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REGULAR ARTICLE

Hot water incorporated with salicylic acid dips maintaining physicochemical quality of 'Holland' papaya fruit stored at room temperature

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ABSTRACT

The effects of hot water incorporated with salicylic acid (SA) dips on quality of 'Holland' papaya fruit stored at room temperature (30 ± 2°C) was investigated. The fruit were immersed in 0, 1.0, 2.0 and 3.0 mM SA solutions at 42 °C for 40 min following at 49 °C for 20 min and untreated (control). Both hot water and hot SA dips prevented the incidence of fungi during storage. The hot SA dips delayed the fruit ripening including maintaining firmness, skin colour, and total soluble solids (TSS) content. Hot SA dips retarded the weight loss rather than hot water dip and control, respectively. All treatments had no affect flesh colour when compared to the control. Hot SA dips enhanced carotenoids, ascorbic acid and antioxidant content during storage. This work suggest that 2.0 mM hot SA dip is a reliable alternative maintaining quality and enhancing bioactive compounds in the papaya fruit during storage.

Keywords: Hot water dip; Papaya fruit; Salicylic acid; Bioactive compounds; Postharvest quality

INTRODUCTION

Papaya (*Carica papaya* L.) fruit is one of a popular exotic fruit in Thailand like pineapple, banana, durian, mangosteen, and mango and so on. The demand of Thai papaya fruit (both green and ripe fruit) in both domestic and overseas market has been recently increased. In, Thailand, papaya fruit cv. 'Kaek Nuan', 'Kaek Dam' and 'Holland' are the most popular commercial varieties. Generally, 'Kaek Nuan' papaya fruit is traded at green stages as the main ingredient of Som Tam, spicy Thai papaya salad. 'Kaek Dam' and 'Holland' papaya fruits are generally traded at ripe stage. However, 'Kaek Dam' papaya fruit has a limitation for export as its big size and long shape. Compared to 'Kaek Dam' papaya fruit, 'Holland' papaya fruit has smaller size and more flesh firmness. Recently, 'Holland' papaya fruit has become the most popular cultivar in Thailand. As a tropical fruit, papaya fruit has various limitations in export due to insect and disease attack, chilling sensitivity during transportation and storage and rapid ripening on the market. Especially in domestic market, most papaya fruit have been sold under ambient temperature (~30°C) which deterioration of the fruit is stimulated, due to increased ripening and the incidence of fungi.

Heat treatments both wet and dry treatment are the promising alternative controlling postharvest diseases and fruit fly attack, alleviating chilling injury and maintaining quality of fruit (Lurie, 1998; Lu et al., 2007). Hot water treatment of 40 min at 42°C followed 20 min for 49°C has been recommended for postharvest disease control and fruit fly disinfestation in mature papaya fruit (Couey and Hayes, 1986). Moreover, heat treatment could induce antioxidant defense responses due to production of bioactive compounds and antioxidant enzymes in fruit (Vincente et al., 2006). Postharvest quality maintenance by hot water treatment has been reported for papaya fruit (Lazan et al., 1989), lemon fruit (Nafussi et al., 2001), banana fruit (Promyou et al., 2008), jujube fruit (Promyou et al., 2012), sweet leaf bush (Supapvanich et al., 2012).

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Salicylic acid (SA), a phytohormone which classified as a phenylpropanoid compound, is naturally stimulated by biotic and abiotic stresses to induce defense responses (Supapvanich and Promyou, 2013). Many previous works have proved that exogenous SA application could delay ripening process (Gerailoo and Ghasemnezhad, 2011), maintain firmness (Tareen et al., 2012; Supapvanich, 2015), alleviate chilling injury (Yang et al., 2012), reduce incidence of fungi and enhance bioactive compounds including antioxidant activity (Wei et al., 2011). Currently, SA has been studied in postharvest conservation of papaya fruit applied alone (Promyou and Supapvanich, 2016). However, the application of SA combined with hot water has not yet been investigated in papaya fruit postharvest preservation. Thus, the objective of this study was to evaluate the effect of quarantine hot water dip or SA combined with the hot water dip, in the postharvest preservation and bioactive compounds of 'Holland' papaya fruit during stored at room temperature (30±2ºC).

MATERIALS AND METHODS

Raw materials

Papaya fruit (*Carica papaya* L.) cv. 'Holland' were derived from a commercial papaya orchard at Tak province. The fruit were harvested when the skin turned to yellow 5% and delivered to laboratory of Faculty of Natural Resources and Agro-Industry, Kasetsart University within 24 hours. The fruit were screened and the fruit with physical damage and disease attack were discarded. The selected fruit were cleaned by rinsing with tap water and then dipped with 200 μL/L sodium hypochlorite solution for 5 min. The fruit were air-dried for 30 min.

Heat treatments

The papaya fruit were separated into five groups. The first group was control, no heat treatment, the second group was immersed in hot water at 42ºC for 40 min following at 49 ºC for 20 min and the third to the fifth group was immersed in 1.0, 2.0 and 3.0 mM SA solution at 42ºC for 40 min following at 49 ºC for 20 min, respectively. After heat treatments, the fruit were dipped in cold water for 10 min and air-dried. The fruit were then covered with fruit net and stored at room temperature (30±2 ºC) for 6 days. Postharvest quality including visual appearance, weight loss, firmness, total soluble solids (TSS) content and superficial colour and bioactive compounds including antioxidant activity, carotenoids and ascorbic acid content were determined in every 3 days of storage.

Weight loss, firmness and TSS content determinations

The weight of the fruit was recorded in every 3 days of storage. The percentage of the fruit weight loss was calculated by comparing with the weight on initial day. The fruit were vertically cut at the middle the fruit. The firmness was measured at middle part of mesocarp by using a TA.XT Plus Texture Analyzer (Stable Micro System Ltd., UK). A cylindrical probe P/4 was used to measure the firmness at a rate of 1 mm/sec. Each fruit was punctured four times. The peak force exerted (expressed as Newton (N)) was used for flesh firmness data.

TSS content was measured by using a hand-held refractometer (ATAGO MNL-1125, Japan). Juice from the flesh was used to assay the TSS and data were present as °Brix.

Superficial colour measurement

Superficial colour of the papaya skin and flesh colour was measured using a Minolta CR-300 (Minotal, Japan). Colour measurements, brightness (*L** value), chroma and hue angle, where 0° = red purple; 90° = yellow; 180° = bluish green; and 270° = blue, of the papaya fruit skin and redness (*a**) and yellowness (*b**) of flesh colour were taken.

Carotenoids content assay

Total carotenoid content of the papaya flesh was determined using the method of Rojsanga, et al. (2014) with slight modification. Five grams of the fruit mesocarp were homogenized with hexane. Samples were centrifuged at 10,000 × g for 20 min. The pellet was again extracted with hexane until no colour. The supernatants were collected and brought to 50 ml with acetone. Absorbance at 454 nm was recorded. The total carotenoid content was calculated based on the calibration curve of beta-carotene and expressed as mg/100g FW.

Ascorbic acid content assay

Two grams of the papaya flesh were homogenized with 10 mL of cold 5% metaphosphoric acid and then filtered using filter paper Whatman No. 1 at 4ºC. The ascorbic acid content was assayed using the method described Hashimoto and Yamafuji (2001). A 0.8 mL of supernatant was mixed with 0.4 ml of 2% di-indophenol. Then, 0.8 ml of 2% thiourea and 0.2 ml of 1% dinitrophenol hydrazine were added into the mixture. The mixtures were incubated at 35°C for 3 h. After incubation, 1 ml of 85% sulfuric acid was added and the mixture was again incubated at room temperature for 30 min. Absorbance at 540 nm were recorded. The ascorbic acid content was present as mg/100 gFW.

Antioxidant activity assay

Two grams of the papaya flesh were homogenized with 10 mL of 60% ethanol and then stirred at 4ºC for 1 hour. After that, the sample was filtered using filter paper Whatman No. 1. The antioxidant capacity of the sample was assayed using a ferric reducing antioxidant potential

(FRAP) assay according to the method of Benzie and Strain (1996). The FRAP reagent was a mixture of 25 mL acetate buffer pH 3, 2.5 mL 10 mM 2,4,6-trioyridyl-1,3,5-triazine (TPTZ) and 2.5 mL 20 mM ferric chloride hexahydrate. The reaction began when 1 mL of the supernatant was added into 3 mL of FRAP solution. The mixture was incubated at room temperature for 30 min and then the absorbance at 630 nm was recorded. The antioxidant activity was calculated based on the standard curve of trolox and the data were expressed as mmole Trolox equivalent (TE)/100 g FW.

Statistical analysis

Data were analyzed using analysis of variance which was performed with the SPSS software version 16. Significant differences between means of data were compared using the least significant difference (LSD) at $P < 0.05$. The data were presented as the mean (n=4) ± SD.

RESULTS AND DISCUSSIONS

Visual appearance

Fig. 1 shows the visual appearance of 'Holland' papaya fruit treated with hot SA solutions, hot water and the control stored at room temperature for 6 days. Both hot water and hot SA solution dips delayed the fruit ripening when compared to the control. On day 6, no green colour was found on the skin of hot water dipped fruit and control one.

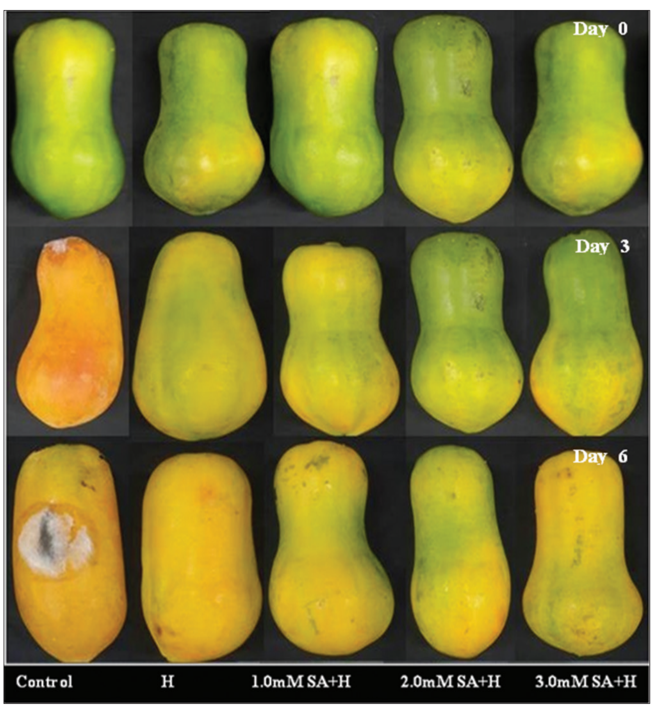

Fig. 1. Visual appearance of 'Holland' papaya fruit dipped with quarantine hot water incorporated with SA (SA+H) during stored at room temperature (30±2°C) for 6 days.

The result shows that the hot SA solution dips delayed the fruit ripening rather than the hot water dip. The incidence of fungi was detected on the control fruit stored for 3 and 6 days whilst no decay was found on the papaya fruit treated with hot water and hot SA solution throughout storage. These suggest that the hot water and hot SA solution dips prevented the incidence of fungi of the papaya fruit during storage. It is widely recognised that hot water dip and SA treatment delay ripening and control postharvest decay of fruit and vegetables (Fallik et al., 1999; Paull and Chen, 2000; Promyou et al., 2012). Both hot water dip and SA application retard ethylene production in climacteric fruit by inhibiting ACC oxidase production (Leslie and Romani, 1988; Paull and Chen, 1990; Lurie et al., 1996; Supapvanich and Promyou, 2013). Regarding to postharvest disease prevention, both heat and SA treatment have been reported for the induction of the complex fruit disease resistance mechanisms by stimulating the expression of pathogenesis related protein genes (Pavoncello et al., 2001; Wang et al., 2011; Supapvanich and Promyou, 2013). Lu et al. (2007) addressed that heat treatment promotes the synthesis and accumulation of antimicrobial compounds (phytoalexins) and defensive enzymes such as chitinases and β- 1,3-glucanases which having ability to degrade fungal walls. Similarly, SA treatment also promotes chitinases (Jiankang et al., 2006).

Weight loss, firmness and TSS content

As the results shown in Fig. 2a, all hot SA solution dips retarded the increase in weight loss of the papaya fruit throughout storage rather than hot water dip and the control. The highest weight loss of the fruit was found in the control. The concentration of SA solution had no influence on the weight loss of the papaya fruit during storage. The papaya fruit dipped in hot water and the control showed a rapid loss of firmness during storage (Fig. 2b). Hot SA dips maintained the firmness of the papaya fruit during storage which this depended on the concentration of SA solution. Hot SA solution at the concentration of 2.0 and 3.0 mM retarded the papaya fruit softening rather than 1.0 mM hot SA solution. There was no significant difference in the firmness of the papaya fruit dipped in 2.0 and 3.0 mM hot SA solutions. These agree with the finding of a previous work that hot water and hot water incorporated with SA dip reduced the weight loss and the softening of rambutan fruit during storage (Supapvanich, 2015). Reducing weight loss and maintaining flesh firmness by heat treatment and exogenous SA application might due to maintaining and improving membrane function and reducing the activity of cell wall hydrolases (Erkan et al., 2005; Supapvanich and Promyou, 2013). Moreover, our previous works also found that hot water dip delayed the loss of firmness and weight loss of jujube fruit (Promyou

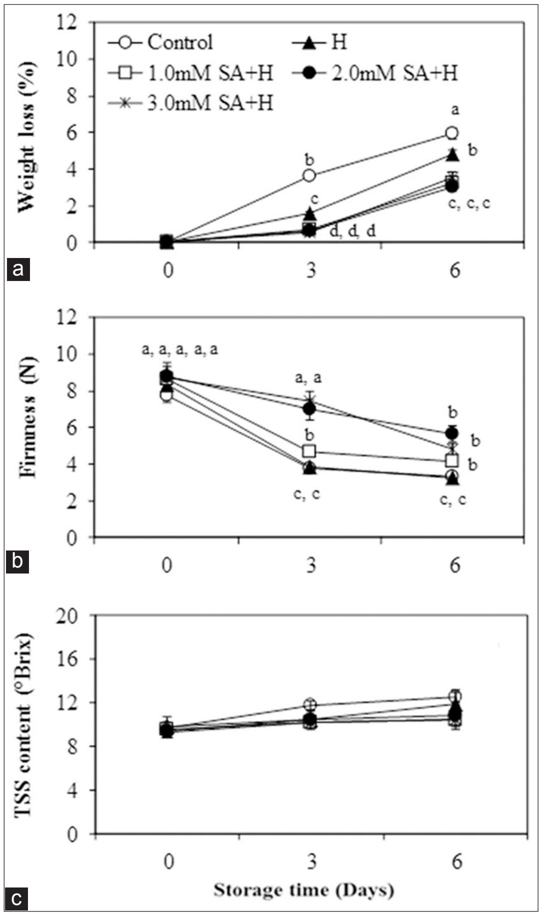

Fig 2. Weight loss (A), firmness (B) and total soluble solids (TSS) content (C) of 'Holland' papaya fruit dipped with quarantine hot water incorporated with SA (SA+H) during stored at room temperature (30±2°C) for 6 days. The vertical bar represents the standard deviation of the mean (n = 4). Values different letters within the same figure are significantly different at P < 0.05.

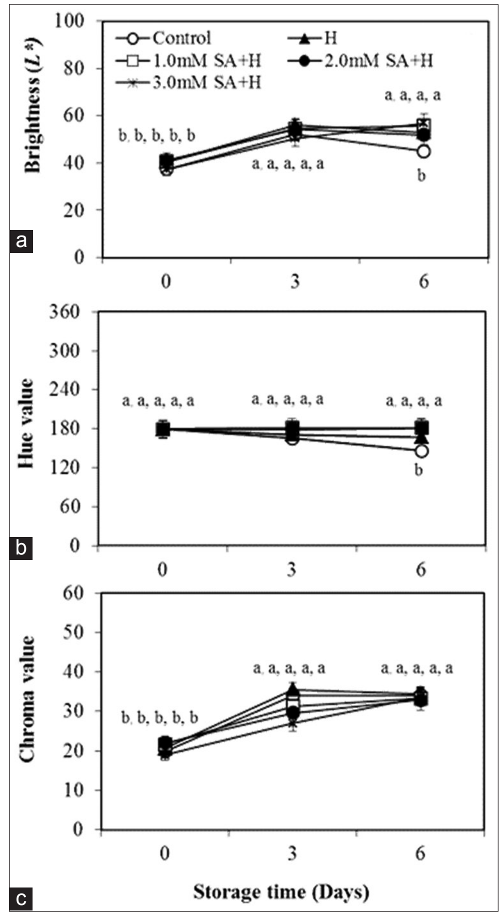

Fig 3. Skin colour, brightness (A), hue value (B) and chroma value (C), of 'Holland' papaya fruit dipped with quarantine hot water incorporated with SA (SA+H) during stored at room temperature (30±2ºC) for 6 days. Data were present mean of 4 replications ± SD. Values different letters within the same figure are significantly different at P < 0.05.

et al., 2012) and 2.0 mM SA dip maintained membrane structure and retarded the softening of 'Kaek Dam' papaya fruit (Promyou and Supapvanich, 2016). These support that hot SA dip could maintain the fresh weight and firmness of the papaya fruit. The TSS content of the papaya fruit was maintained by hot water and hot SA dips (Fig. 2c). The control fruit had TSS content slightly higher than all heat treated papaya fruits over storage. On day 6, TSS of hot water dipped fruit increased whilst that of all hot SA dipped fruits remained constant. It is accepted that the increase in TSS content is an indicator fruit ripening. Thus, this result indicates that hot SA dips had more efficient delaying the ripening process of the papaya fruit than hot water dip.

Skin and flesh colour

Figs. 3 and 4 show colour of the papaya fruit skin and flesh during storage. The L^* value of the papaya fruit skin significantly increased during storage for 3 days (P< 0.05) and then remained constant (Fig. 3a). On day 6, L^* value of the control fruit was significantly lower than that of all heat treated papaya fruits (P< 0.05). The hue value of the fruit skin dipped in hot SA solutions was maintained whilst that of the hot water dipped fruit decreased slightly during storage (Fig. 3b). That of the control fruit also decreased rather than other treatments during storage and it reached to 90° (yellow) on day 6. Chroma value of the fruit skin increased significantly during storage for 3 days (P< 0.05) and then remained constant over the storage. There was no significant difference in each treatment during storage (Fig. 3c). The changes in these superficial colour parameters of the papaya fruit skin indicated that heat treatment retarded the ripening of the papaya fruit during storage. The changes of skin colour were concomitant with the visual appearance of the papaya fruit as shown in Fig. 1. The flesh colour parameters (a^* and b^* values) of the papaya fruit stored for 6 days were determined. The a^* value of both control and hot water dipped fruits was slightly higher than that of hot SA solution dipped papaya fruits; however, no significant differences were detected in all treatments (Fig. 4a). The *b** values of all treatments were similar (Fig. 4b). These indicated that hot water dip and hot SA solution dip had no affect the fruit flesh colour changes when compared to the control fruit.

Bioactive compounds

The changes in bioactive compounds content, carotenoids, ascorbic acid and antioxidant activity contents, were shown in Fig. 5. Carotenoids content of the papaya fruit was enhanced by hot SA dips which 2.0 mM hot SA dip had higher potential enhancing carotenoids content than others (Fig. 5a).Whereas, both hot water dip and the control did not enhance carotenoids content and it remained constant over storage. This result is similar with the report of Huang et al. (2008) that preharvest SA treatment increased carotenoid content in navel orange fruit during storage. In the similar vein, ascorbic acid content of the papaya fruit was also enhanced hot SA dips, especially at 1.0 mM and 2.0 mM (Fig. 5b). Ascorbic acid content of 2.0 mM hot SA dipped papaya fruit was higher than that of 1.0 mM hot SA dipped fruit whilst that of 3.0 mM hot SA dipped fruit, hot water dipped fruit and the control were remained constant throughout storage. Similarly, Coltro et al. (2014) suggested that heat shock incorporated with SA treatment induced ascorbic acid content in strawberry fruit during storage. Moreover, enhancing ascorbic acid content by SA treatment had been reported for kiwifruit (Aghdam et al., 2011) and strawberry (Asghari, 2006). Antioxidant activity of the papaya fruit increased throughout storage (Fig. 5c). The antioxidant activity was also enhanced by hot SA dips. 2.0 mM hot SA dip enhanced antioxidant activity more than other hot SA dips. These suggest that 2.0 mM hot SA dip is a good alternative improving nutritional quality of the papaya fruit during storage. This is supported by our previous work which 2.0 mM SA dip enhanced total phenols and antioxidant activity content in 'Kaek Dam' papaya fruit during cold storage (Promyou and Supapvanich, 2016). Huang et al. (2008) had described that exogenous SA application activates biosynthesis of bioactive compounds as well as defence mechanism in plants. In other fruits such as strawberry (Asghari, 2006) and grape berries (Sarikhani et al., 2010), exogenous SA treatment enhances their bioactive compounds content including antioxidant activity. The results in this work agree with the report of Supapvanich (2015) which ascorbic acid and antioxidant activity content of rambutan fruit were induced by lukewarm water incorporated with 1.0 mM SA treatment. Moreover, the combination of heat and SA treatment induced antioxidants in peach fruit (Cao et al., 2010) and increased ascorbic acid content in strawberry fruit (Coltro et al., 2014).

CONCLUSION

In conclusion, the results of this work support the use of quarantine hot water incorporated with SA dip as a possible strategy to inhibit the incidence of fungi, to maintain fruit firmness and fresh weight and to enhance bioactive compounds including total carotenoids, ascorbic acid and total antioxidant activity contents in 'Holland' papaya fruit during storage at room temperature (30±2ºC). It is considered that quarantine hot water incorporated with 2.0 mM SA dip could be a reliable alternative to maintaining postharvest quality of 'Holland' papaya fruit on market.

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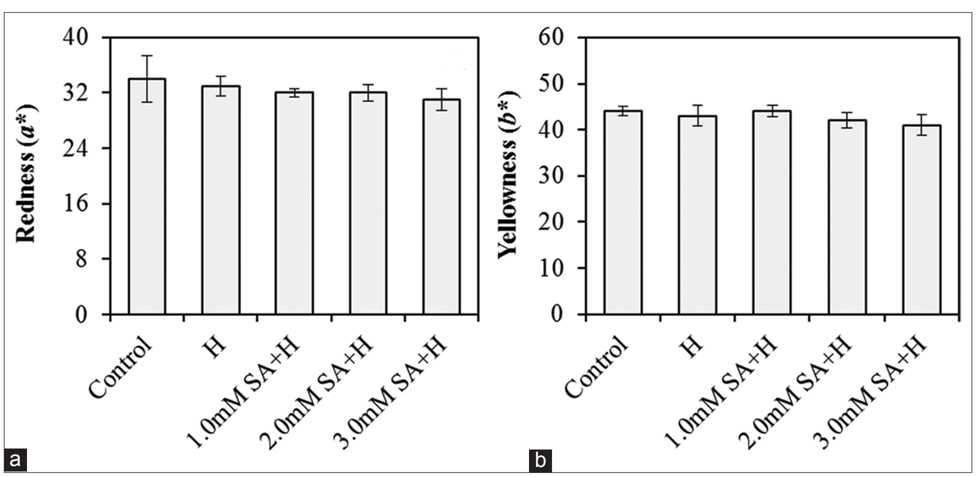

Fig 4. Flesh colour, redness (a*) (A) and yellowness (b*) (B), of 'Holland' papaya fruit dipped with quarantine hot water incorporated with SA (SA+H) during stored at room temperature (30±2ºC) for 6 days. The vertical bar represents the standard deviation of the mean (n = 4). Values different letters within the same figure are significantly different at P < 0.05.

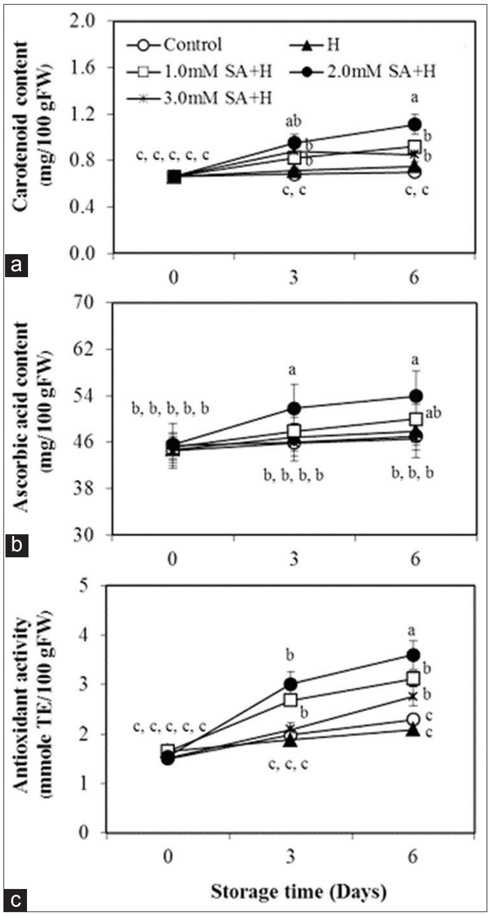

Fig 5. Carotenoids content (A), ascorbic acid content (B) and antioxidant activity (C) of 'Holland' papaya fruit dipped with quarantine hot water incorporated with SA (SA+H) during stored at room temperature (30±2°C) for 6 days. The vertical bar represents the standard deviation of the mean (n = 4). Values different letters within the same figure are significantly different at $P < 0.05$.

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Author's contributions

S. Supapvanich was the project director who planned the overall experiments, interpreted and analyzed some data and wrote this article. S. Promyou supervised certain experiment and methodology and analysed some data.

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