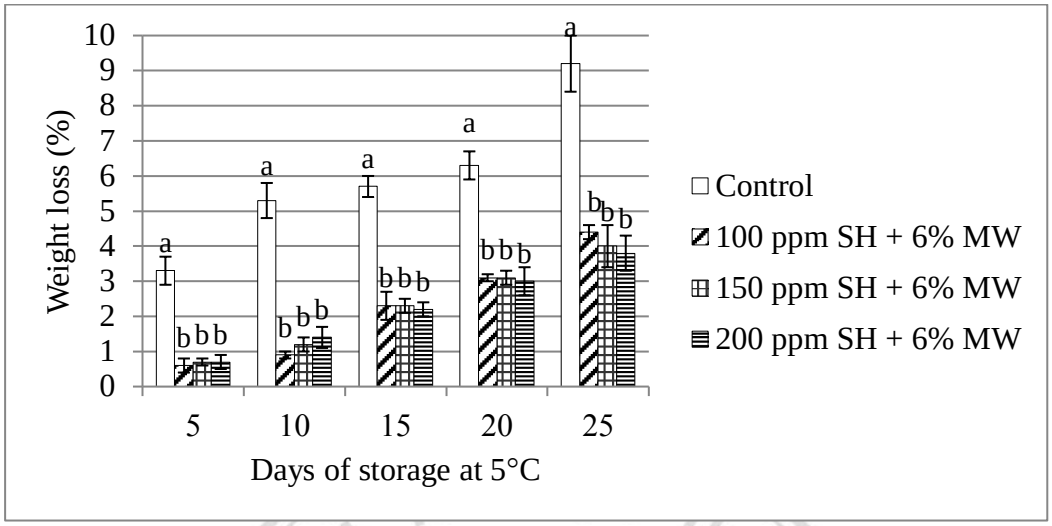

Figure 5.5 Change in weight loss of treated and control fruits during storage period at 5ºC.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significantly different ($P \leq 0.05$).

5.4.4 Total microorganism populations on fruit surface and fruit decay

Total microorganism populations on the longan fruit surface including fungi, yeasts, and bacteria of treated and control fruits tended to increase with the time spent in storage (control fruits increased from 2.1 to 19.6 x 10^6 CFU ml^{-1} and treated fruits increased from 0.1-0.7 to 2.2-5.9 x 10^6 CFU ml^{-1} after 25 days in storage) (Figure 5.6). Whangchai *et al*. (2006) found that microorganism populations on the longan fruit surface markedly increased after 3 days in storage at 25°C. There was marked difference in total microorganism between control and treated fruits ($P \leq 0.05$), and control fruits had much higher total microorganism than treated fruits during the storage period. This result demonstrates that SH dipping in combination with 6% MW coating significantly reduced total microorganism population on the surface of longan fruit cv. Long. About 106 species of microorganism have been isolated from longan fruit, comprising 36 bacteria, 63 mold and 7 yeast species (Lu *et al*., 1992). Major postharvest pathogens of longan fruit are *Enterobacter srtohrnrd* sp., *Acinetobacte* sp. (Lu *et al*., 1992) for bacteria; and *Botryodiplodia* sp. (Jiang, 1997), *Penicillium* sp., *Rhizopus* sp., *Alternaria* sp. (Lu *et al*., 1992), *Lasiodiplodia* sp., *Cladosposporim* sp. (Sardsud *et al*., 1994) for mold. Cerioni e*t al*. (2009) reported that SH is included in treatment due to its

fungicidal property. SH is used to prevent microbial inoculation (Sawyer, 1978). Litchi fruits (cv. Shahi and China) dipped in SH (0.2% for 4 min at 52°C) reduced microbial load to below detectable limits (Kumar *et al*., 2012). Bhowmik and Pan (1992) observed a significant reduction in microbial spoilage after sanitation of tomato fruit with SH before packaging. Ukuku (2006) reported that using 200 ppm of hypochlorite solutions reduced total bacterial, *Pseudomonas* spp., yeasts and moulds, and lactic acid bacteria counts in cantaloupes by 2.7, 0.38, 2.7 and 1.8 log units respectively. Total bacterial count, and yeast and mould count were found to be approximately 4 and 2.5 log CFU ml^{-1} respectively in the untreated litchi fruits, whereas, they were found to be nil (below detectable level) in the SH treated litchi fruits during storage period (Kumar *et al*., 2012). All treatments containing SH significantly reduced initial aerobic plate count on fresh-cut cilantro compared to those washed with tap water alone (Kim *et al*., 2007). Beltran *et al*. (2005) found that after 13 days in storage at 4°C the microbial loads increase but the chlorine wash reduced final microbial count by 2.7 log unit on fresh-cut iceberg lettuce when compared to control. Kim *et al*. (2007) also found that fresh-cut cilantro samples containing SH had significantly lower coliform/*E. coli* counts than the water control through most of the storage period. Throughout refrigerated storage, strawberries pre-washed with SH (200 µg/mL) presented lower microbial loads ($P < 0.05$) than untreated, ultrasonicated, UV-C irradiated or water-washed samples (Alexandre *et al*., 2012). Waxing is primarily done to protect from mold growth on fruits and vegetables (Thirupathi *et al*., 2006). Waxing establishes a barrier against the entrance of fungal and bacterial pathogens into the product. Waxing creates a hydrophobic (non-water compatible) surface which is not conducive to pathogen growth and development (Postharvest Handling Technical Bulletin, 2004).

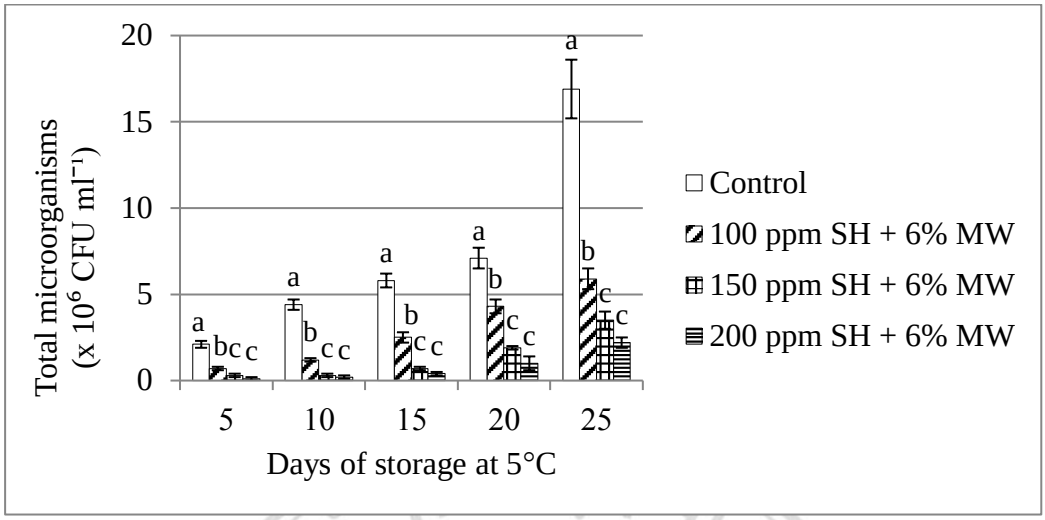

Figure 5.6 Changes in total microorganism populations on surface of treated and control longan fruits cv. Long during the storage period at 5°C.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significantly different ($P \leq 0.05$).

Longan fruits are very susceptible to postharvest decay as a result of both bacterial and fungal infections, including yeasts (Jiang *et al*., 2002). There was significant difference in the percentage of fruit decay between treated and control fruits during storage period ($P \leq 0.05$). The control fruits began to decay (3.3%) after 10 days in storage, and thereafter decay accelerated with increased storage time (after 25 and 30 days it was 50.4 and 91.0% respectively) (Figure 5.7). Our finding is consistent with the reported data on fruit decay of untreated longan fruits (Apai, 2010; Huyen and Thuy, 2011; Hai *et al*., 2011 and 2014). Apai (2009) reported that the control fruits had the highest disease development and flesh rot along with the highest browning index during the storage period. Increased decay of longan fruit caused wilt and freshness reduction and resulted in browning on the pericarp (Shodchit *et al*., 2008). As seen in Figure 5.7, fruits under SH_2 treatment had 5.9% fruit decay after 25 days, and SH_3 treatment began to decay (5.6%) after 30 days in storage. In contrast, SH_1 treatment began to decay (1.4%) after 15 days and reached 47.1% after 30 days in storage. Huyen and Thuy (2011) found that the best treatment of 2% chitosan coating had 11.4% fruit decay after 20 days in storage. Fruits coated in 6% MW had the lowest fruit decay (9.4%) after 25 days in storage (Hai *et al*., 2014). Results in this study showed that the dose of 200 ppm SH in association with 6% MW was effective to control fruit decay (0%) in longan fruit cv.

Long for 25 days. This study indicates that low fruit decay correlated with low total microorganism populations and low browning index (Figure 5.1, Figure 5.6, and Figure 5.7). Tongdee (2001) explained that fruit deteriorates rapidly after harvest, mainly on account of fruit rotting caused by saprophytic fungal growth on the fruit surface and dehydration of the rind. SH was included in treatment due to its fungicidal property (Cerioni e*t al*., 2009). SH is used to prevent microbial inoculation (Sawyer, 1978). Hot water dipping with sodium hypochlorite (200 ppm) at 52°C for 3 to 4 min was recommended for fungal disinfection of mango fruit (APEDA, 2007). Kim *et al*. (2007) reported that fresh-cut cilantro treated with SH had no decay by day 4 in storage when compared to control. Waxing establishes a barrier against the entrance of fungal and bacterial pathogens into the product. Waxing creates a hydrophobic (non-water compatible) surface which is not conducive to pathogen growth and development (Postharvest Handling Technical Bulletin, 2004). Baldwin *et al*. (1999) concluded that the carnauba wax coating reduced fruit decay in mango fruits during storage.

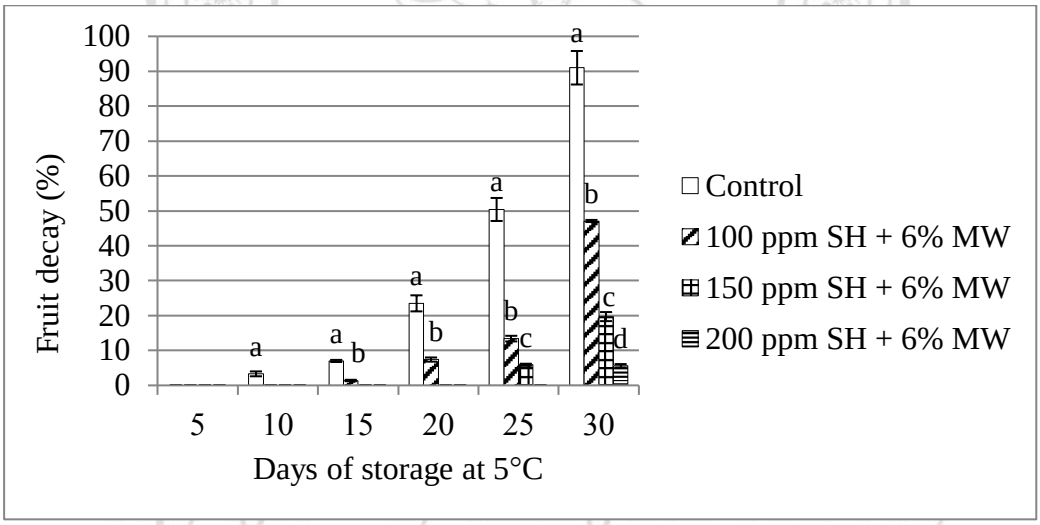

Figure 5.7 The percentage of fruit decay of treated and control fruits during storage period at 5ºC.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significantly different ($P \leq 0.05$).

5.4.5 Change in total soluble solids (TSS) content and eating quality

There was no different in TSS contents between treated and control fruits after 15 days in storage, thereafter they significantly differed by day 20 and 25 in storage ($P \leq 0.05$).

After 25 days in storage the TSS content of control fruits was 23.1%, and treated samples ranged from 20.5 to 20.9% (Figure 5.8). Our results are consistent with the finding of Hai *et al*. (2014) in which the TSS contents of MW coated fruits and control fruits ranged from 20.6 to 23.7% after 20 days in storage. Our results also are in accordance with the reported data on TSS content of longan fruit (Hoan *et al*., 2001; Apai, 2009 and 2010; Hai *et al*., 2011; Huyen and Thuy, 2011). As shown in Figure 5.8, the treated fruits had TSS contents which were close to those found in the fresh longan cv. Long at harvesting time (19.9%). From these results it can be assumed that the doses of SH and MW used in this research had no effect on the TSS content of fruits. In this study the TSS measurement showed no consistent pattern between treatments or the control fruits, but generally the TSS content of fruit in all treatments and the control increased after storage time perhaps due to dehydration. Apai (2010), Hai *et al*. (2011, and 2014) also assumed that the increase of TSS content in longan fruits during the storage period is perhaps due to dehydration.

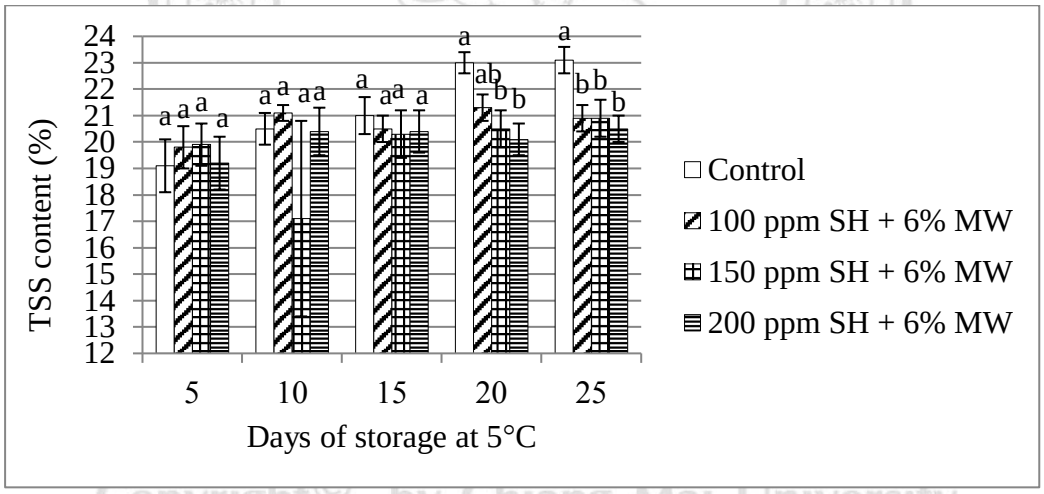

Figure 5.8 Changes in TSS content of treated and control fruits during storage period at 5ºC.

Vertical bars represent standard errors. Columns with different letters of each storage period indicate significantly different ($P \leq 0.05$).

Eating quality of treated fruits and control fruits gradually decreased with increased storage time. The eating quality of SH_1 treatment and control, SH_2 treatment, and SH_3 treatment was acceptable until day 15, 20, and 25 in storage respectively (Figure 5.9). Whangchai *et al*. (2006) reported that eating quality of all treated fruits decreased

gradually with storage period. The SH_3 treatment had the highest eating quality scores, and significantly differed from those of other treatments and control fruits during the storage period ($P \leq 0.05$). This result demonstrates that 200 ppm SH in combination with 6% MW did not adversely affect eating quality of longan fruit cv. Long. Huyen and Thuy (2011) concluded that 2% chitosan coating maintains sensory quality of longan fruit through the storage period. Citric, ascorbic or oxalic acid dipping in combination with ozone fumigation did not adversely affect eating quality of longan fruit cv. Daw (Whangchai *et al*., 2006). The 'Shahi' and 'China' litchi fruits treated with SH remained organoleptically acceptable until 45 and 30 days respectively, whereas, untreated fruits were considered as unusable after a storage time longer than 15 days due to visible mould growth was observed (Kumar *et al*., 2012). Fresh-cut cilantro treated with SH resulted in better quality score than the control (Kim *et al*., 2007).

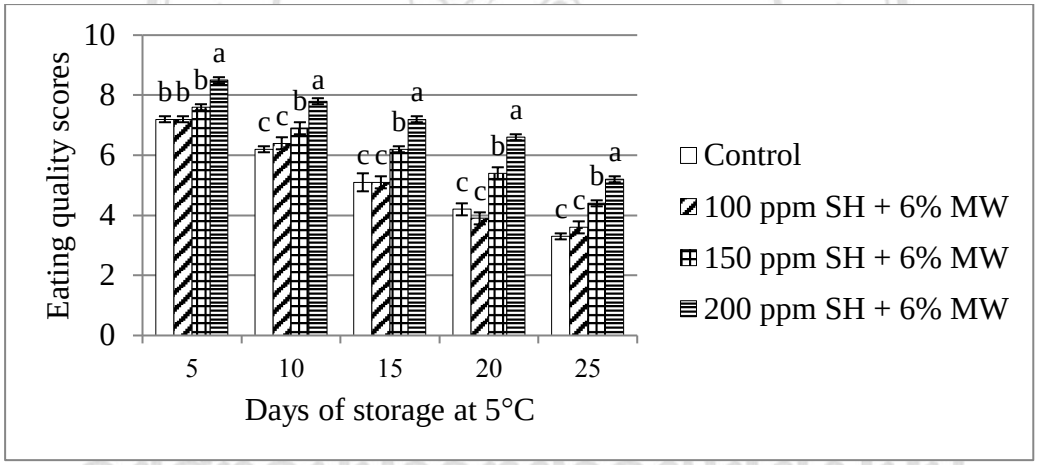

Figure 5.9 Eating quality of treated and control fruits during storage period at 5ºC.
Vertical bars represent standard errors. Columns with different letters of each storage period indicate significantly different ($P \leq 0.05$).

5.4.6 Storage life of longan fruits

Fruits under the control were not acceptable by day 10 in storage, and fruits in the SH_1 and SH_2 treatment accepted for marketable for 10 and 15 days respectively. While, fruits in SH_3 treatment showed the best postharvest quality and the longest storage life for 20 days in storage (Table 5.1; and Figures 5.10 and 5.11).

Table 5.1 The storage life of 'Long' longan fruits were considered as acceptable for marketing purposes

Treatments	Storage life (days)	Cause of limitation when extend storage time
Control (SH_0)	5	BI ≥ 2.0, fruit decay ≥ 10%, high weight loss and eating quality score < 5
100 ppm SH + 6% MW (SH_1)	10	BI ≥ 2.0, fruit decay ≥ 10%, and eating quality score < 5
150 ppm SH + 6% MW (SH_2)	15	BI ≥ 2.0, fruit decay ≥ 10%, and eating quality score < 5
200 ppm SH + 6% MW (SH_3)	20	BI ≥ 2.0

(BI: Browning Index)

5.5 Conclusion

Soaking in 200 ppm sodium hypochlorite in association with 6% bees-carnauba mixed wax coating, (instead of sulphur compounds or carbendazim application) seems to provide an interesting technological alternative method for the prevention of fruit decay and the maintenance of visual appearance in fresh Vietnamese longan fruit cv. Long. This treatment suggests that application of the above preservative agents could be feasible for longan fruits storage on a commercial scale.

(a)

(b)

Figure 5.10 Treated and control longan fruits cv. Long after 5 (a) and 10 (b) days in storage at 5°C.

(c)

(d)

(e)

Figure 5.11 Treated and control longan fruits cv. Long after 15 (c), 20 (d) and 25 (e) days in storage at 5°C.