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Full Length Article

The Prevention of Pericarp Browning and the Maintenance of Post-harvest Quality in Vietnamese Longan cv. Long, Using Sodium Metabisulfite Treatment

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ABSTRACT

The impact of sodium metabisulfite ($Na_2S_2O_5$) treatment on the prevention of pericarp browning and the maintenance of the postharvest quality of Vietnamese longan cv. Long during storage was studied by soaking bunches of the fruit in 2.5 or 5 or 7.5% of sodium metabisulfite solution for 5 and 10 min at room temperature and then storing them at 5±1ºC for 28 days. The visual appearance expressed as pericarp and flesh color; the lightness of fruit pericarp (L* value); the yellowness of fruit pericarp (b* value); polyphenol oxidase (PPO) activity; the percentage of fruit decay and fruit drop; total soluble solids (TSS) content were studied. The results show that the 10 min soaking treatment in 7.5% sodium metabisulfite solution maintained L* and b* values and low PPO activity, with the fruit showing no signs of severe pericarp browning or fruit decay throughout the 21 days in storage. Moreover, the postharvest quality of the longan fruit revealed no difference over time; plus the percentage of fruit drop was only 5.2%, when compared with the control was 5.8% and other treatments ranged from 5.5 to 5.9%.

Key Words: 'Long' longan; Pericarp browning; Fruit decay; Fruit drop; Storage period

INTRODUCTION

The longan fruit (*Dimocarpus longan* Lour.) is grown commercially in many countries, including China, Thailand, Taiwan, India and Vietnam (Jiang *et al*., 2002). In Vietnam, the area of longan grown was around 122,000 ha, with more than 95,000 ha harvested and with a yield of 610,000 tons in 2009 (The Electric Newspaper of Communist Party of Vietnam, 2009). *Nhan* is the local term for the longan in Vietnam and the most popular cultivar in the north of the country is the *Nhan Long* (cv.Long), which produces large fruit with a small seed (80 to 100 fruits/kg) (FAO, 2004). In recent years, there has been a significant increase in the yields and area under cultivation of the 'Long' cultivar in northern Vietnam, producing fruit not only of a high quality, but also with a high economic value (Nguyen *et al*., 2001). The quantity of domestic and exported longan fruit has always been limited by its highly perishable nature, short storage life and susceptibility to postharvest diseases, as well as rapid pericarp browning during storage (Tongdee, 2001; Jiang *et al*., 2002). Postharvest longan fruit can discolour rapidly due to desiccation during storage at either too low or high temperature. Fruit rot usually follows skin browning (Apai, 2010). Browning can be associated with dehydration, heat stress, senescence, chilling injury or disease (Pan, 1994). Browning of longan fruits results from the oxidation of phenolic compounds by endogenous polyphenol oxidase (PPO) (Jiang *et al*., 2002).

At present in Vietnam, the recommended method to control postharvest decay and prevent pericarp browning of 'Long' longan fruits have been using treatment of dipping the fruits in 0.2% carbendazim solution for 3 min and then storing them at 10ºC. The results showed that the 'Long' longan fruit can be prolonged shelf-life with good quality for 20 days and the percentage of fruit decay was about 10% (Nguyen *et al*., 2001). Longan consumers are becoming cautious regarding carbendazim residues, due to it is a type of pesticide. It harms to the health of humans, so it should be used in planting. There is a need to develop effective methods to replace carbendazim treatment, with something less harmful to humans and the environment. An alternative method is the use of sodium metabisulfite. Sulfiting agents such as sulfur dioxide, sodium metabisulfite have been used in food (Tongdee, 1993). Sodium metabisulfite was used to wash mushroom to remove un-wanted particulate matter and to enhance mushroom whiteness (Apai, 2009). The sulfities display a wide range of useful effects in food, including inhibition of non-enzymatic browning, as an

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antioxidant and as a reducing agent by inhibition of various enzymatic catalysed reactions (notable enzymatic browning involving oxidation of phenolic compounds present in food) and inhibition and control of microorganisms (Tongdee, 1993). According to the decision of number 46/2007/QD-BYT of the Vietnam Ministry of Health, the sodium metabisulfite is regarding as a substance in the "Codex inventory of all compounds as processing aids" (Vietnam Ministry of Health, 2007). The threshold for sulfite sensitivity varies among individuals and the type of food, ranging from about 3 mg to 120 mg SO_2 equivalent. A joint FAO/WHO Expert Committee on Food Additives applied a 100-fold safety factor and estimated the acceptable daily intake (ADI) for humans at 0.7 mg/kg of body weight day (Tongdee, 1993). Allowable SO_2 level for fresh grape in USA was 10 ppm, for fresh lychee in France was 30 ppm (temporary level considering to lower to 10 ppm) (Tongdee, 1993). Sodium metabisulfite is generally recognized as safe (GRAS) approved by Food and Drug Administration (FDA) and used as food preservative (Apai, 2009).

The main purpose of this study was to find the best treatment from the treatments of soaking 'Long' longan fruits in 2.5 or 5 or 7.5% sodium metabisulfite solution for 5 and 10 min as an alternative treatment to carbendazim dipping and to reduce postharvest decay, to prevent pericarp browning and maintain the quality of fresh bunches of 'Long' longan fruit during storage at low temperatures.

MATERIALS AND METHODS

Plant material: Mature 'Long' longan fruit from the 2010 crop of a commercial orchard in Hung Yen Province in Vietnam were used for the research. The longan fruits were harvested in the morning and then packaged in 20 kg plastic baskets, lined with leaves and then transported to the laboratory within 2 to 3 h. Bunches of the fruit were then selected for uniformity of shape, color and the number of fruit per bunch, prior to use in this experiment.

Studying methods: The optimal and feasible concentrations of sodium metabisulfite (SMB) were selected after preliminary tests. The bunches were first soaked in 2.5 or 5 or 7.5% sodium metabisulfite solution for 5 and 10 min at room temperature, while the control fruits were not soaked. The bunches were dried for 10 min and packaged in polypropylene bags (305 x 457 mm in size & 0.035 mm thick) with 1 kg in each bag. The bags were then stored at 5±1ºC in a cold room and sampled/analyzed at 7 days intervals. Each treatment had three replications.

A completely randomized design was used for the experiment. T_0 was the control and the T_1 and T_2 fruits were treated with 2.5% SMB for 5 and 10 min, respectively, the T_3 and T_4 fruits with 5% SMB for 5 and 10 min, respectively and the T_5 and T_6 fruits with 7.5% SMB for 5 and 10 min, respectively.

The pericarp color was measured using a colorimeter (Konica Minolta, Japan) and L* indicates lightness, ranged from black = 0 to white = 100, b* indicates chromaticity on a blue (-) to yellow (+) axis (MacGuire, 1992).

The total soluble solids content was determined using a digital refractometer (PAL-1, Atago, Japan).

Visual appearance expressed as pericarp browning and flesh color. Pericarp browning was estimated by observing the extent of total browned area on each fruit surface on the following scale: 1 = 0% (no browning); 2 = 1-25% (slight browning); 3 = 26-50% (moderate - serious browning); 4 = 51-75% (serious browning) and 5 = 76-100% (poor quality) pericarp browning area. A browning index was calculated using the following formula: □ (browning scale x percentage of corresponding fruits in each class). Fruits with browning index above 2.0 were considered as un-acceptable. Flesh color was assessed visually by observing the change in chromatic level on each of fruit. The following scale was used: 1 = normal color; 2 = slightly abnormal color, but still acceptable; 3 = moderately abnormal color and un-acceptable and 4 = severely abnormal color. A flesh color index was calculated using the following formula: □ (flesh color scale x percentage of corresponding fruits in each class). Fruits having a flesh color index above 2.0 were rated as un-acceptable (Jiang & Li, 2001).

Polyphenol oxidase (PPO) was extracted according to the method of Huang *et al*. (1990). Longan pericarp (10 g) was homogenized in 40 mL of 0.05 M potassium phosphate buffer (pH 6.2) containing 1 M KCL and 2% polivinylpyroritidone and then centrifuged for 5 min at 13,500 rpm (Hermel model Z383K) and 4ºC. The supernatant was collected as the enzyme extract. PPO activity was assayed by a modification based on the method of Jiang and Fu (1998) using the reaction mixture of 0.05 M potassium phosphate buffer (pH 7.5) containing 0.2 M catechol (0.2 mL) and crude enzyme (0.5 mL). Tubes were incubated for 5 min at 30ºC, the absorbance was measured at 420 nm by visible spectrophotometer (model Thermo Spectronic). The unit of enzyme activity was defined as the amount of enzyme that caused a change of 0.01 in absorbance per minute.

Fruit decay was assessed as the percentage of fruit decay as follows:

$$\text{Percentage of fruit decay} = \frac{\text{Number of fruit decay}}{\text{Total fruit}} \times 100$$

Fruit drop was determined by the percentage of fruit becoming detached from the bunch.

$$\text{Percentage of fruit drop} = \frac{\text{Number of fruit drop}}{\text{Total fruit}} \times 100$$

Statistical analysis was carried out using the SPSS software (version 13) and Duncan's Multiple Range Test ($P \leq 0.05$) was used to analyze the significant differences between treatments and control.

RESULTS AND DISCUSSION

Changes in visual appearance during storage period: Fig. 1 indicates the changes in visual appearance expressed as browning index (BI) of longan fruits treated with various concentrations of SMB and the control during the storage period. Fruits with BI above 2.0 (more than 25% pericarp browning area) were considered as un-acceptable for marketing purposes. According to Fig. 1, there was significantly different on BI between the control, T_1, T_2 and T_3-T_6 treatments after 7 days in storage ($P \leq 0.05$). Bunches of fruit under the T_0-T_2 treatments had BI higher than 2.0 and they were not acceptable by day 7 in storage. This result indicates that without or low concentration of SMB did not inhibit pericarp browning. For the un-treated longan fruits, pericarp browning occurred after a delay of 5 days with a BI above 2.0 (Apai, 2010). Jaitrong (2006) also found that un-treated longan fruit pericarp browned during storage at 2-7ºC for 5 days. After 21 days in storage, there was significant difference on BI of all treatments and the T_3-T_5 treatments were not acceptable because of BI higher than 2.0. Whangchai *et al*. (2006) reported that pericarp browning increased with increasing storage time. The T_6 treatment showed the best pericarp color and the longest storage life at 21 days. This result explains that soaking fruits in 7.5% SMB for 10 min prevented pericarp browning and it acts as an inhibiting agent for enzymatic browning involving oxidation of phenolic compounds present in fruit pericarp. Sodium metabisulfite prevented skin browning (Tongdee, 1993). Jiang *et al*. (2002) reported that dipping in sodium metabisulfite is effective against pericarp browning. Our results are consistent with reported data on BI of longan fruit pericarp (Nguyen *et al*., 2001; Whangchai *et al*., 2006; Apai, 2009 & 2010).

The changes in visual appearance expressed as flesh color index (FCI) of longan fruits during storage period were observed and results are showed in Fig. 2. Fruits with FCI above 2.0 were considered as un-acceptable. It can be seen that, the FCI was not different in all treatments and the control by day 7 and there was significant difference between T_0-T_2 treatments, when compared with T_3-T_6 treatments, which were not different by day 14 ($P \leq 0.05$). After 21 days in storage, the flesh color of the longan fruits remained acceptable for all treatments (FCI below 2.0), when compared to the control, which was not acceptable due to FCI above 2.0. This result demonstrates the effectiveness of SMB in maintaining flesh color of longan fruit. The control fruits showed pulp rot in accordance to the highest browning index (Apai, 2009). Our results are in accordance with reported data on flesh quality of treated 'Long' longan fruits, which were acceptable by day 20 in storage (Nguyen *et al*., 2001). After 28 days in storage, the FCI of all most of treatments was significantly different (except T_4 & T_5 treatment was similar) and the fruits of T_4-T_6 treatments maintained an acceptable flesh color (Fig. 2). It means that the treatments with 5% SMB for 10 min and 7.5% SMB for 5 and 10 min improved flesh color due to which inhibit enzymatic browning and control microorganisms and fungi (Tongdee, 1993).

Fig. 1: Changes in browning index (BI) of longan fruit pericarp either treated or not, during storage period at 5ºC. BI: 1 = 0%; 2 = 1-25%; 3 = 26-50%; 4 = 51-75%, and; 5 = 76-100% pericarp browning area. Fruits with BI above 2.0 were considered as unacceptable. Vertical bars represent standard errors. Columns with different letters indicate significant differences by Duncan's multiple range test ($P \leq 0.05$)

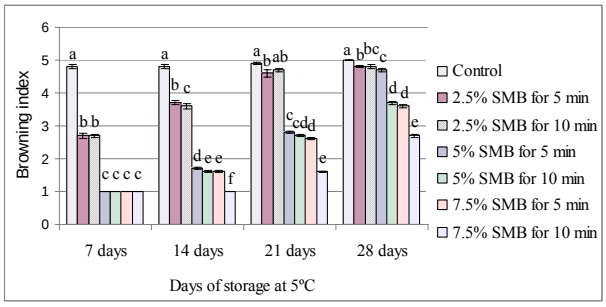
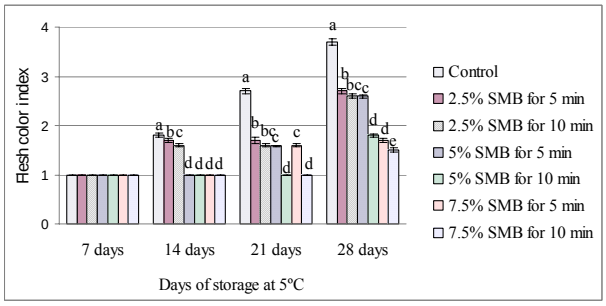


Fig. 2: Changes in flesh color index (FCI) of whole longan fruits, either treated or not, during storage period at 5ºC. FCI: 1 = normal color; 2 = slightly abnormal color, but still acceptable; 3 = moderately abnormal color and un-acceptable and; 4 = severely abnormal color. Fruits with FCI above 2.0 were considered as un-acceptable. Vertical bars represent standard errors. Columns with different letters indicate significant differences by Duncan's multiple range test ($P \leq 0.05$)



Changes in L* and b* values: The L* values (lightness) of fruit pericarp were measured and results are shown in Fig. 3. It can be seen that, after 21 days in storage, there was significantly different on L* values between the control; T_1-T_2; T_3- T_4; T_5- T_6 treatments ($P \leq 0.05$). The L* values of T_5-T_6 treatments were higher than other treatments and the control and they were not different. The L* values of treated fruits was higher than L* values of the control fruits during storage period. This result demonstrates the effectiveness of anti-browning agent in maintaining the lightness of fruit pericarp. Jiang (1999) reported that the browning reaction

Fig. 3: L* value indicates the lightness of longan fruit pericarp. Analyses were realized on eighteen fruits per time in each treatment and the control during storage period at 5ºC. Vertical bars represent standard errors. Columns with same letters are not significantly different by Duncan's multiple range test ($P \leq 0.05$)

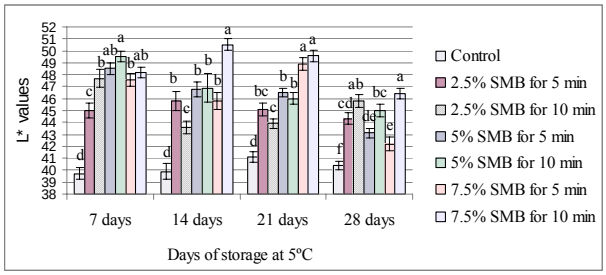
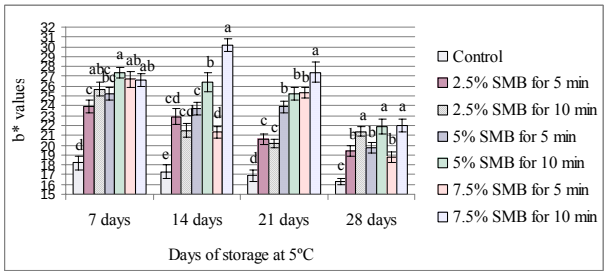


Fig. 4: b* value indicates the yellowness of longan fruit pericarp. Analyses were realized on eighteen fruits per time in each treatment and the control during storage period at 5ºC. Vertical bars represent standard errors. Columns with different letters indicate significant differences by Duncan's multiple range test ($P \leq 0.05$)



on fruit pericarp is caused by oxidation of phenolic compounds by PPO activity. Sodium metabisulfite inhibited the oxidation of phenolic compounds (Tongdee, 1993). After 28 days in storage, there was significant difference on L* values in all treatments and the control and the L* values ranged from 40.4 to 46.4 and which tended to decrease in all treatments ($P \leq 0.05$). The L* values of longan fruit pericarp decreased from 53.5 to 42.3, when treated fruits were stored at 5ºC for 24 days. Our results are consistent with reported data on L* values of pericarp of longan fruit (Rattanapanone *et al*., 2001; Jaitrong, 2006; Shodchit *et al*., 2008; Apai, 2009). Apai (2010) demonstrated that un-treated fruits had lower L* values. According to Fig. 3, the fruits soaked in 7.5% SMB for 10 min had higher L* values than the fruits, which underwent other treatments and the control during storage period. This result explains that treatment with 7.5% SMB for 10 min significantly inhibited the browning reaction on longan pericarp ($P \leq 0.05$).

The b* values (yellowness) of fruit pericarp were measured and results are shown in Fig. 4. After 21 days in storage the b* values ranged from 16.9 to 27.4 and the b* values of T_3-T_5 treatments were similar, T_1 treatment was

Fig. 5: Changes in activity of polyphenol oxidase (PPO) in longan pericarp of treated fruits and the control fruits during storage period at 5ºC. Vertical bars represent standard errors. Columns with different letters indicate significant differences by Duncan's multiple range test ($P \leq 0.05$)

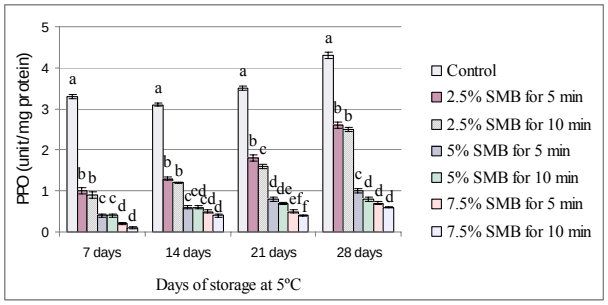
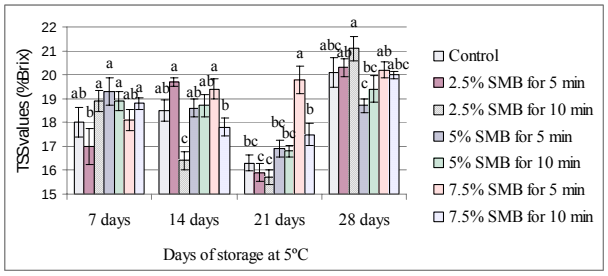


Fig. 6: Changes in TSS values of treated fruits and the control fruits during storage period at 5ºC. Vertical bars represent standard errors. Columns with same letters are not significantly different by Duncan's multiple range test ($P \leq 0.05$)



similar to T_2 treatment and they were significantly different with T_6 treatment and the control ($P \leq 0.05$). After 28 days in storage, the b* values ranged from 16.3 to 22.0, the fruits in T_1, T_3, T_5 treatment had b* values, which was similar. There was not a significant difference on b* value in the T_2, T_4, T_6 treatment by day 28 ($P \leq 0.05$). The b* values of treated fruits were higher than b* values of the control fruits during storage period. This result justifies the effectiveness of SMB in maintaining the yellowness of fruit pericarp by against oxidation of phenolic compounds by PPO activity as described by (Tongdee, 1993; Jiang, 1999). It can be seen from Fig. 4, the b* values tended to decrease in all treatments and the control after 28 days in storage. Shodchit *et al*. (2008) demonstrated that b* values of treated fruits tended to decrease with increasing storage time. The fruits soaked in 7.5% SMB for 10 min had higher b* values than the fruits which underwent other treatments and the control during storage period. This result shows that treatment with 7.5% SMB for 10 min maintained the longevity of yellowness of fruit pericarp better than other treatments. Boonin *et al*. (2006) concluded that longan fruit cv. Daw soaked in 5% oxalic acid before 7.5% sodium metabisulfite, and the mixed solution of sodium metabisulfite and oxalic

Fig. 7: The percentage of fruit decay of treated fruits and the control fruits during storage period at 5ºC. Vertical bars represent standard errors. Columns with same letters are not significantly different by Duncan's multiple range test ($P \leq 0.05$)

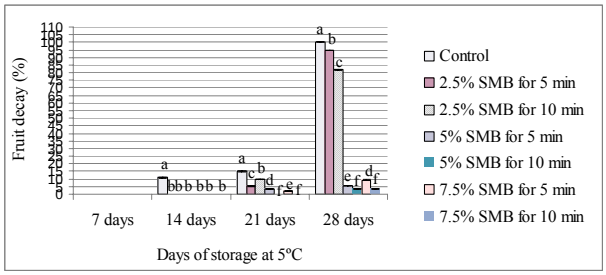
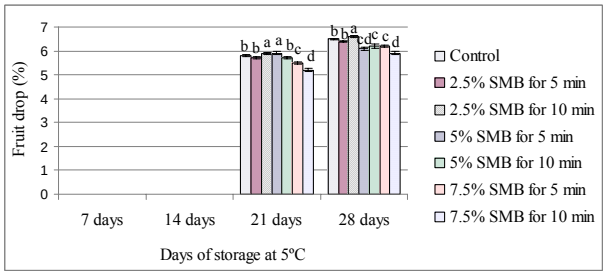


Fig. 8: The percentage of fruit drop of treated fruits and the control fruits during storage period at 5ºC. Vertical bars represent standard errors. Columns with same letters are not significantly different by Duncan's multiple range test ($P \leq 0.05$)



acid solution could maintain b* values, when compared to the other treatments and the control.

Changes in PPO activities: Tissue browning pericarp of longan fruit is dependent upon PPO activity (Kader, 2002). There has been widespread acceptance that litchi pericarp browning is caused by a rapid degradation of phenols by PPO activity (Underhill *et al*., 2001). Fig. 5 indicates the changes in PPO activity in 'Long' longan pericarp of treated fruits and the control fruits during storage period at 5ºC. It can be seen that, there was significantly different on PPO activity in all treatments and the control by day 21 in storage. After 28 days in storage, the PPO activity of the T_4-T_6 treatments was not different, and T_1- T_2 treatments also was not different ($P \leq 0.05$). The control fruits had the highest PPO activity (which ranged from 3.1 to 4.3 unit/mg protein) and it was strongly different with treated fruits, which remained low PPO activity (from 0.1 to 2.6 unit/mg protein) during storage period ($P \leq 0.05$). These results explain that sodium metabisulfite treatments in this study significantly inhibited PPO activity of longan pericarp during storage period, when compared with the control. Sodium metabisulfite displays as an antioxidant and as a reducing agent by inhibition of enzymatic browning involving oxidation of phenolic compounds by PPO activity (Tongdee, 1993; Jiang, 1999). Wu *et al*. (1999) found that sulfur dioxide inhibited enzymatic skin browning during storage by inhibited PPO activity. Low PPO activity was found by Whangchai *et al*. (2006), when fruits were treated by sulfur dioxide. This study indicates that low PPO activity correlated with high concentration and dipping time in SMB solution (Fig. 5) and low PPO activity correlated with low browning index (Fig. 1 & Fig. 5). The fruits soaked in 7.5% SMB for 10 min had the lowest PPO activity and which ranged from 0.1 to 0.6 unit/mg protein during 28 days in storage. This result demonstrates that the high concentration of SMB in combination with dipping time significantly inhibited PPO activity.

Change in total soluble solids content (TSS values): The TSS values of 'Long' longan fruits are shown in Fig. 6. After 21 days in storage, the TSS values of treated fruits and the control fruits ranged from 15.7 to 19.8% Brix, the TSS value of T_0, T_3, T_4 treatment was not different and the TSS value of T_1, T_2 treatment also was not different ($P \leq 0.05$). These TTS values are in accordance with reported data, which ranged from 16.9 to 20.9% Brix (Tran, 1999; Nguyen *et al*., 2001). After 28 days in storage, the TSS values ranged from 18.7 to 21.1% Brix and the TSS value of T_6 treatment was not significantly different with the control ($P \leq 0.05$). These TSS values are close to those found in the fresh longan (17% & 21% Brix). These results can be assumed that the doses of SMB used in this research had no effect on the TSS values of 'Long' longan fruit. Nguyen *et al*. (2001) reported that the doses of carbendazim did not effect on the TSS values of 'Long' longan fruit during storage period. Our results also are in accordance with the reported data on TSS values of longan fruit, which ranged from 19.3 to 20.4% Brix (Apai, 2009 & 2010). In this study the TSS measurement showed no consistent pattern between treatments, but generally these TSS values of fruit in all treatments and the control increased after 28 days in storage perhaps due to dehydration.

Fruit decay: The percentage of fruit decay in the control was 11.0% after 14 days in storage, thereafter increasing with the time spent in storage (after 21 days it was 15.0% & after 28 days it was 100%) (Fig. 7). The control fruits had the highest disease development and flesh rot in accordance with the highest browning index during storage period (Apai, 2009). Apai (2010) demonstrated that there was little or no disease development during the first 5 days of storage, after that disease incidence increase with increasing storage time. The more fruit decay of longan fruit caused wilt and freshness reduction and then resulted in browning on the pericarp (Shodchit *et al*., 2008). It can be seen from Fig. 7, the fruits soaked in 5 or 7.5% SMB for 10 min showed no fruit decay by day 21 and had the lowest fruit decay (3.7%) by day 28 in storage and they were significant difference with other treatments and the control ($P \leq 0.05$). These results demonstrate that the high doses of SMB in combination with dipping time significantly prevented fruit decay in 'Long' longan fruit during storage period. Our

results are significantly different to the results found by Nguyen *et al*. (2001), who found that percentage of fruit decay of 'Long' longan fruit was about 10% after 20 days in storage at 10ºC. 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. The most important microorganisms are *Botryodiplodia* sp. and yeasts *Saccharomyces* sp. Sodium metabisulfite controlled saprophytic surface fungi and it also inhibited and controlled microorganisms (Tongdee, 1993). Sulphur dioxide has fungistatic properties (Coates & Johnson, 1993).

Fruit drop: The percentage of fruit drop was calculated and results are shown in Fig. 8. After 14 days in storage, no fruit had fallen away from the bunches, after which time the percentage of fruit drop tended to increase and it ranged from 5.2 to 5.9% by day 21 and from 5.9 to 6.6% by day 28. According to Fig. 8, after 21 days in storage, the percentage fruit drop in T_1, T_4 treatment did not differ significantly, when compared to the control. There was slightly different on the percentage of fruit drop between treated fruits and the control fruits after 28 days in storage, but this rate was not significant ($P \leq 0.05$). These results demonstrate that the effectiveness of anti-browning agent is not influence on the rate of fruit dropping from the longan bunches. Nguyen *et al*. (2001) also found that 'Long' longan fruit drop ranged from 4.9 to 5.7% and the percentage of fruit drop of treated fruits were not different, when compared with the control fruits after 20 days in storage. Shodchit *et al*. (2008) reported that the fall-off longan fruits cv. Daw, which were treated with various concentrations of N-acetyl -L - cysteine, 4- hexylresorcinol and the control were not different, when stored for 6 days at 15 ±2ºC.

CONCLUSION

Soaking 'Long' longan fruit in 7.5% SMB solution for 10 min instead of carbendazim provides an interesting technological alternative for the prevention of pericarp browning and fruit decay and maintenance of postharvest quality during the first 21 days in storage at 5ºC. In addition, the SO_2 residue detected in the flesh of the fruit after 7 days in storage was 0 ppm and no residue was detected in the pericarp of the longan fruit after 21 days in storage.

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