CHAPTER 4

Results

Experiment 1

Effects of SA and MJ on chilling injury and fruit quality of mango fruit cv. Nam Dok Mai No. 4 during low temperature storage.

Changes in chilling injury and fruit quality of Nam Dok Mai No. 4 fruits, and reduction in CI and maintaining the fruit quality by SA and MJ treatments during storage at 5 °C are described as follows.

1. Chilling injury during low temperature storage

Visual symptoms of CI

Figures 4.1 and 4.2 show the CI symptoms and CI index of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C (Appendix: Table 1). It was found that CI symptoms such as exocarp browning started to occur in the control fruits on Day 21 of storage with the score of 0.42. The CI index increased rapidly with the storage time. At the end of 42 days of storage, the CI index reached its peak of 5 with more than 75% surface area affected by browning. Surface pitting (2.5-5%) and endocarp browning (5-7.5%) in some fruits after storage for 35 and 42 days (data not shown) were observed. CI symptoms were visible only on the exocarp without noticeable effect on the mesocarp.

The CI symptoms of fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM first appeared on Day 21 were similar to the control fruits. CI symptoms and CI indices of SA and MJ treated fruits increased with storage time but they were significantly lower and less severe than the control fruits after Day 21 up to the end of storage time. At the end of 42 days of storage, CI indices of 0.1 mM SA, 1 mM SA, and 0.1 mM MJ treated fruits were 4, 1.5, and 4 respectively indicating

Figure 4.1 Effects of SA and MJ on chilling injury symptoms of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C for 42 days.

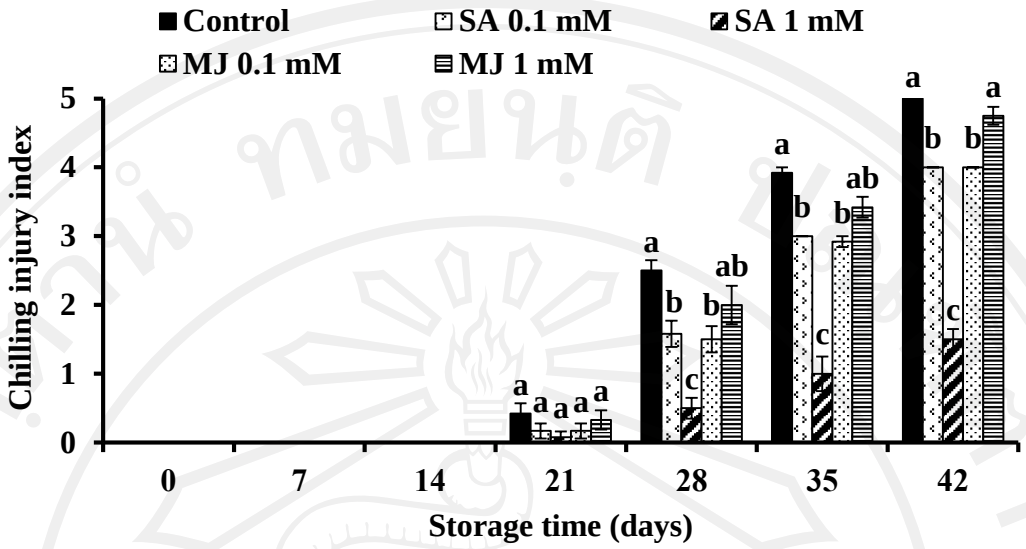

Figure 4.2 Effects of SA and MJ on chilling injury index of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

that these treatments significantly reduced CI by 20, 70 and 20% respectively compared with the control. Among the treatments, 1.0 mM SA was most effective in reducing the CI index of Nam Dok Mai No. 4 fruit during storage at 5 °C (Figures 4.1 and 4.2).

2. Fruit quality during low temperature storage

Exocarp and mesocarp color

Figure 4.3 shows L*, a*, b*, C* and h° values of exocarp of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 2). The exocarp of control fruits showed a typical pattern of decreasing L* and h° values and increasing a*, b* and C*. The fruit exocarp color gradually changed from green to yellow during storage at 5 °C for a longer period. The L*, a*, b*, C* and h° values of control fruits were 32.32, -0.50, 17.85, 17.32 and 91.99 respectively at the end of 42 days of storage. Changes in exocarp color of SA and MJ treated fruits were not significantly different except L^* values. The SA and MJ fruits presented higher L* value than the control fruits on Days 28-42. At the end of storage, fruits treated with 1 mM SA had the highest brightness.

Figure 4.4 shows L*, a*, b*, C* and h° values of mesocarp of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 3). The L* and h° values gradually

declined and a*, b* and C* values increased during storage. The L*, a*, b*, C* and h° values of the control fruits were 38.00, -0.53, 9.39, 9.47 and 92.00 respectively at the end of storage. Mesocarp color changes of SA and MJ treated fruits were not significantly different throughout storage time.

TSS, TA and TSS/TA ratio

Figure 4.5 shows the TSS, TA and TSS/TA ratio of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 4). It was found that TSS of the control fruits started with 7.82 % on Day 0 and gradually increased with the storage time. At the end of storage, TSS was 12.52% or increased 60% (Figure 4.5a), while TA of the control fruits was 2.70% on Day 0 and slightly decreased with storage time. At the end of storage, TA was as low as 2.06% or decreased 24% (Figure 4.5b). TSS/TA ratio of the control fruits also increased with the storage time. TSS/TA ratio was 2.90 on Day 0 and was 6.17 or increased 113% at the end of storage (Figure 4.5c). Changes in TSS, TA and TSS/TA ratio of the fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different (Figure 4.5).

Fruit firmness

Figure 4.6 shows the fruit firmness of Nam Dok Mai No. 4 mango during storage at 5 °C (Appendix: Table 5). It was found that the firmness of the control fruits was 16.81 kg/cm^2 on Day 0 and gradually decreased with the storage time. At the end of 42 days of storage, fruit firmness was 11.89 kg/cm^2 or decreased about 29%. Firmness of the fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period.

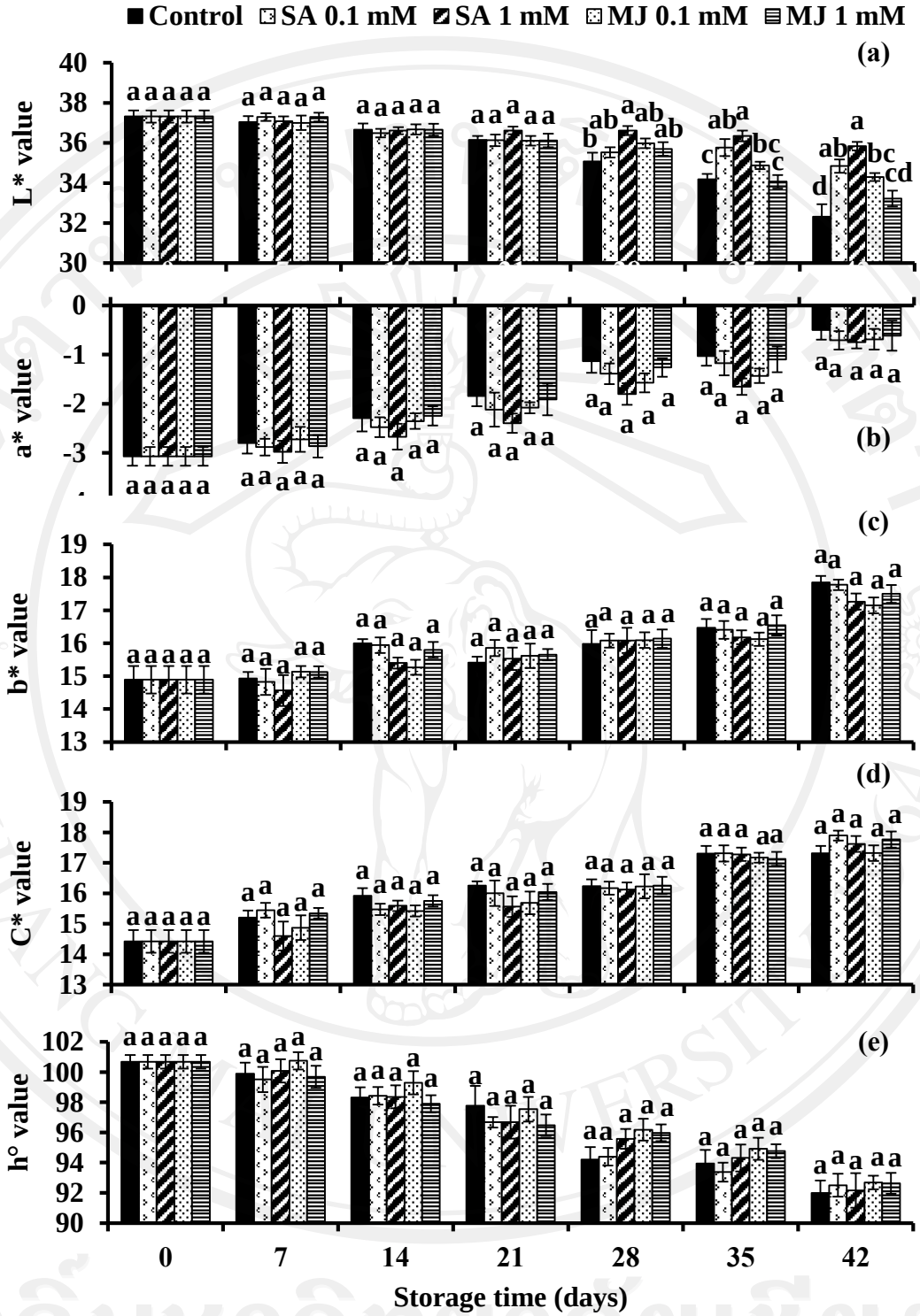

Figure 4.3 Effects of SA and MJ on L* (a), a* (b), b* (c), C* (d) and h° (e) values of exocarp of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

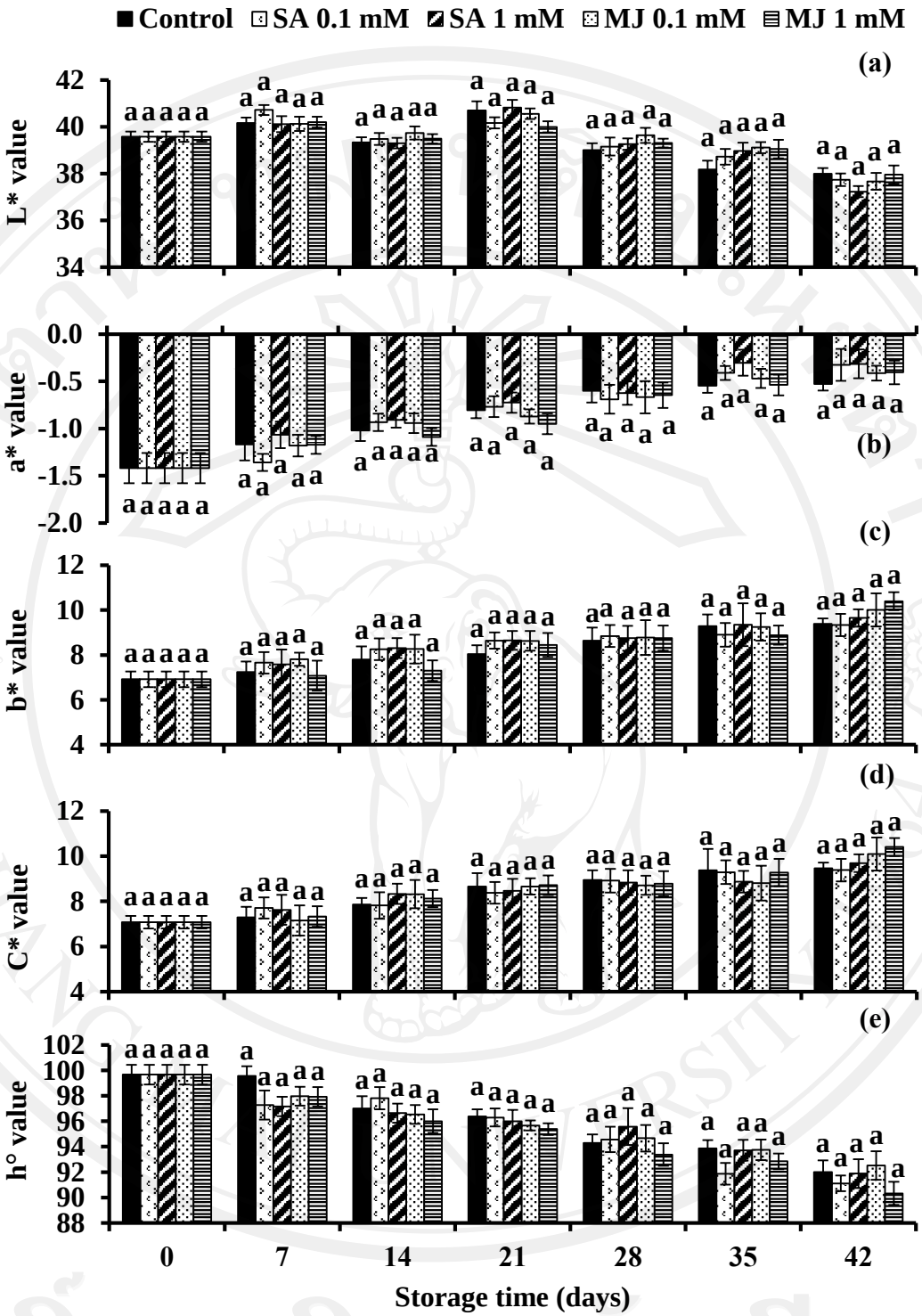

Figure 4.4 Effects of SA and MJ on L* (a), a* (b), b* (c), C* (d) and h° (e) values of mesocarp of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

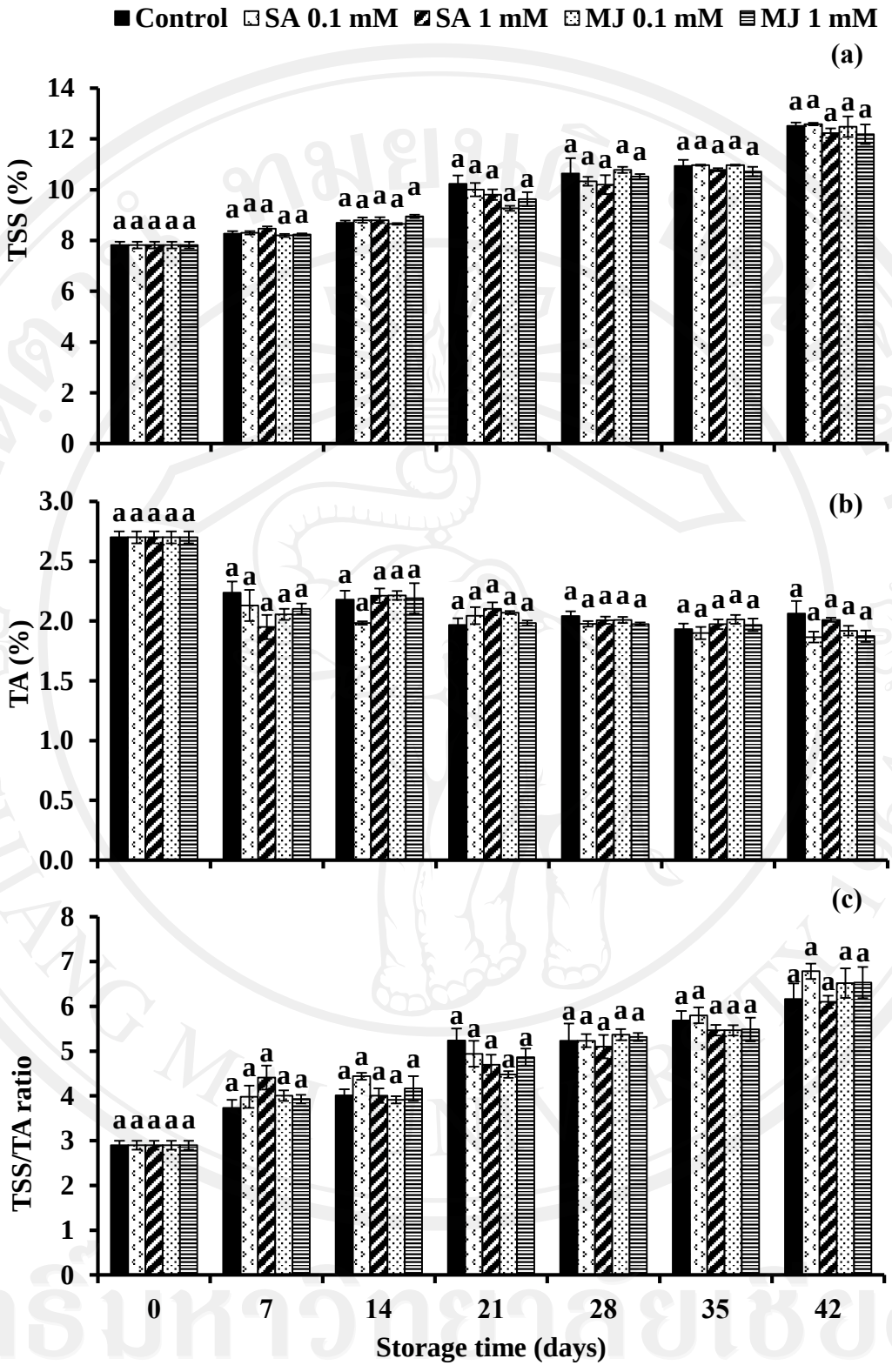

Figure 4.5 Effects of SA and MJ on TSS (a), TA (b) and TSS/TA ratio (c) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

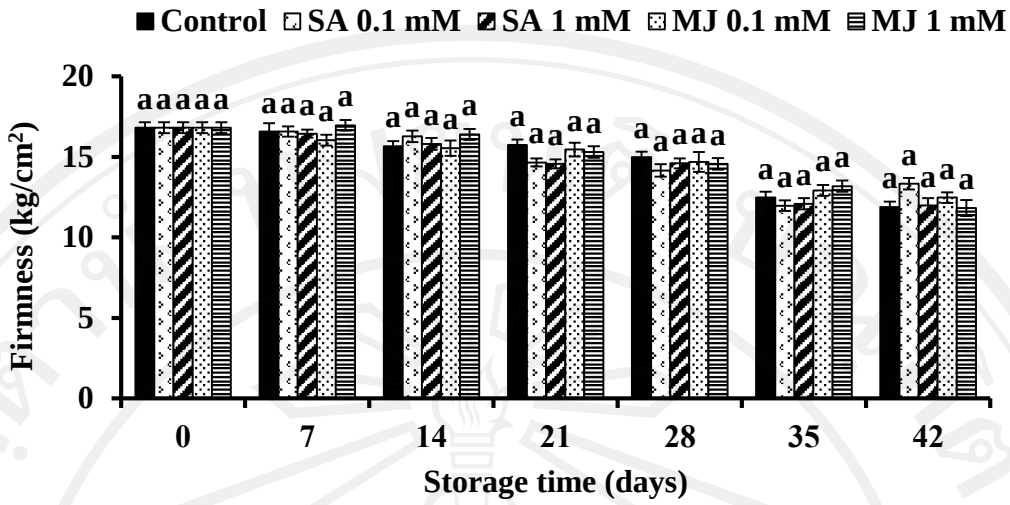

Figure 4.6 Effects of SA and MJ on firmness of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Weight loss

Figure 4.7 shows the weight loss of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 6). It was found that weight loss of the control fruits gradually increased with the storage time. At the end of storage, the control fruits had 4.97% weight loss. Weight loss of fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period.

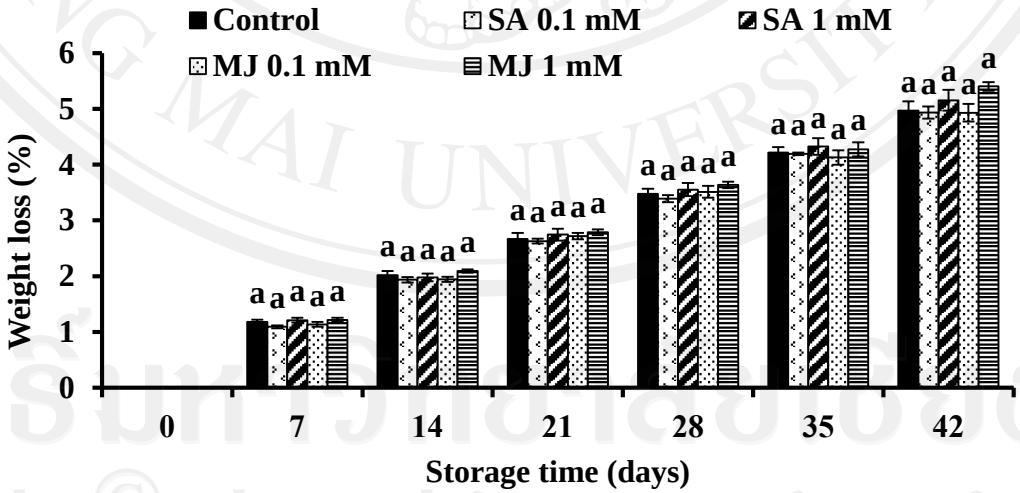

Figure 4.7 Effects of SA and MJ on weight loss of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Disease index

Figure 4.8 shows the disease index of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 7). It was found that disease of the control fruits manifested as anthracnose that appeared on the fruit exocarp less than 25% surface area (disease index = 0.05) after storage at 5 °C for 21 days and slightly increased with the storage time. At the end of storage, the control fruits had disease index of 0.41. The disease index of fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period.

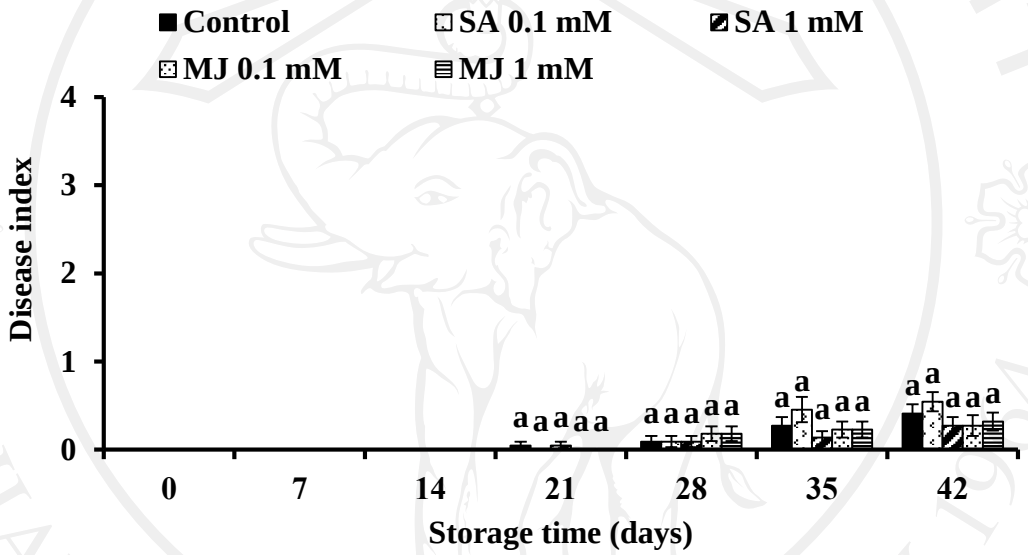

Figure 4.8 Effects of SA and MJ on disease index of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Fruit quality when ripe

All the treated mango fruits ripened after being transferred from cold storage at 5 °C to room temperature (25±2 °C) at each period of cold storage. The effects of SA and MJ treatments on ripe fruit quality were the following.

Numbers of days for complete ripening

Nam Dok Mai No. 4 mango fruit in all treatments that had not been stored at 5 °C required 10.20 days for ripening at room temperature. The fruits in all treatments at each time point of cold storage required 7.80 to 9.60 days for ripening (Figure 4.9,

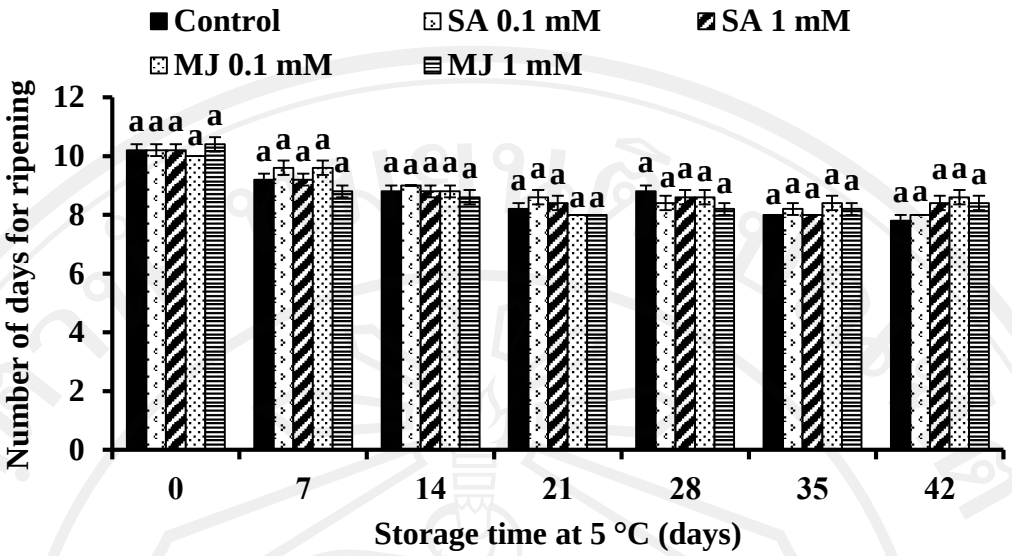

Figure 4.9 Effects of SA and MJ on number of days for ripening of mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

Appendix: Table 8). The number of days for ripening of the fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period (Figure 4.9, Appendix: Table 8). It was also found that a longer period of storage at 5 °C resulted in faster ripening.

Exocarp and mesocarp color of ripe mango

Figure 4.10 shows L*, a*, b*, C* and h° values of exocarp of ripe mango fruits after transfer to room temperature at each period of cold storage (Appendix: Table 9). The exocarp of all ripe fruits at each time was yellow, lower L* and h° values and higher a*, b* and C* values than those of the green fruits. The a*, C* and h° values of exocarp did not change, except the brightness and yellow color which gradually decreased with the storage time as a result of decreasing L* and b* values. L* values of SA and MJ fruits were higher than the control fruits on Days 21-42. At the end of 42 day storage, the fruits treated with 1 mM SA had the highest brightness. However, SA and MJ treatment did not affect a*, b*, C* and h° values of exocarp of ripe mango fruits (Appendix: Table 9).

Figure 4.11 shows L*, a*, b*, C* and h° values of mesocarp of ripe mango fruits after transfer to room temperature at each period of cold storage (Appendix: Table 10).

Similar trend in color change was also observed for mango mesocarp. The brightness and yellowness of mesocarp slightly decreased during storage. SA and MJ treatment did not affect L*, a*, b*, C* and h° values of mesocarp of ripe mango fruits (Appendix: Table 10).

TSS, TA and TSS/TA ratio of ripe mango

Figure 4.12 shows the TSS, TA and TSS/TA ratio of ripe mango after transfer to room temperature at each period of cold storage (Appendix: Table 11). It was found that TSS of all treated fruits varied between 14.22 and 15.75% (Figure 4.12a) and TA varied between 0.11 and 0.14% (Figure 4.12b) during cold storage period. TSS/TA ratios of all the treated fruits varied between 133.77 and 143.82 on Day 0 and gradually decreased with storage time. At the end of 42 days of storage, the TSS/TA ratio of all treated fruits varied between 109.38 and 117.75 (Figure 4.12c). TSS, TA and TSS/TA ratio of ripe fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period.

Firmness of ripe mango

Figure 4.13 shows the firmness of ripe mango fruits after transfer to room temperature at each period of cold storage (Appendix: Table 12). It was found that the firmness of all treated fruits varied between 0.54 and 0.76 kg/cm^2. The firmness of ripe fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period.

Disease index of ripe mango

Figure 4.14 shows the disease index of ripe mango fruits after transfer to room temperature at each period of cold storage (Appendix: Table 13). It was found that the disease index of ripe fruits was higher than that of the unripe ones during storage at 5 °C and gradually increased with storage time. At the end of 42 days of storage, all the treated fruits had disease indices of 1.27 to 1.55. The disease index of fruits treated with either SA or MJ at the concentrations of 0.1 and 1.0 mM were not significantly different during the storage period.

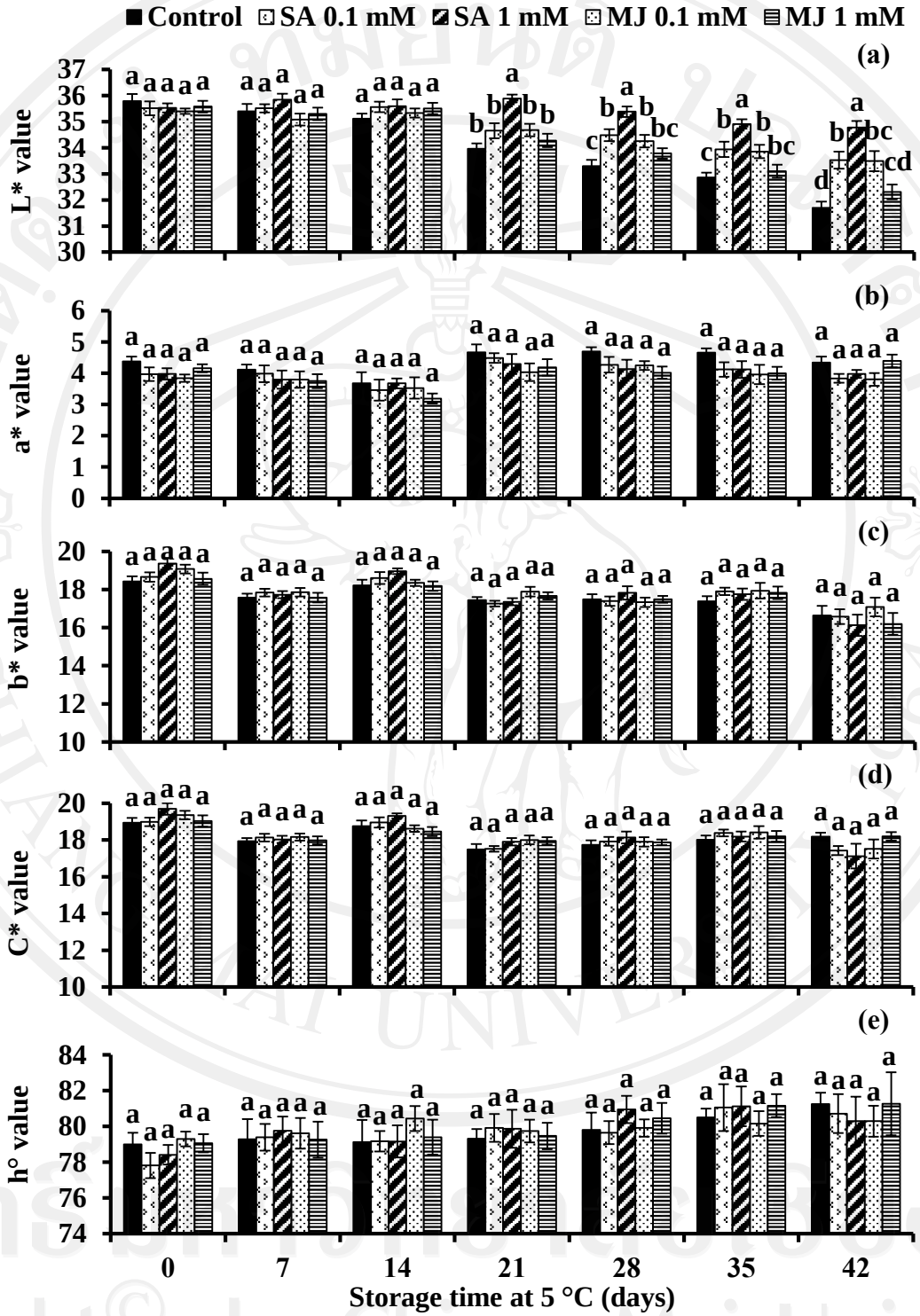

Figure 4.10 Effects of SA and MJ on L* (a), a* (b), b* (c), C* (d) and h° (e) values of exocarp of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

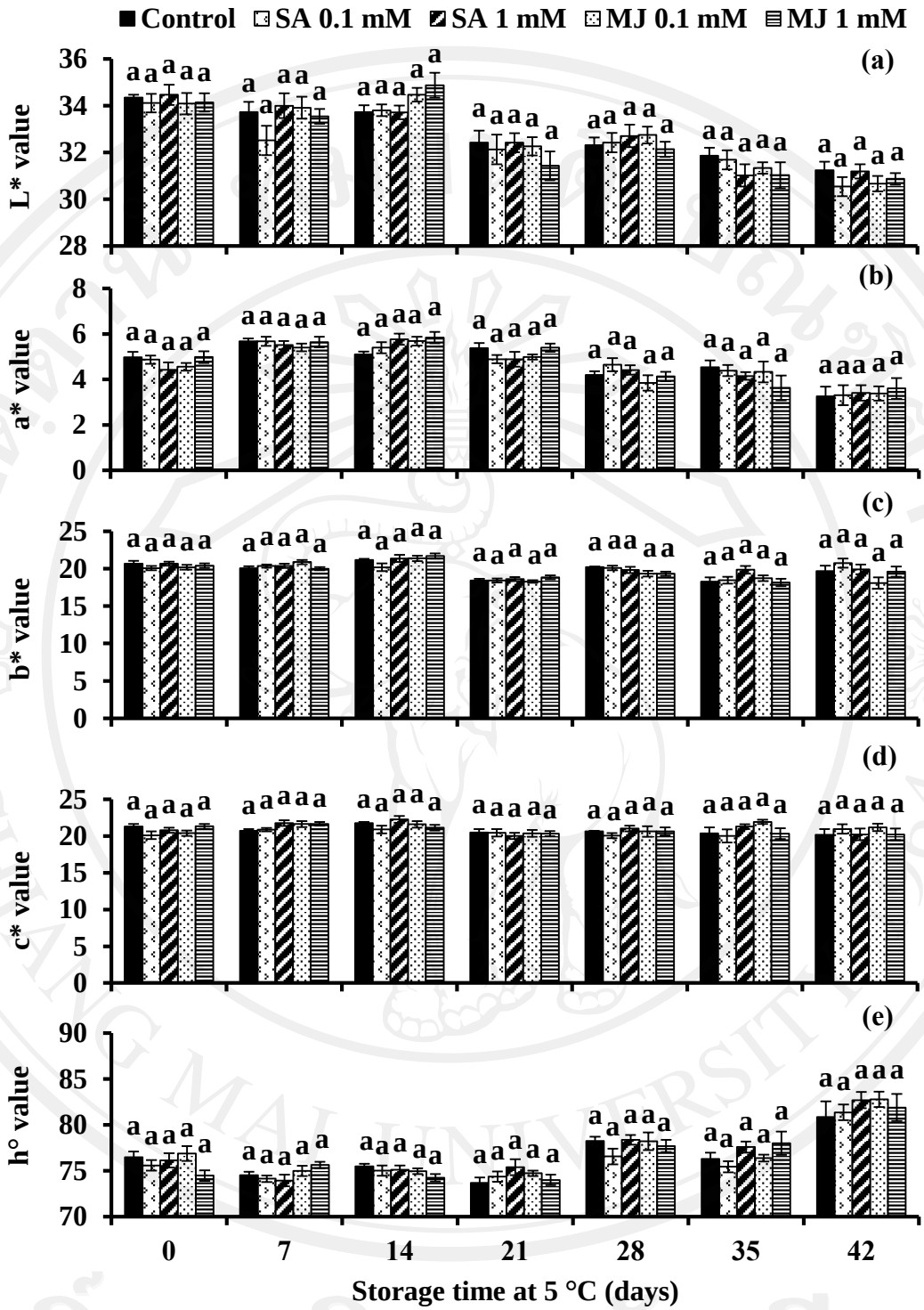

Figure 4.11 Effects of SA and MJ on L* (a), a* (b), b* (c), C* (d) and h° (e) values of mesocarp of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

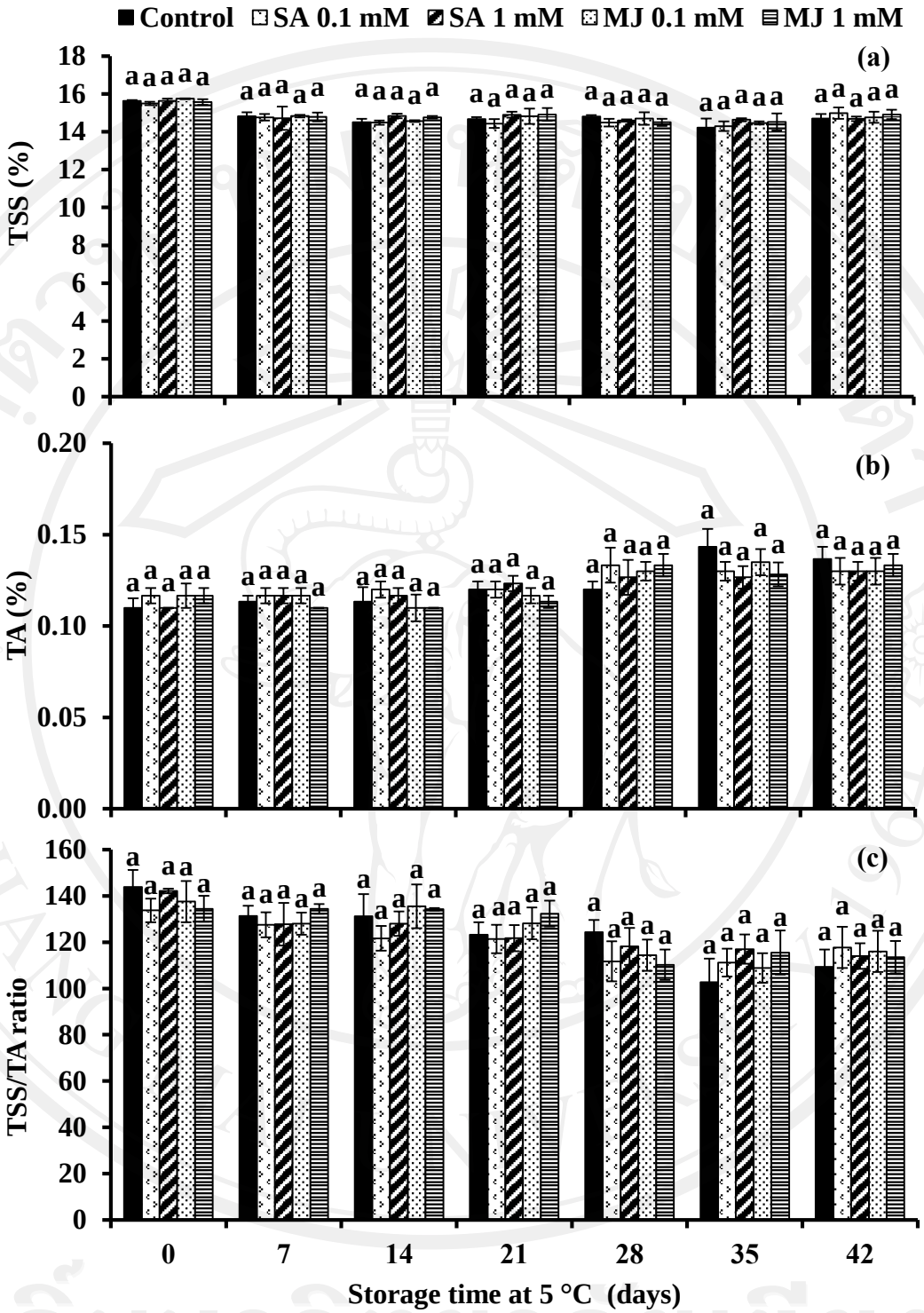

Figure 4.12 Effects of SA and MJ on TSS (a), TA (b) and TSS/TA ratio (c) of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

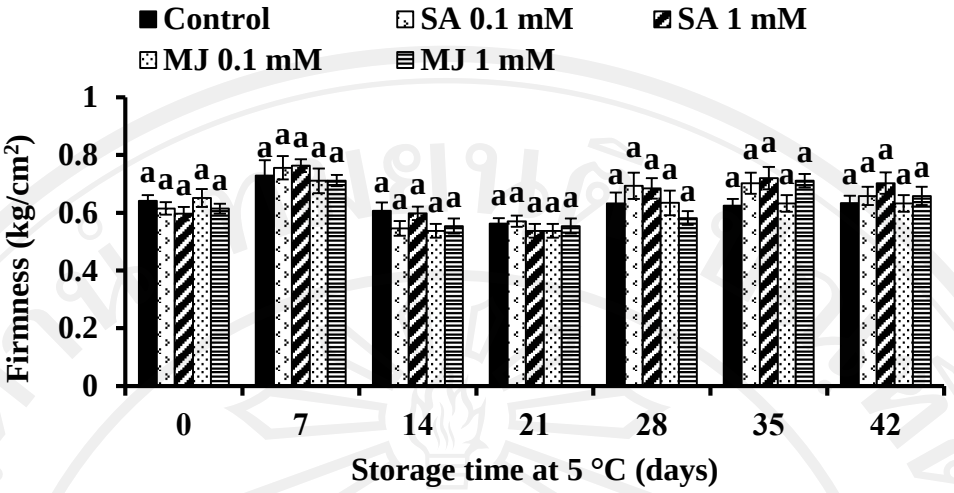

Figure 4.13 Effects of SA and MJ on firmness of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

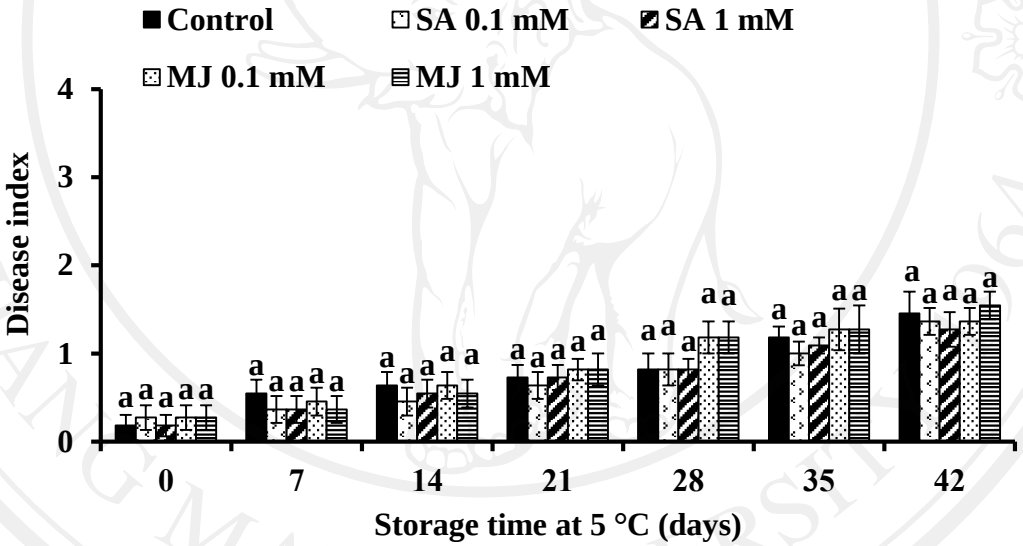

Figure 4.14 Effects of SA and MJ on disease index of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

Overall quality acceptance of ripe mango

Figure 4.15 shows the overall quality acceptance scores of ripe mango fruits after transfer to room temperature at each period of cold storage (Appendix: Table 14). The overall quality acceptance scores of ripe fruits varied between 8.00 and 8.60 on Day 0 of cold storage and gradually decreased with the storage time. SA and MJ treated

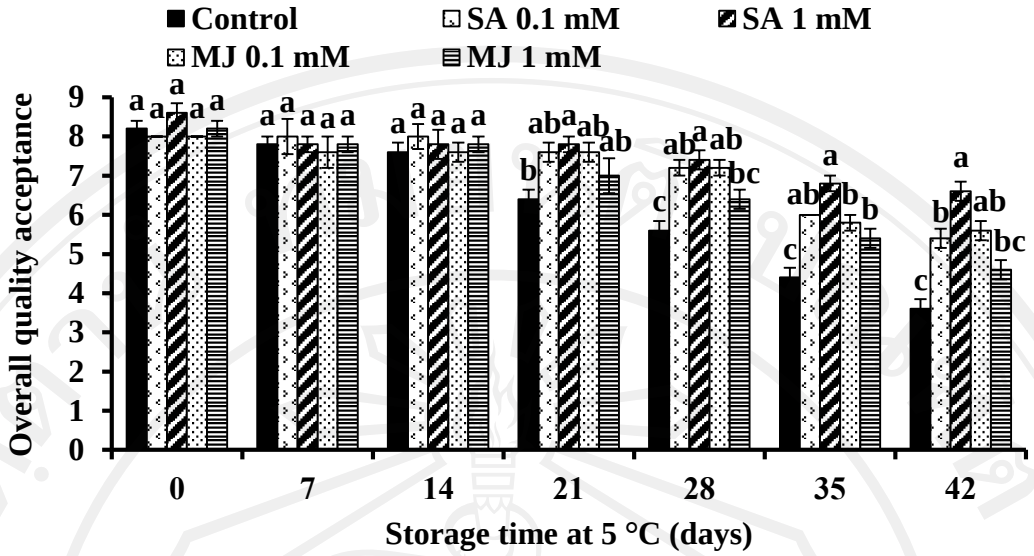

Figure 4.15 Effects of SA and MJ on overall quality acceptance of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

fruits showed significant higher overall quality acceptance scores than that of the control fruits on Days 21-42. Interestingly, the fruits treated with 1 mM SA had an overall quality acceptance score of 6.60, whereas the scores of other treatments and the control fruits were less than 6 at the end of 42 days storage period.

CI index of ripe mango

The CI symptoms and CI index of ripe fruits were higher than those of unripe mango during storage at 5 °C (Figures 4.16 and 4.17, Appendix: Table 15). The CI symptoms of ripe fruit began after cold storage for 21 days and continued for the fruits stored at longer periods (Figures 4.16 and 4.17). Ripe fruits in the control group rapidly developed CI after cold storage for 21-42 days. Dipping fruits in 0.1 mM SA, 1 mM SA and 0.1 mM MJ significantly reduced this symptom. On Day 42, the CI index was significantly reduced by 17, 60 and 13% respectively in the fruits treated with 0.1 mM SA, 1.0 mM SA and 0.1 mM MJ. Treatment with 1.0 mM SA was most effective in reducing the CI index of ripe fruits at all storage times.

For the criterion of acceptability in visual marketing quality of mango fruit, it was found that dipping fruits in 0.1 mM SA and 0.1 mM MJ could prolong storage time at 5 °C for 28 days with CI indices of 1.83 and 2.00 respectively whereas the CI index

of the control group was over 2 (Figure 4.17). Interestingly, treatment with 1.0 mM SA prolonged the storage time up to 42 days with a CI index of 2.00 (Figure 4.17, Appendix: Table 15).

Figure 4.16 Effects of SA and MJ on chilling injury symptoms of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

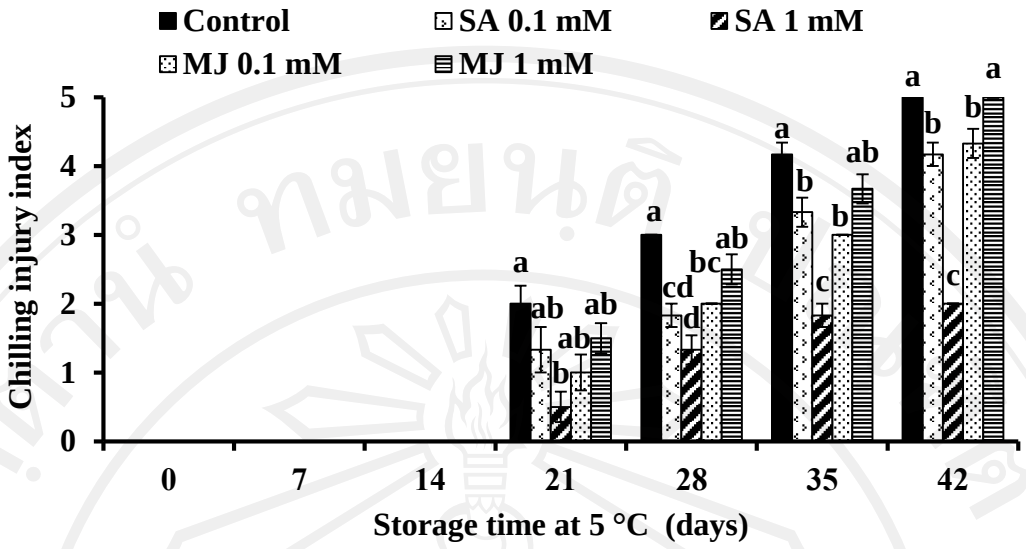

Figure 4.17 Effects of SA and MJ on the chilling injury index of ripe mango fruits cv. Nam Dok Mai No. 4 after transfer to room temperature.

Experiment 2

Effects of SA and MJ on free radicals and oxidative membrane damage of mango fruit cv. Nam Dok Mai No. 4 during low temperature storage.

Free radicals content and oxidative membrane damage of Nam Dok Mai No. 4 fruits increased throughout storage at 5 °C. The effects of SA and MJ treatments on these parameters were noted.

1. Free radical content

Superoxide radical ($O_2^{\bullet-}$) content

Figure 4.18 shows the $O_2^{\bullet-}$ content in the exocarp and mesocarp of Nam Dok Mai No. 4 mango fruits during storage at 5 °C (Appendix: Table 16). $O_2^{\bullet-}$ content in the exocarp and mesocarp in the control fruits increased continuously with storage time (Figures 4.18a and 4.18b). $O_2^{\bullet-}$ content in the exocarp was higher than that in the mesocarp throughout the storage period (Figures 4.18a and 4.18b). At the end of storage (Day 42), $O_2^{\bullet-}$ in the exocarp and mesocarp were 315 and 222% respectively higher compared with the original level (Day 0) (Figures 4.18a and 4.18b).

Changes in $O_2^{\bullet-}$ content in the exocarp and mesocarp of SA and MJ treated fruits increased during storage as with the control fruits (Figures 4.18a and 4.18b). This increase in $O_2^{\bullet-}$ content was reduced when the fruits were treated with SA and MJ. In the exocarp, $O_2^{\bullet-}$ content of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 9-21, 32-41, 16-30 and 2-13% respectively throughout the storage period (Figure 4.18a). In the mesocarp, the $O_2^{\bullet-}$ content of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 10-21, 35-47, 18-35 and 5-13% respectively throughout the storage period (Figure 4.18b). Treatment with 1 mM SA was most efficient in reducing $O_2^{\bullet-}$ content in both the exocarp (32-41%) and mesocarp (35-47%).

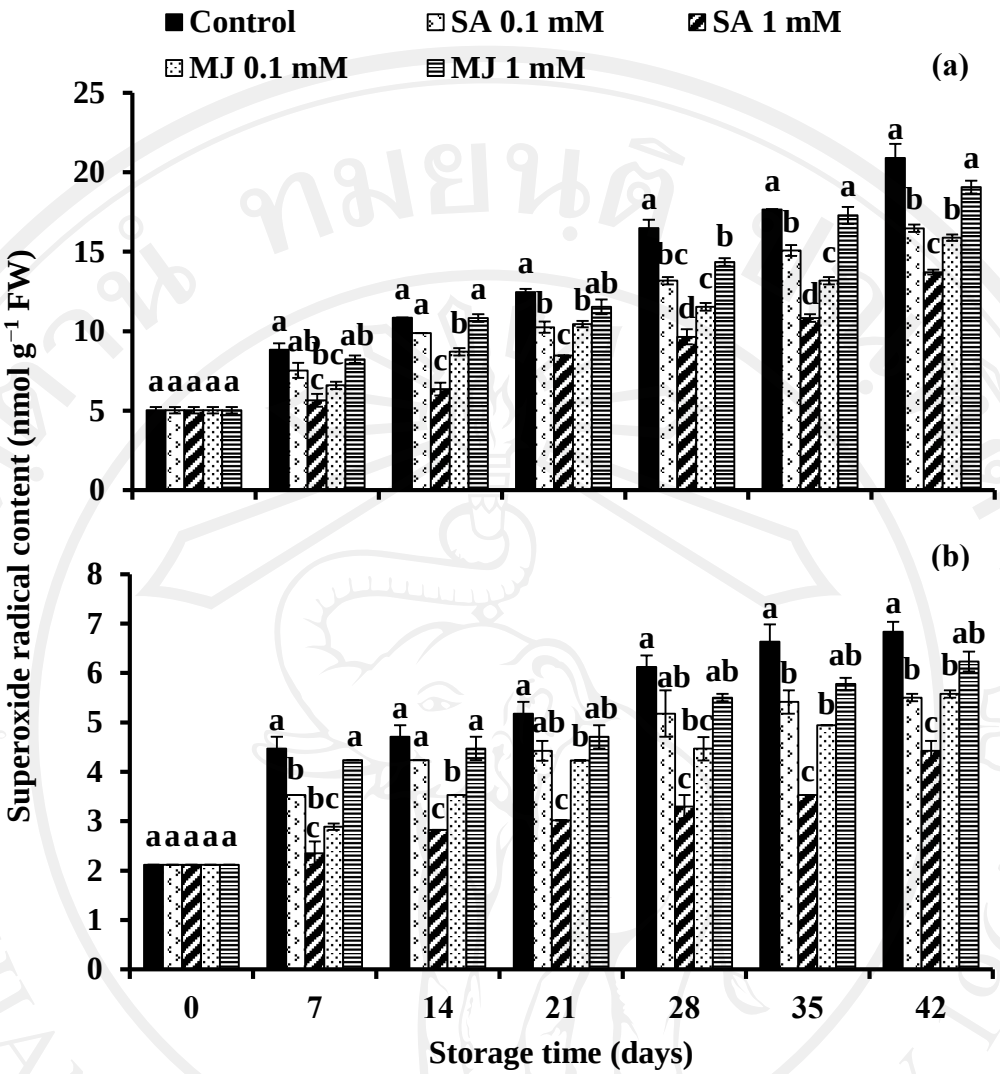

Figure 4.18 Effects of SA and MJ on superoxide radical content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Hydrogen peroxide (H_2O_2) content

Figure 4.19 shows the H_2O_2 content in the exocarp and mesocarp of Nam Dok Mai No. 4 mango fruits during storage at 5 °C (Appendix: Table 17). The H_2O_2 content in the exocarp was higher than the mesocarp throughout storage (Figures 4.19a and 4.19b). The H_2O_2 content in the exocarp and mesocarp of the control fruits increased slightly during the first 21 days and then rapidly increased with the remaining time (Figures 4.19a and 4.19b). At the end of storage time (Day 42), H_2O_2 in the exocarp and mesocarp was 342 and 700% respectively higher compared with the original level (Day 0) (Figures 4.19a and 4.19b).

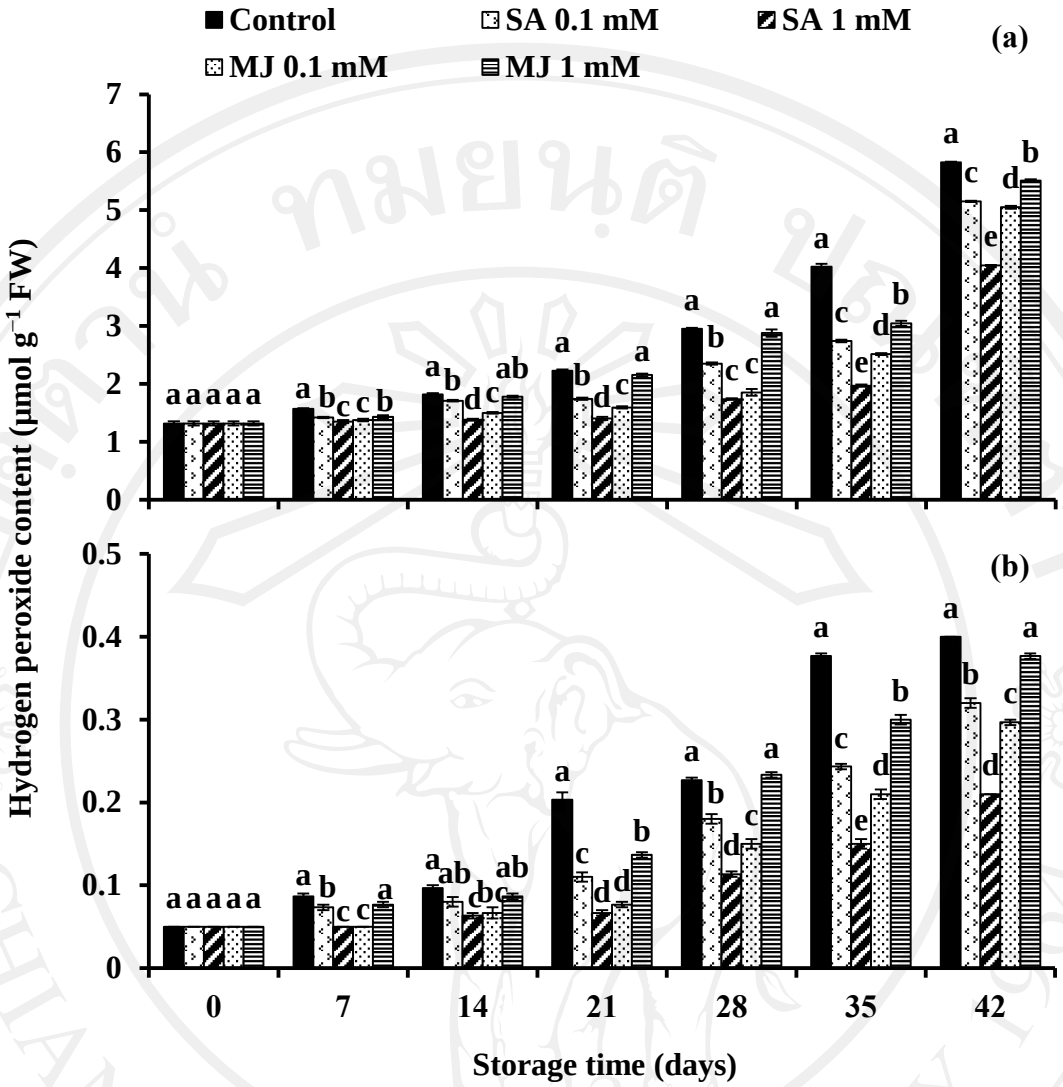

Figure 4.19 Effects of SA and MJ on hydrogen peroxide content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

The H_2O_2 content in the exocarp and mesocarp of SA and MJ treated fruits increased continuously during storage time as did the control fruit (Figures 4.19a and 4.19b). The increase in H_2O_2 content was reduced when the fruits were treated with SA and MJ. In the exocarp, H_2O_2 content in 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 6-32, 14-51, 12-38 and 2-24% respectively throughout storage (Figure 4.19a). In the mesocarp, the H_2O_2 content of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 15-46, 34-67, 26-62 and 6-33% respectively throughout storage (Figure 4.19b). Treatment with 1 mM SA was most efficient in reducing H_2O_2 content in both the exocarp (14-51%) and mesocarp (34-67%).

Hydroxyl radical ($OH^{\bullet}$) content

Figure 4.20 shows the $OH^{\bullet}$ content in the exocarp and mesocarp of Nam Dok Mai No. 4 mango fruits during storage at 5 °C (Appendix: Table 18). The $OH^{\bullet}$ content in the exocarp and mesocarp of the control fruits rapidly increased with storage time (Figures 4.20a and 4.20b), while the $OH^{\bullet}$ content in the exocarp was higher than that in the mesocarp throughout storage (Figures 4.20a and 4.20b). At the end of storage (Day 42), the $OH^{\bullet}$ content in the exocarp and mesocarp was 353 and 265% respectively higher compared with the original level (Day 0) (Figures 4.20a and 4.20b).

The changes in $OH^{\bullet}$ content in the exocarp and mesocarp of SA and MJ treated fruits gradually increased during storage time as did the control fruits (Figures 4.20a and 4.20b). This increase in $OH^{\bullet}$ content was reduced when the fruits were treated with SA and MJ. In the exocarp, $OH^{\bullet}$ content of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 11-21, 37-47, 19-30 and 2-9% respectively throughout storage (Figure 4.20a). In the mesocarp, the $OH^{\bullet}$ content of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 19-27, 27-51, 17-28 and 5-10% respectively throughout storage (Figure 4.20b). Treatment with 1.0 mM SA was most efficient in reducing $OH^{\bullet}$ content in both the exocarp (37-47%) and mesocarp (27-51%).

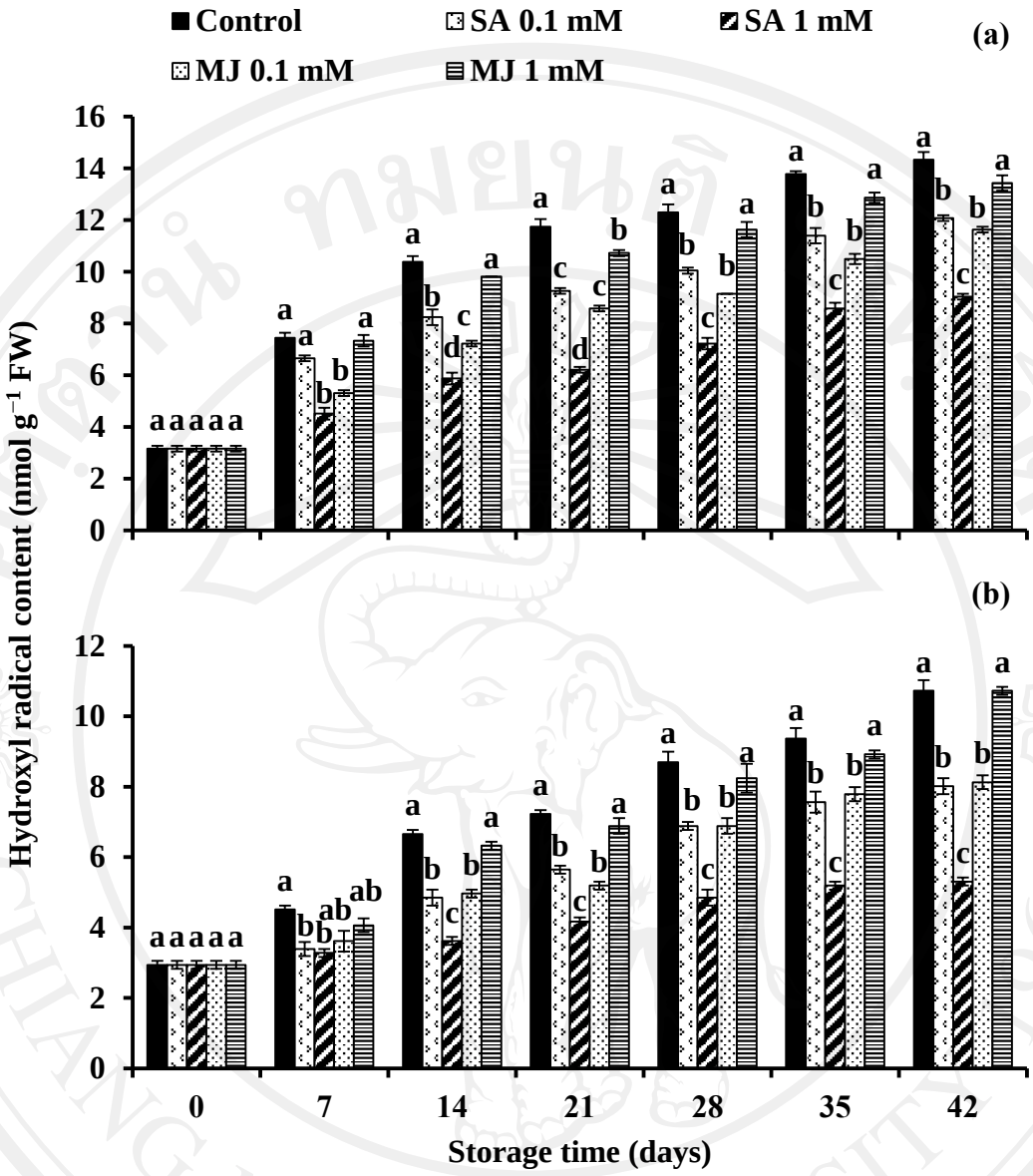

Figure 4.20 Effects of SA and MJ on hydroxyl radical content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

2. Oxidative membrane damage

Lipoxygenase (LOX) activity

Figure 4.21 shows the activity of LOX in the exocarp and mesocarp of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C (Appendix: Table 19). LOX activity in both exocarp and mesocarp of the control fruits gradually increased with storage time (Figures 4.21a and 4.21b). The mesocarp showed higher LOX activity than

the exocarp throughout storage (Figures 4.21a and 4.21b). At the end of storage (Day 42), LOX activity in the exocarp and mesocarp was 394 and 141% respectively higher than the original level (Day 0) (Figures 4.21a and 4.21b).

The changes of LOX activity in the exocarp and mesocarp in SA and MJ treated fruits showed a similar pattern with the control fruits (Figures 4.21a and 4.21b). This increase in LOX activity was reduced when the fruits were treated with SA and MJ. In the exocarp, LOX activity of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 19-32, 34-43, 16-27 and 10-19% respectively throughout storage (Figure 4.21a). In the mesocarp, LOX activity of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 16-21, 21-31, 8-20 and 3-5% respectively throughout storage (Figure 4.21b). Treatment with 1 mM SA was most efficient in reducing LOX activity in both exocarp (34-43%) and mesocarp (21-31%).

Malondialdehyde (MDA) content

Figure 4.22 shows the MDA content in the exocarp and mesocarp of Nam Dok Mai No. 4 mango fruits during storage at 5 °C (Appendix: Table 20). MDA content in the exocarp and mesocarp of the control fruits gradually increased with storage time (Figures 4.22a and 4.22b). MDA content in the exocarp was higher than that in the mesocarp (Figures 4.22a and 4.22b). At the end of storage (Day 42), MDA content in the exocarp and mesocarp was 163 and 267% respectively higher than the original level (Day 0) (Figures 4.22a and 4.22b).

The changes in MDA content in the exocarp and mesocarp in SA and MJ treated fruits showed a similar pattern with the control fruits (Figures 4.22a and 4.22b). This increase in MDA content was reduced when the fruits were treated with SA and MJ. In the exocarp, MDA content of 0.1 and 1 mM SA, 0.1 and 1 mM MJ treated fruits was lower than those in the control fruits by 5-22, 22-31, 14-21 and 1-16% respectively throughout storage (Figure 4.22a). In the mesocarp, the MDA content of fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was lower than that of the control by 8-24, 19-36, 5-27 and 1-10% respectively throughout storage (Figure 4.22b). Treatment of

1 mM SA was most efficient in reducing MDA content in both the exocarp (22-31%) and mesocarp (19-36%).

Electrolyte leakage (EL)

Figure 4.23 shows EL in the exocarp and mesocarp of Nam Dok Mai No. 4 mango fruits during storage at 5 °C (Appendix: Table 21). EL in the exocarp and mesocarp of the control fruits gradually increased with storage time (Figures 4.23a and 4.23b). EL in the mesocarp was higher than that of the exocarp (Figures 4.23a and 4.23b). At the end of storage (Day 42), the EL of the exocarp and mesocarp was 51 and 71% respectively higher than the original level (Day 0) (Figures 4.23a and 4.23b).

The changes of EL in the exocarp and mesocarp in SA and MJ treated fruits were similar to the control fruits (Figures 4.23a and 4.23b). The increase in EL was reduced when the fruits were treated with SA and MJ. The EL in the exocarp of mango fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was lower than those in the control fruits by 10-14, 17-25, 9-13 and 3-9% respectively throughout storage (Figure 4.23a). The EL in the mesocarp of fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was lower than those in the control fruits by 8-18, 19-21, 8-17 and 3-7% respectively throughout storage (Figure 4.23b). Treatment with 1 mM SA was most efficient in reducing EL in both the exocarp (17-25%) and mesocarp (19-21%).

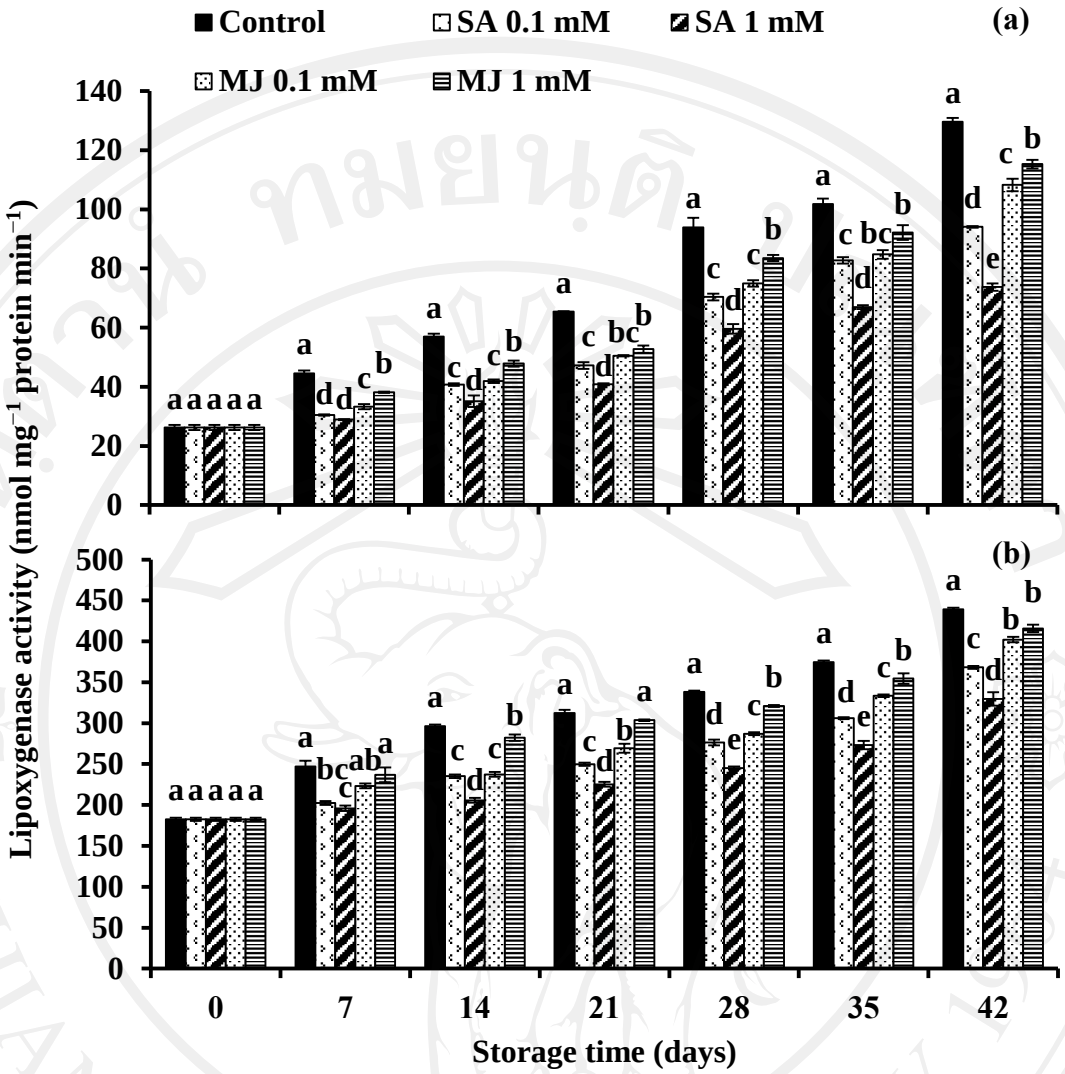

Figure 4.21 Effects of SA and MJ on lipoxygenase activity in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

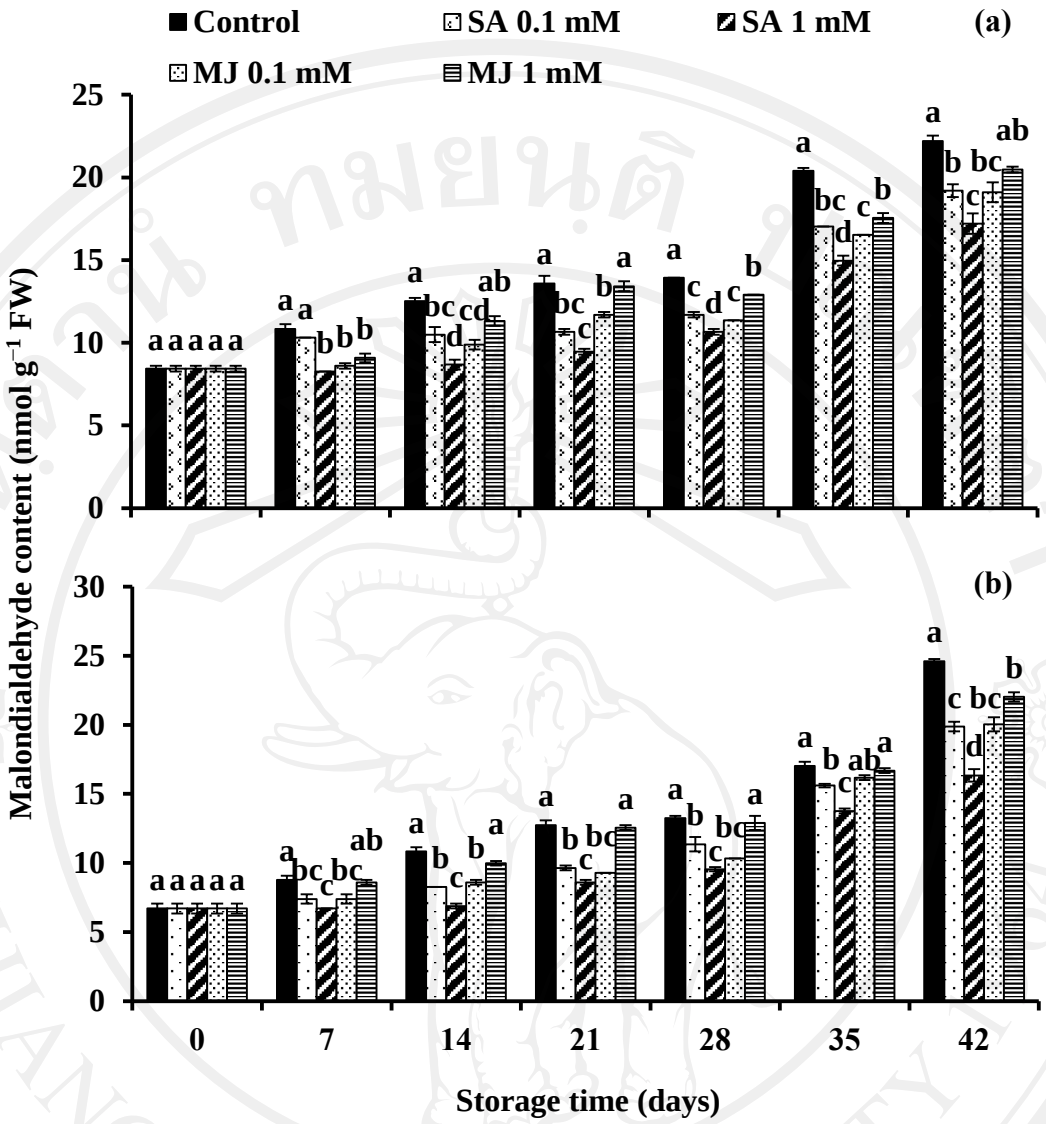

Figure 4.22 Effects of SA and MJ on malondialdehyde content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

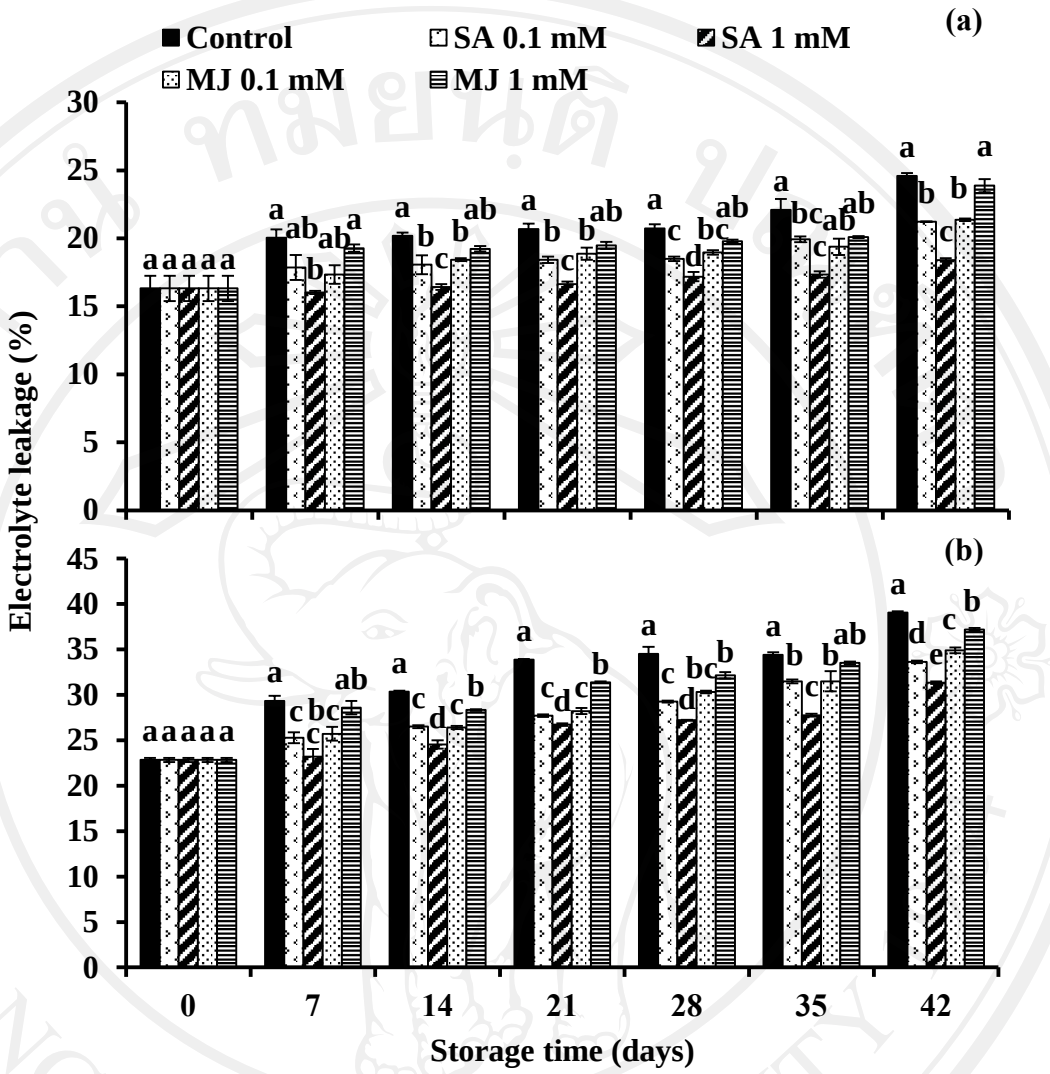

Figure 4.23 Effects of SA and MJ on electrolyte leakage in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Experiment 3

Effects of SA and MJ on antioxidant defense system of mango fruit cv. Nam Dok Mai No. 4 during low temperature storage.

The antioxidant defense system, both enzymatic and non-enzymatic antioxidants of Nam Dok Mai No. 4 fruits changed during storage at 5 °C. Increase in the antioxidant defense system was observed in SA and MJ treated fruits.

1. Enzymatic antioxidants

Superoxide dismutase (SOD) activities

SOD activity in the mesocarp was markedly higher than that in the exocarp throughout storage period at 5 °C (Figures 4.24a and 4.24b, Appendix: Table 23). SOD activity in the exocarp and mesocarp of the control fruits rapidly increased after exposing to low temperature and reached its peak on Day 21 and then decreased afterwards (Figures 4.24a and 4.24b). At the peak time (Day 21), SOD activity in the exocarp and mesocarp was 412 and 60% respectively higher than the original level (Day 0) (Figures 4.24a and 4.24b).

The changes in SOD activity in both exocarp and mesocarp of SA and MJ treated fruits were similar to the control fruits (Figures 4.24a and 4.24b). SA and MJ treatment enhanced the increase in SOD activity in both exocarp and mesocarp during the first 21 days and delayed the decrease in SOD activity afterwards (Figures 4.24a and 4.24b). SOD activity in both exocarp and mesocarp of SA and MJ treated fruits were significantly higher than those in the control fruits throughout storage at 5 °C (Figures 4.24a and 4.24b). In the exocarp, SOD activity of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 25-65, 88-176, 51-98 and 3-15% respectively throughout storage (Figure 4.24a). In the mesocarp, SOD activity of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 18-41, 61-112, 20-62 and 3-16% respectively throughout storage (Figure 4.24b). Treatment with 1 mM SA stimulated SOD activity in both the exocarp (88-176%) and mesocarp (61-112%) throughout the cold storage period (Figures 4.24).

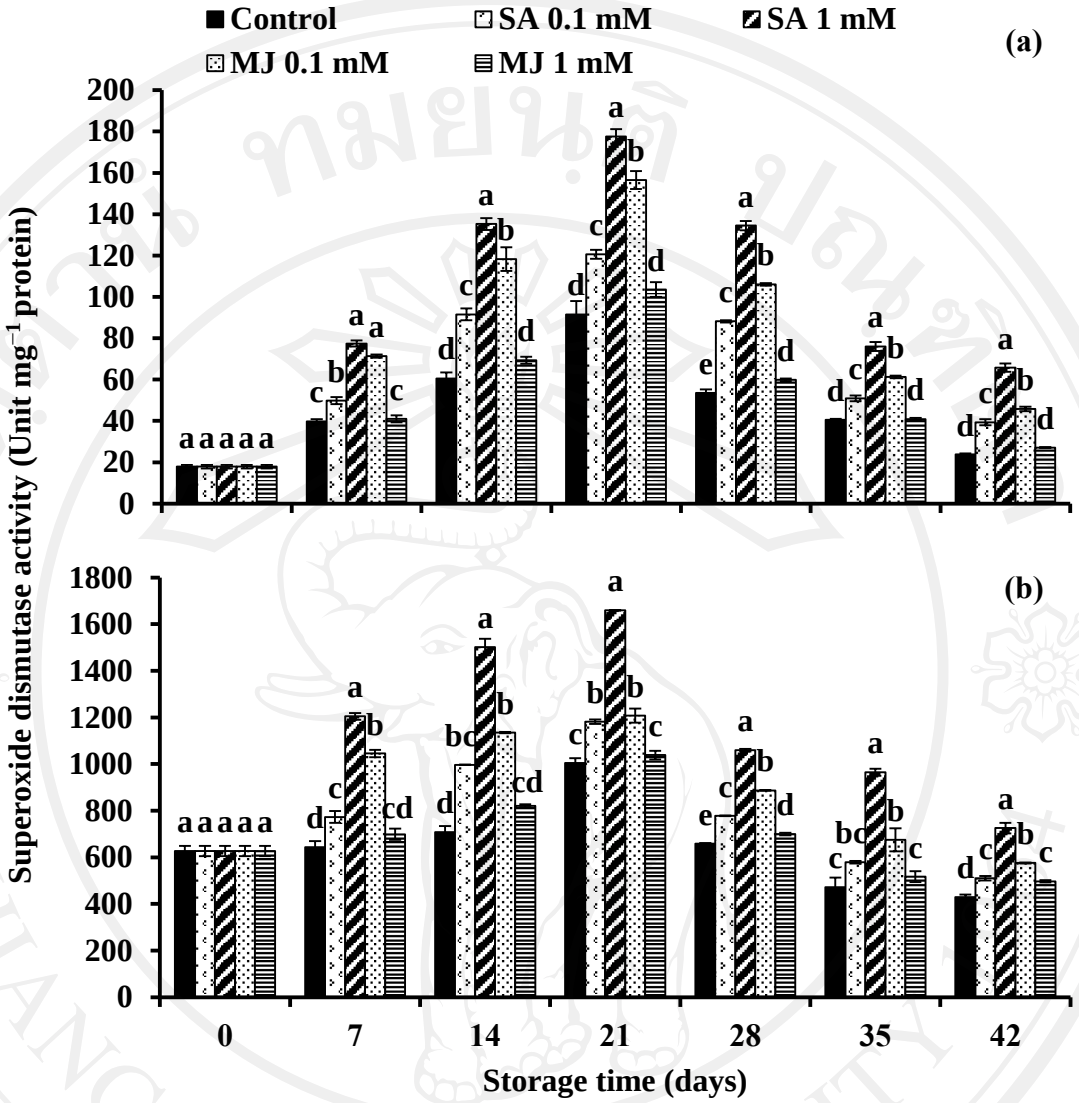

Figure 4.24 Effects of SA and MJ on superoxide dismutase activity in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Catalase (CAT) activities

CAT activity in the mesocarp was higher than that in the exocarp throughout storage period (Figures 4.25a and 4.25b, Appendix: Table 24). CAT activity in the exocarp and mesocarp of the control fruits increased rapidly and reached its peak on Day 7 and then gradually decreased thereafter (Figures 4.25a and 4.25b). At the peak time (Day 7), CAT activity in the exocarp and mesocarp was 39 and 95% respectively higher than the original level (Day 0) (Figures 4.25a and 4.25b).

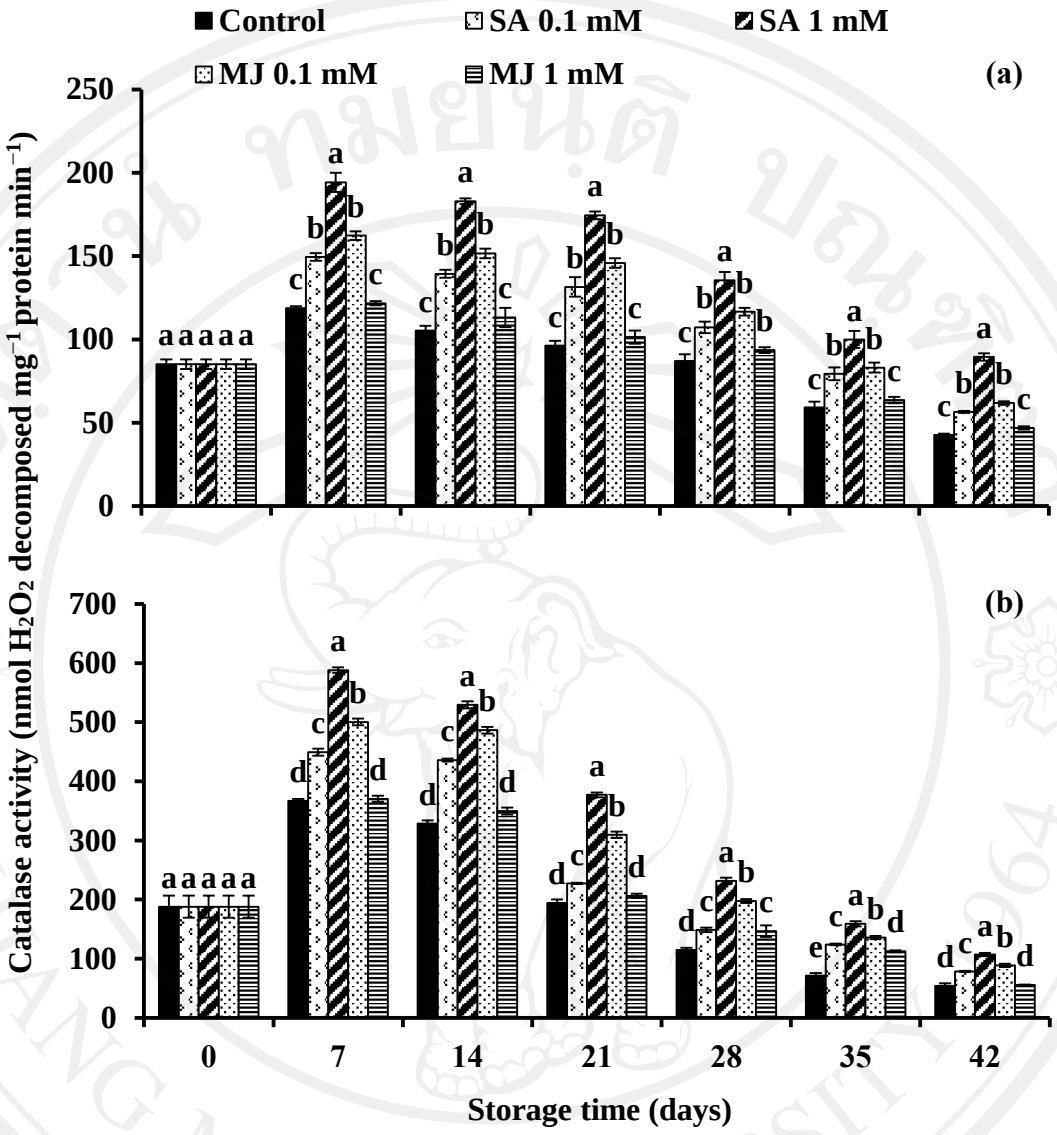

Figure 4.25 Effects of SA and MJ on catalase activity in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

The changes in CAT activity in both exocarp and mesocarp of SA and MJ treated fruits were similar to that in the control fruits (Figures 4.25a and 4.25b). SA and MJ treatment enhanced the increase in CAT activity in both exocarp and mesocarp on Day 7 and delayed the decrease in CAT activity afterwards (Figures 4.25a and 4.25b). CAT activity in both exocarp and mesocarp of SA and MJ treated fruits was significantly higher than those in the control fruits throughout storage at 5 °C (Figures 4.25a and 4.25b). In the exocarp, CAT activity of the fruits treated with 0.1 and 1 mM

SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 23-37, 56-110, 34-51 and 3-10% respectively throughout storage (Figure 4.25a). In the mesocarp, CAT activity of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 17-74, 60-123, 36-90 and 3-58% respectively throughout storage (Figure 4.25b). Treatment with 1 mM SA had the most potential to stimulate CAT activity in both the exocarp (56-110%) and mesocarp (60-123%) throughout the cold storage (Figure 4.25).

Ascorbate peroxidase (APX) activities

APX activity in the mesocarp was markedly higher than that in the exocarp throughout storage (Figures 4.26a and 4.26b, Appendix: Table 25). APX activity in the exocarp and mesocarp of the control fruits gradually increased after exposure to low temperature and reached its peak on Day 28 and then decreased with the remaining time (Figures 4.26a and 4.26b). At the peak time (Day 28), APX activity in the exocarp and mesocarp was 179 and 344% respectively higher than the original level (Day 0) (Figures 4.26a and 4.26b).

The changes in APX activity in both exocarp and mesocarp of SA and MJ treated fruits were similar to the control fruits (Figures 4.26a and 4.26b). SA and MJ treatment enhanced the increase in APX activity in both exocarp and mesocarp during the first 28 days and delayed the decrease in APX activity afterwards (Figures 4.26a and 4.26b). APX activity in both exocarp and mesocarp of SA and MJ treated fruits was significantly higher than those in the control fruits throughout storage at 5 °C (Figures 4.26a and 4.26b). In the exocarp, APX activity of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 35-78, 87-140, 42-80 and 16-49% respectively throughout storage period (Figure 4.26a). In the mesocarp, APX activity of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 16-82, 51-132, 31-84 and 3-61% respectively throughout storage (Figure 4.26b). Treatment with 1 mM SA was the best stimulant for APX activity in both the exocarp (87-140%) and mesocarp (51-132%) throughout the cold storage (Figure 4.26).

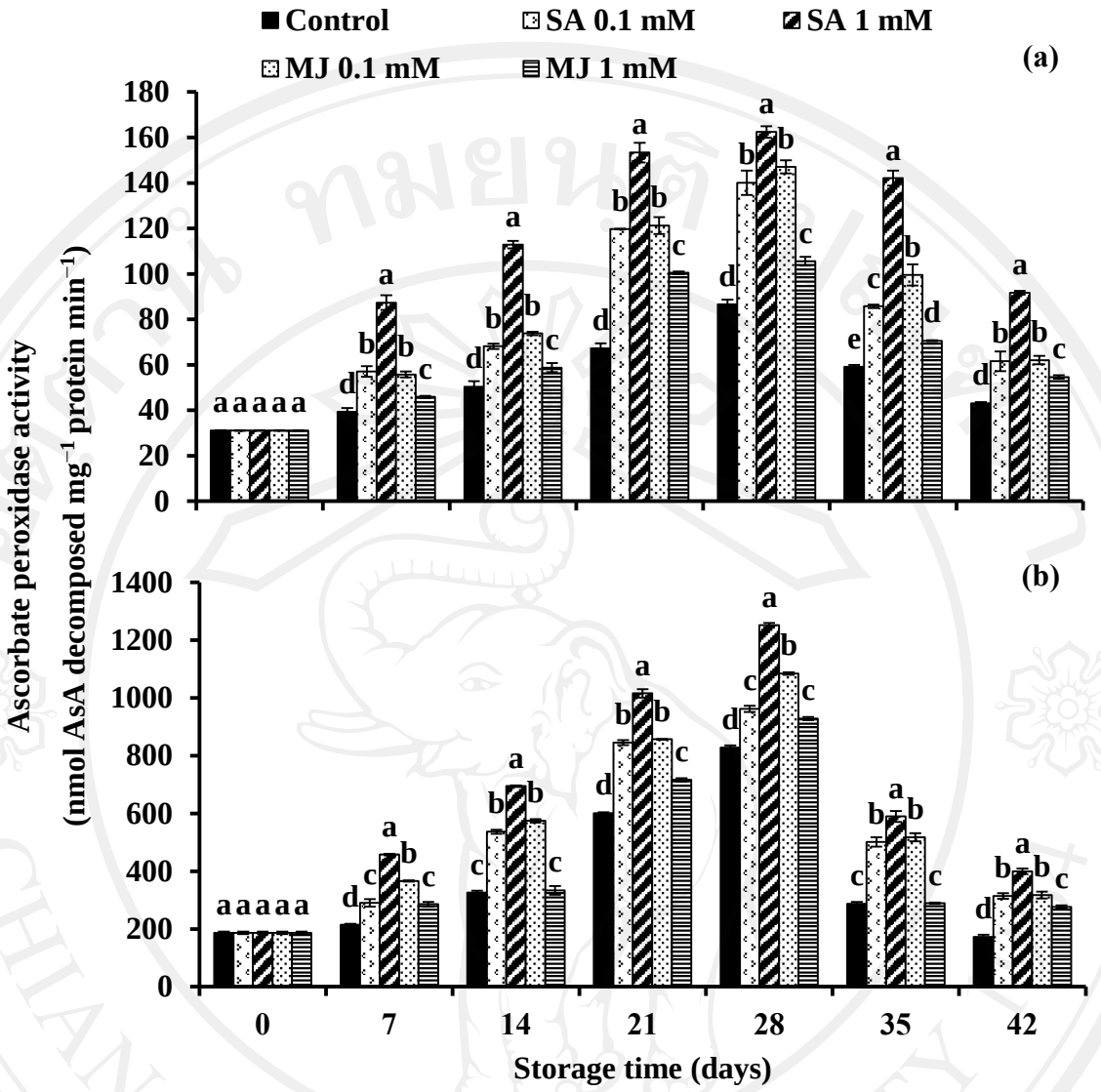

Figure 4.26 Effects of SA and MJ on ascorbate peroxidase activity in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Expression of *SOD, CAT* and *APX* genes

The effects of SA on the expression of *SOD, CAT* and *APX* genes of Nam Dok Mai mango fruit during storage at 5 are shown in Figure 4.27 (Appendix: Table 26). Expression of *SOD, CAT*, and *APX* genes in the exocarp of the control fruits was similar to their enzyme activities (Figures 4.24-4.26). The expression of *SOD, CAT* and *APX* genes was highly correlated ($p = 0.01$) with their enzyme activity ($R^2 = 0.879$, 0.678 and 0.866 respectively) (data not shown). SA treatment significantly enhanced the increases in *CAT, SOD* and *APX* gene expression during the first 7, 21 and 28 days respectively

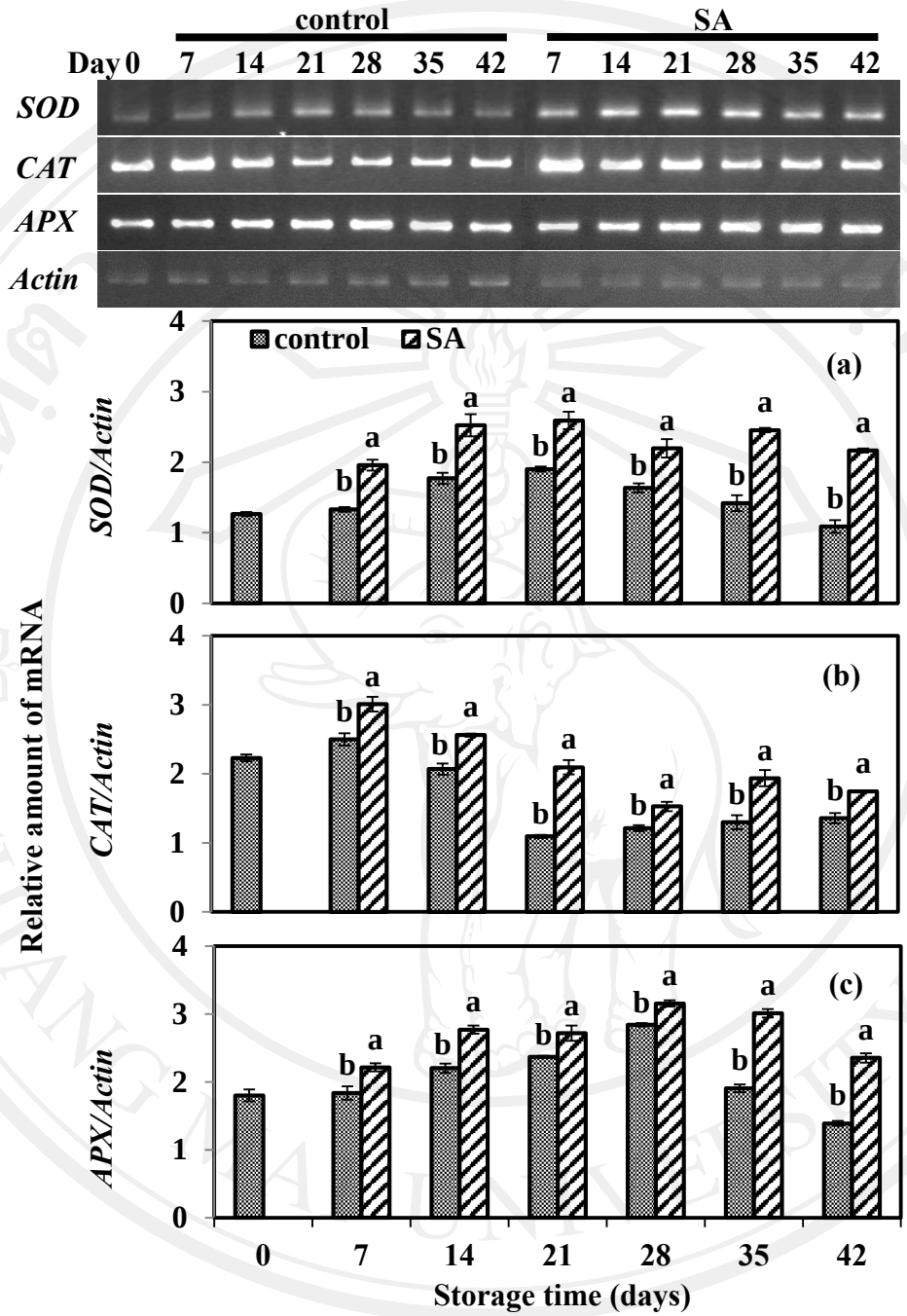

Figure 4.27 Effect of SA on expression of *SOD* (a), *CAT* (b) and *APX* (c) genes in exocarp of Nam Dok Mai No. 4 mango fruits during storage at 5 °C.

and delayed the decrease in these gene expressions thereafter (Figure 4.27). The *SOD*, *CAT* and *APX* genes were more highly expressed significantly in SA treated fruits than those in the control fruits during the whole storage period (Figure 4.27). Relative expression levels of *SOD*, *CAT*, and *APX* genes in SA treated fruits were higher than

those in the control fruits by 34-99, 20-91 and 11-69% respectively throughout the cold storage (Figures 4.27a, 4.27b and 4.27c).

The PCR products of *SOD*, *CAT* and *APX* genes were sequenced by Macrogen and the nucleotide sequences from RT-PCR are shown in Appendices: 1-3. These sequences were confirmed by using the NCBI Blast program and ClustalW program with other plant species as shown in Appendices: 4-6.

Non-enzymatic antioxidants

Total phenolic content

Figure 4.28 shows the amount of total phenolic compounds in the exocarp and mesocarp of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 27). Total phenolic content in both exocarp and mesocarp of the control fruits increased continuously and reached its peak on Day 21 and then decreased afterward (Figures 4.28a and 4.28b). Total phenolic content of the exocarp was markedly higher than the mesocarp throughout storage period (Figures 4.28a and 4.28b). At the peak time (Day 21), total phenolic content in the exocarp and mesocarp was 32 and 24% respectively higher than the original level (Day 0) (Figures 4.28a and 4.28b).

The changes of total phenolic content in both exocarp and mesocarp of SA and MJ treated fruits were similar to the control fruits (Figures 4.28a and 4.28b). SA and MJ treatment enhanced increases in total phenolic contents in both exocarp and mesocarp during the first 21 days and delayed the decrease in the amounts afterwards (Figures 4.28a and 4.28b). The amount of total phenolic compounds in both exocarp and mesocarp of SA and MJ treated fruits were significantly higher than those in the control fruits throughout storage at 5 °C (Figures 4.28a and 4.28b). In the exocarp, the total phenolic content in the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 8-21, 24-52, 16-31 and 2-10% respectively throughout storage (Figure 4.28a). In the mesocarp, the total phenolic content in the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than the control fruits by 4-24, 19-66, 11-33 and 1-7% respectively throughout storage (Figure 4.28b).

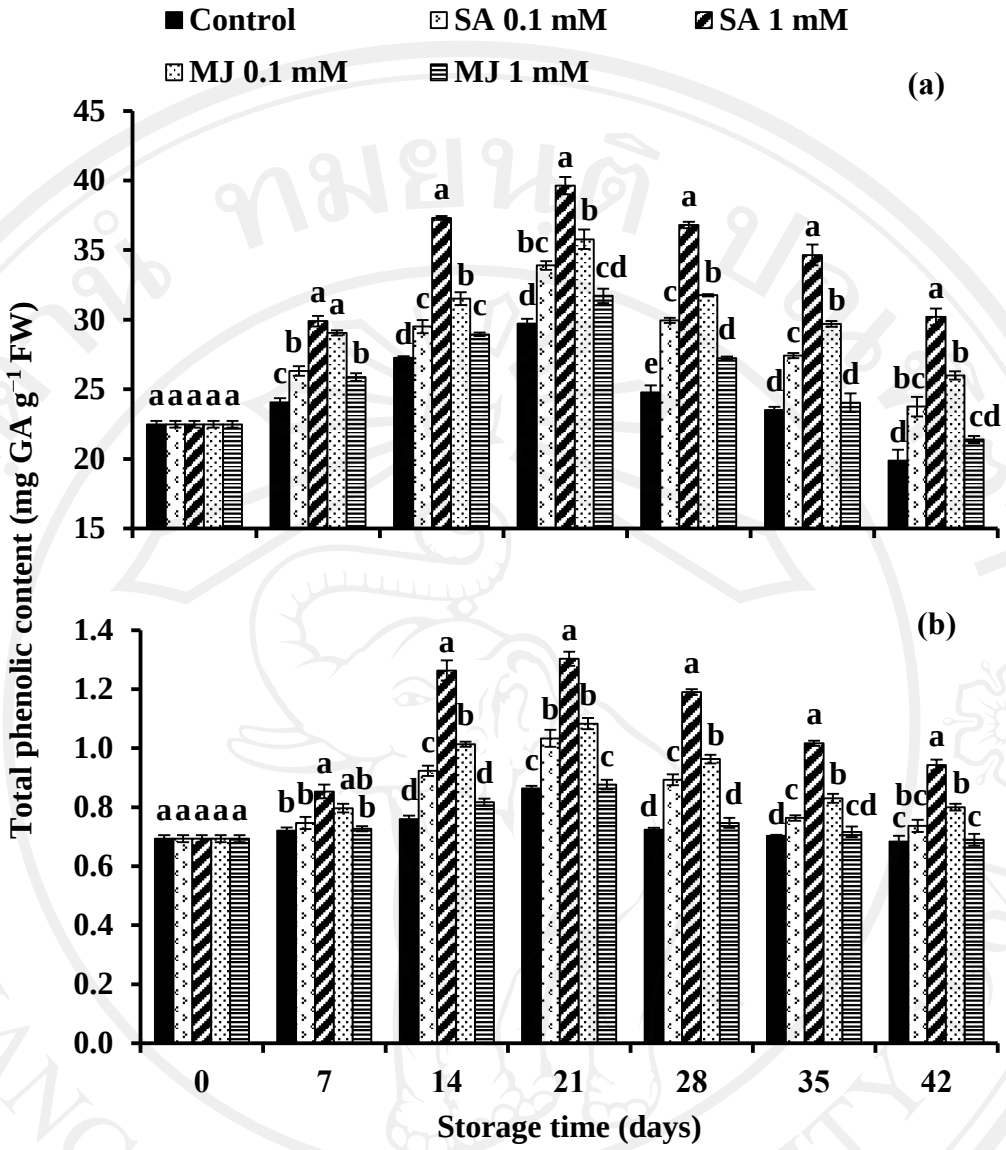

Figure 4.28 Effects of SA and MJ on total phenolic content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Treatment with 1 mM SA was best to stimulate total phenolic content in both the exocarp (24-52%) and mesocarp (19-66%) throughout the cold storage (Figure 4.28).

Ascorbic acid content

Figure 4.29 shows the amount of ascorbic acid in the exocarp and mesocarp of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 28). Ascorbic acid in both exocarp and mesocarp of the control fruits decreased rapidly on Day 7 and then decreased slightly thereafter (Figures 4.29a and 4.29b). Ascorbic acid content in the

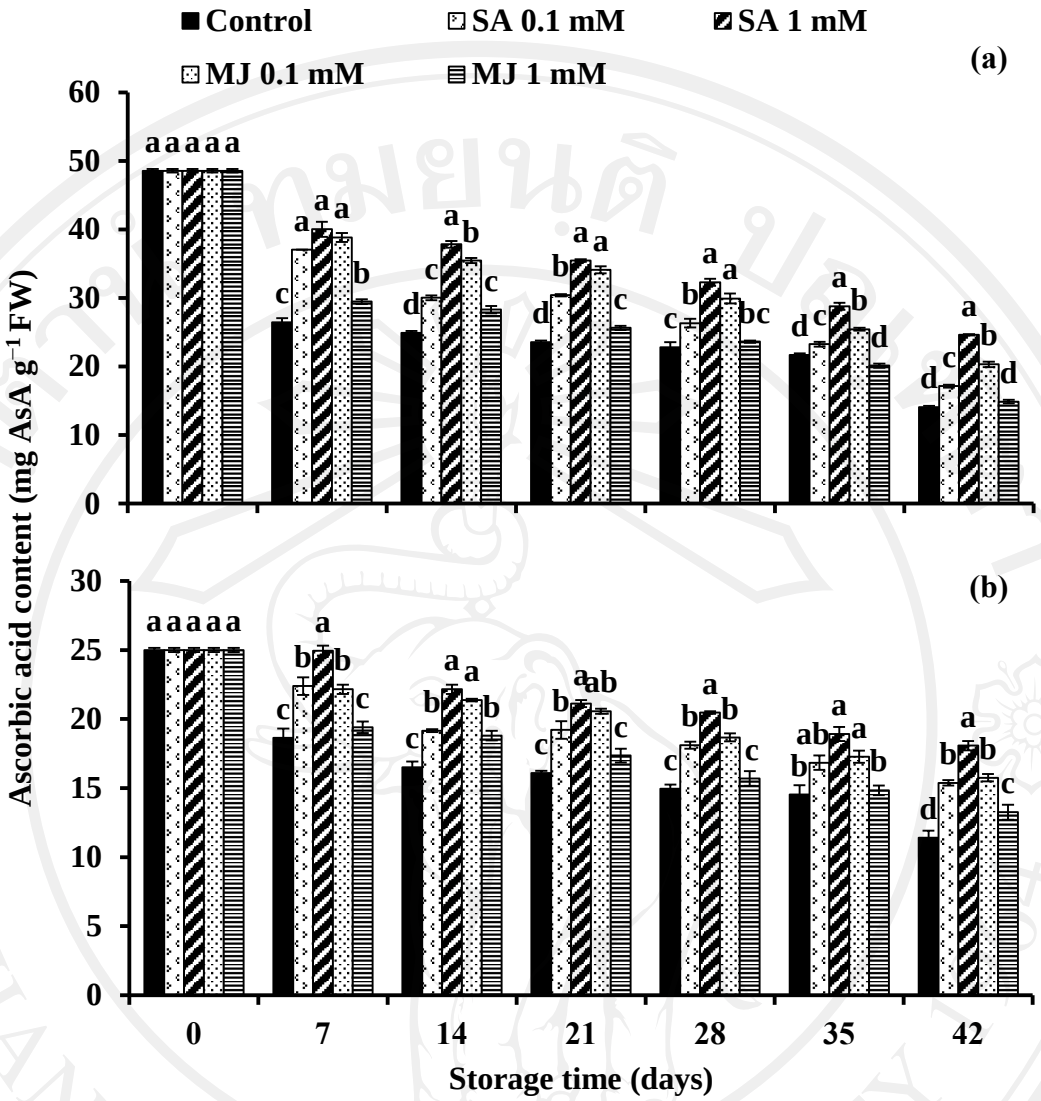

Figure 4.29 Effects of SA and MJ on ascorbic acid content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

exocarp was also markedly higher than that in the mesocarp throughout storage (Figures 4.29a and 4.29b). At the end of storage (Day 42), ascorbic acid in the exocarp and mesocarp were 71 and 54% respectively lower compared to the original level (Day 0) (Figures 4.29a and 4.29b).

The changes in ascorbic acid content in both exocarp and mesocarp of SA and MJ treated fruits were similar to the control fruits (Figures 4.29a and 4.29b). SA and MJ treatment delayed the decrease in ascorbic acid during the cold storage (Figures 4.29a and 4.29b). Ascorbic acid in both the exocarp and mesocarp of SA and MJ treated fruits

was significantly higher than those in the control fruits throughout storage at 5 °C (Figures 4.29a and 4.29b). In the exocarp, ascorbic acid of fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 16-40, 42-75, 26-47 and 4-14% respectively throughout storage (Figure 4.29a). Ascorbic acid in the mesocarp of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those of the control fruits by 16-35, 30-58, 19-38 and 2-16% respectively throughout storage (Figure 4.29b). Treatment with 1 mM SA was best to maintain ascorbic acid content in both the exocarp (42-75%) and mesocarp (30-58%) throughout the cold storage (Figure 4.29).

Total glutathione content

Figure 4.30 shows the amount of total glutathione in the exocarp and mesocarp of Nam Dok Mai mango during storage at 5 °C (Appendix: Table 29). Total glutathione content in both the exocarp and mesocarp of the control fruits gradually decreased with storage time (Figures 4.30a and 4.30b). Total glutathione content in the mesocarp was markedly higher than that in the exocarp throughout storage (Figures 4.30a and 4.30b). At the end of storage (Day 42), the total glutathione content in the exocarp and mesocarp was 68 and 49% respectively lower than the original level (Day 0) (Figures 4.30a and 4.30b).

The changes in total glutathione content in both exocarp and mesocarp of SA and MJ treated fruits were similar to the control fruits (Figures 4.30a and 4.30b). SA and MJ treatment delayed the decreases in total glutathione contents during cold storage (Figures 4.30a and 4.30b). The amount of total glutathione in both exocarp and mesocarp of SA and MJ treated fruits were significantly higher than those in the control fruits throughout storage at 5 °C (Figures 4.30a and 4.30b). In the exocarp, the total glutathione content of fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 5-49, 11-91, 8-43 and 4-15% respectively throughout storage (Figure 4.30a). In the mesocarp, the total glutathione content of the fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 6-22, 10-30, 6-18 and 2-6% respectively throughout storage (Figure 4.30b). Treatment with 1 mM SA was best to maintain total glutathione content in both the exocarp (11-91%) and mesocarp (10-30%) throughout the cold storage (Figure 4.30).

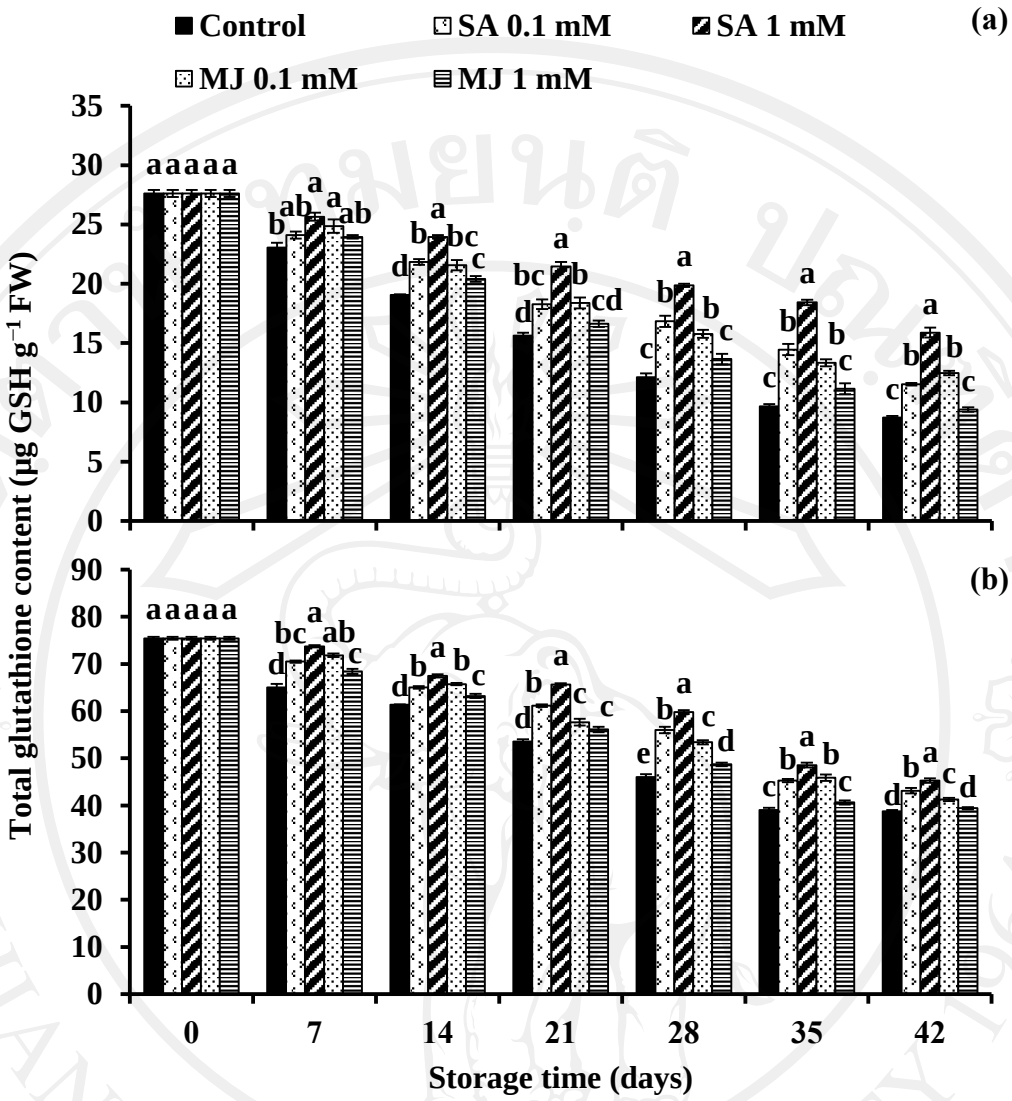

Figure 4.30 Effects of SA and MJ on total glutathione content in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

Total antioxidant capacity (TAC)

Figures 4.31 and 4.32 show the TAC by DPPH and ABTS radical scavenging activity methods in the exocarp and mesocarp of Nam Dok Mai mango during storage at 5 °C (Appendices: Tables 30 and 31). TAC by the ABTS method was higher than that by the DPPH method in both exocarp and mesocarp of all treated fruits (Figures 4.31 and 4.32). TAC by both methods of all treated fruits gradually increased until Day 21 when the capacity was highest, then decreased thereafter (Figures 4.31 and 4.32). TAC by DPPH and ABTS methods in the exocarp and mesocarp of mango exhibited a similar

pattern during cold storage at 5 °C. SA and MJ treated fruits had similar but significantly higher TAC compared to the control fruits throughout storage at 5 °C.

TAC by the DPPH method (Figure 4.31, Appendix: Table 30), in the exocarp of mango fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 2-20, 18-41, 13-28 and 1-8% respectively throughout storage (Figure 4.31a). In the mesocarp, TAC of mango fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 9-53, 38-137, 27-66 and 3-20% respectively throughout storage (Figure 4.31b). Treatment with 1 mM SA was best to stimulate TAC in both the exocarp (18-41%) and mesocarp (38-137%) throughout the cold storage (Figure 4.31).

TAC by the ABTS method (Figure 4.32, Appendix: Table 31), in the exocarp of mango fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 10-27, 20-58, 13-29 and 1-8% respectively throughout storage (Figure 4.32a). In the mesocarp, TAC of mango fruits treated with 0.1 and 1 mM SA, 0.1 and 1 mM MJ was higher than those in the control fruits by 11-37, 41-100, 24-63 and 2-15% respectively throughout storage (Figure 4.32b). Treatment with 1 mM SA was best to stimulate TAC in both the exocarp (20-58%) and mesocarp (41-100%) throughout the cold storage (Figure 4.32).

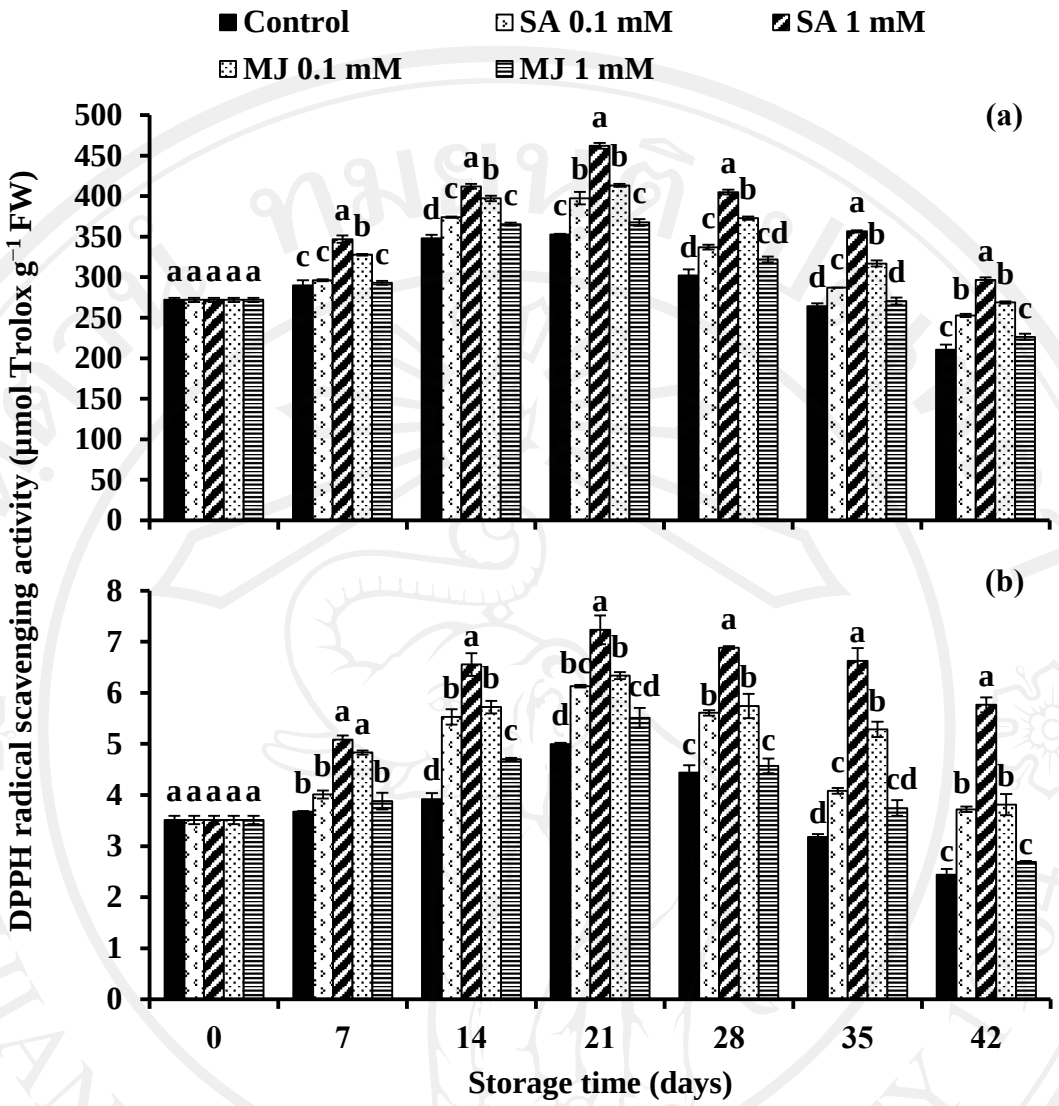

Figure 4.31 Effects of SA and MJ on total antioxidant capacity by DPPH radical scavenging activity in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.

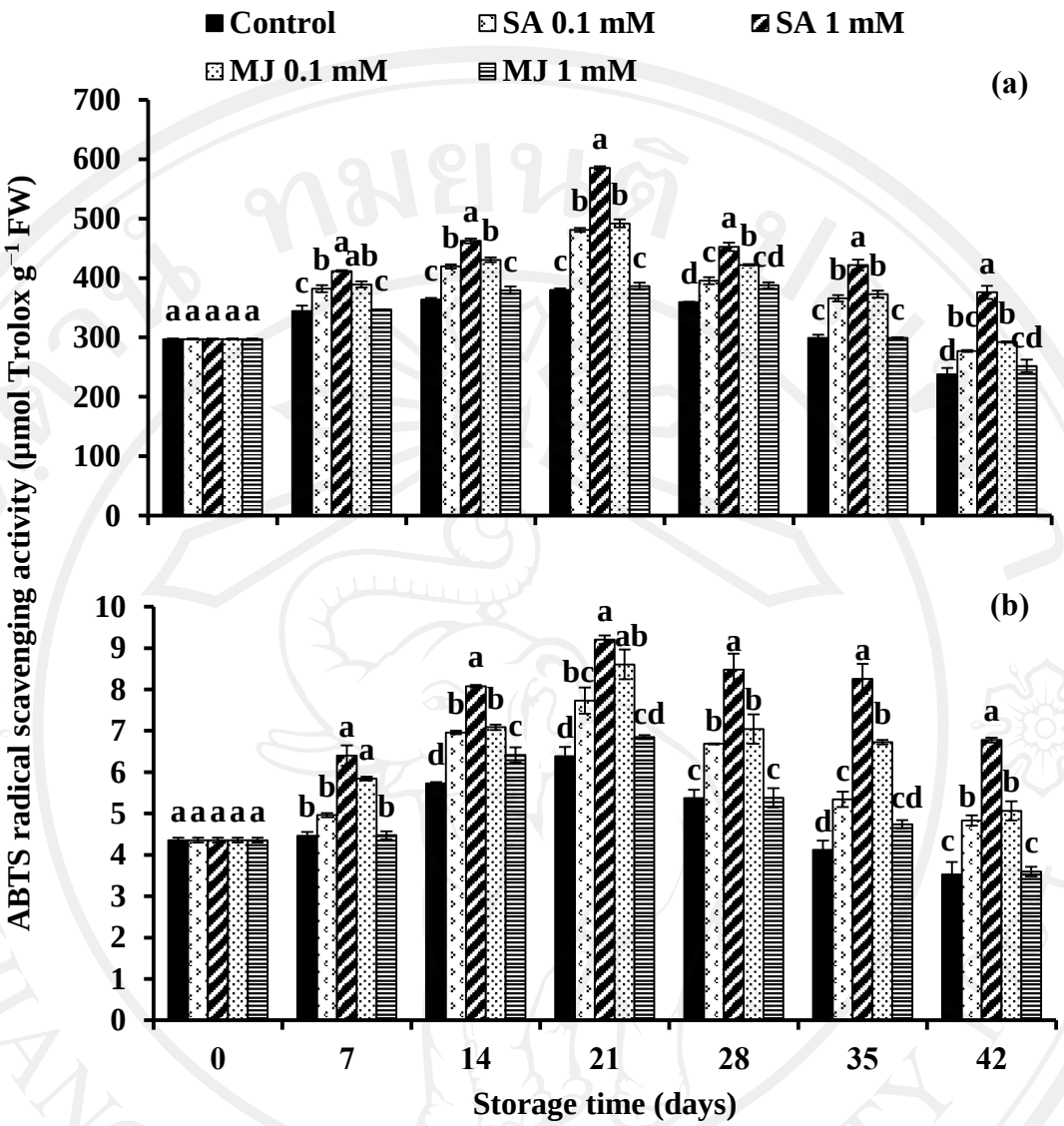

Figure 4.32 Effects of SA and MJ on total antioxidant capacity by ABTS radical scavenging activity in exocarp (a) and mesocarp (b) of mango fruits cv. Nam Dok Mai No. 4 during storage at 5 °C.