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ORIGINAL ARTICLE

# Effects of fresh *Aloe vera* gel coating on browning alleviation of fresh cut wax apple (*Syzygium samarangenese*) fruit cv. Taaptimjaan

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**Abstract** The effect of natural coating by using fresh *Aloe vera* (*A. vera*) gel alleviating browning of fresh-cut wax apple fruits cv. Taaptimjaan was investigated. The fresh-cut fruits were dipped in fresh *A. vera* gel at various concentrations of 0, 25, 75 or 100 % (v/v) for 2 min at 4 ± 1 °C for 6 days. Lightness ($L^*$), whiteness index (WI), browning index (BI), total color difference ($\Delta E^*$), sensorial quality attributes, total phenolic (TP) content, antioxidant activity and polyphenol oxidase (PPO) and peroxidase (POD) activities were determined. During storage, $L^*$ and WI of the fresh-cut fruits surface decreased whilst their BI and $\Delta E^*$ increased. *A. vera* coating maintained the $L^*$ and WI and delayed the increase in BI and $\Delta E^*$, especially at 75 % *A. vera* dip. The fresh-cut fruits dipped in 75 % *A. vera* had the lowest browning score, the highest acceptance score and delayed the increase in TP content and PPO activity. However POD activity was induced by *A. vera* coating. Antioxidant activity had no effect on browning incidence of the fresh-cut fruits. Consequently, *A. vera* gel coating could maintain quality and retarded browning of fresh-cut wax apple fruits during storage.

**Keywords** Fresh-cut wax apple fruit · Fresh *Aloe vera* gel · Enzymatic browning · Edible coating

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## Introduction

Browning generation is a key factor limiting quality, shelf-life and marketing acceptability of fresh-cut products. Generally, browning incidences of food are classified into two types of enzymatic and non-enzymatic browning. Most browning reactions occurring in fresh fruits and vegetables are associated with the enzymatic browning type. The mechanism of this browning reaction involves the action of browning enzymes, such as PPO (EC 1.14.18.1), POD (EC 1.11.1.7) and phenylalanine ammonia lyase (PAL; EC 4.3.1.24) and 27 subsequent series of the polymerization of endogenous phenolic compounds. It is widely recognized that PPO plays a major role in browning incidence in fruits and vegetables that are particularly sensitive to oxidative browning. Phenolic compounds in cells of intact commodities are generally separated from PPO by compartmentalization and browning disorder does not appear (Iyengar and McEvily 1992). Physical damages of tissues such as cutting, trimming or minimal processing cause cellular discomparmentation and further rapid browning incidence in fruit and vegetables products.

Wax apple fruit (*Syzygium samarangenese*) or called rose apple or java apple, an exotic tropical fruit, has become economically important in Southeast Asia such as Taiwan, Malaysia, Indonesia and Thailand (Shu et al. 2008; Vara-Ubol et al. 2006). Taste of the fruit is the combination of apple-like crispness, watery sweet with low sour, and the aroma of roses (FAO 2005; Vara-Ubol et al. 2006). In Thailand, not only is intact wax apple fruit economically important but the fresh-cut fruits have also become a popular fresh-cut product (Worakeeratikul et al. 2007). Wax apple fruit cv. Taaptimjaan is the most popular commercial cultivar in Thailand because of its ruby-red skin, juicy sweet and pleasant aroma. Moreover, 'Taaptimjaan' wax apple

fruit consists of high bioactive compounds, especially phenolic compounds content and high sensitivity to enzymatic browning reaction after minimal process (Supapvanich et al. 2011). Thus, browning is the major factor affecting the organoleptic properties and limiting shelf-life of fresh-cut wax apple fruit during storage. A range of antibrowning agents such as organic acids, cysteine (Son et al. 2001), carageenan (Lee et al. 2003), milk protein (Le Tien et al. 2001), glutathione (Supapvanich et al. 2014), honey (Jeon and Zhao 2005). Furthermore, pineapple fruit juice has been studied to maintain fresh-liked quality and to prevent browning of fresh-cut fruit (Chaisakdanugull et al. 2007; Supapvanich et al. 2012). Consumers have been recently concerning the use of natural agents instead of synthetic compounds. Using *Aloe vera* (*A. vera*) gel coating is an alternative to maintain quality and prevent browning in fresh-cut products. There are certain previous works reporting use of *A. vera* gel to maintain postharvest quality of table grapes (Serrano et al. 2006), apple fruit (Ergun and Satici 2012), nectarine fruit (Ahmed et al. 2009), sweet cherry fruit (Asghari et al. 2013; Paladines et al. 2014), and tomato fruit (Chauhan et al. 2015). In fresh-cut fruit, *A. vera* gel was used to maintain physical quality including surface browning prevention of minimally processed cantaloupe (Yulianingsih et al. 2013), kiwifruit (Benitez et al. 2013). In apple slices, *A. vera* gel was used to prevent surface browning (Chauhan et al. 2011; Song et al. 2013). A minimize electrolyte leakage, changes in tristimulus colour coordinates and oxidizing enzymes were reported in *A. vera* coated apple slices (Chauhan et al. 2011). Moreover, certain researches reported that *A. vera* coating comprised antibacterial and antifungal properties which reduced microbial growth in table grapes and sweet cherries (Valverde et al. 2005; Martinez-Romero et al. 2006). Thus, *A. vera* gel coating might be a potential alternative natural agent for minimally processed fruits and vegetables.

However, there have been few studies about the use of *A. vera* gel coating to maintain quality of fresh-cut exotic fruit during storage. Thus, the aim of this work was to investigate the effect of fresh *A. vera* gel coating on browning inhibition of fresh-cut wax apple fruit cv. Taaptipjan during storage.

## Materials and methods

### Plant material preparation and fresh-cut processing

'Taaptimjaan' wax apple fruit (*Syzygium samarangenese*) at commercial maturity stage were obtained from Talaad Thai market, the biggest fresh fruit distribution market in Thailand. Fruit were selected based on uniform size, red skin color ($a^* = 28$–$32$), and without physical damage and diseases. After washing with tap water twice, fruit were immersed in 100 μL $L^{-1}$ sodium hypochlorite for 5 min. Fruit were then cut into longitudinal half with a sharp knife and each half was cut at the exposed end into four equal pieces. The endocarp tissue and calyx end of the fruit were removed.

### Coating material preparation

*Aloe vera* cv. Aloe barbadensis Mill leaves were obtained from an orchard in Rachaburi province, western Thailand. Leaves were delivered to the laboratory of King Mongkut's Insitute of Technology Ladkrabang within 3 h after harvest. After washing with tap water and immersing in 100 μL $L^{-1}$ sodium hypochlorite for 5 min, leaf peel and the latex were removed. The inner transparent tissue were blended and then filtered through a sterilized cotton cloth sheet. The pure untreated *A. vera* homogenates were diluted with sterilized distilled water to achieve the concentrations of 25, 50, 75 and 100 % (v/v).

### Experimental design

Fresh-cut wax apple fruits were divided into 5 groups by either dipping in sterilized distilled water (control), 25, 50, 75 or 100 % *A. vera* gel for 2 min. After treatment, five pieces of the fresh-cut fruit (ca 200 g) were placed on a polyethylene terephthalate (PET) plastic box (15 cm × 21 cm × 2.5 cm size) and then stored at 4 ± 1 °C and 92 ± 1 % RH for 6 days.

### Color and browning index measurement

The flesh cut surface color was measured using a Minolta Chroma Meter CR-300 (Minolta Co, Ltd, Netherland). Tristimulus color coordinates in term of CIE $L^*$, $a^*$ and $b^*$ values of the fruit flesh were recorded. All measurements were referenced to the CIE using the standard illuminant D65 and 10° observer. The flesh color was presented as $L^*$, whiteness index ($WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$) and total color difference ($\Delta E^* = [(L_2^* - L_1^*)^2 + ((a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2]^{1/2}$). The browning index was determined using the method described by Supapvanich et al. (2011). Three grams of the fruit flesh were homogenized with 30 mL of 80 % (v/v) ethanol and then stirred at room temperature for 1 h. The extract was filtered using Whatman No.1 filter paper. The absorbance at 420 nm was measured. The browning index (BI) was expressed as $OD_{420}$ per g fresh weight.

### Sensory evaluation

The samples were analyzed for browning disorder, odor and overall acceptability by 18 semi-trained panelists. The

samples were presented in a white plastic plate under normal white light. Browning scores of fresh-cut fruit were evaluated using browning scores of 1 = no brown, 3 = moderate brown and 5 = extreme brown, whereas odor scores were also evaluated using 5-point scoring method as follows: 1 = very poor, 3 = fair and 5 = excellent (normal wax apple odor). Overall acceptability was evaluated on the scale of 1–5, where 1 = very poor, 3 = medium and 5 = excellent. It is noteworthy that sensory evaluation was only performed on day 0 and day 6.

### Total phenolic content and antioxidant activity

A 3 g of the sample was homogenized with 2 mL of 90 % ethanol and then the volume was adjusted to 20 mL with distilled water. Homogenized sample was stirred at room temperature for 30 min and then centrifuged for 15 min at 10,000×*g*. Supernatant was used to assay total phenolic (TP) content and antioxidant activity content. TP content was determined using a spectrophotometric method described by Slinkard and Singleton (1997). The extract solution was reacted with 50 % (w/v) Folin–Ciocalteu reagent and saturated $Na_2CO_3$ solution. The absorbance at 750 nm was recorded. Data were expressed as mg gallic acid per g fresh weight (mg GA $g^{-1}$ FW). Antioxidant activity was determined using ferric reducing antioxidant potential (FRAP) assay as described by Benzie and Strain (1996). The extract was reacted with FRAP reagent which consisted of acetate buffer pH 3, 10 mM 2,4,6-tripyridyl-1,3,5-triazine (TPTZ) and 20 mM ferric chloride hexahydrate (in the ratio of 10:1:1). The absorbance at 630 nm was recorded. Data were present in term of μmole Trolox equivalents per g fresh weight (μmole TE $g^{-1}$ FW).

### Polyphenol oxidase and peroxidase activities

A 10 g of the sample was homogenized in 25 mL of 0.1 M sodium phosphate buffer pH 7.0 containing 0.2 g of polyvinylpyrrolidone (PVPP). The extract was centrifuged at 10,000×*g* for 10 min. The supernatant was collected. PPO activity was performed using the method of Galeazzi et al. (1981). The reaction was started when 1 mL of supernatant was added into the mixture of 1 mL sodium phosphate buffer pH 7.0 and 1 mL guaiacol solution. One unit of PPO activity was defined as a change of 0.001 in absorbance at 420 nm per min. POD activity was assayed by the method described by Zhang et al. (2005). The reaction began when 0.25 mL of extract was mixed into 2.25 mL of the mixture of 1 % $H_2O_2$ and 100 mM pyrocatechol in sodium phosphate buffer pH 7.0. One unit of POD activity was defined as a change of 0.01 in absorbance at 470 nm per min. Both PPO and POD activities were present as units per g fresh weight (units/g FW).

### Statistical analysis

A completely randomized design was used in this study. All physicochemical measurements were performed in four replicates. The data obtained by physicochemical measurements and sensory evaluation were analyzed using ANOVA and the means compared by a Post Hoc least significant difference (LSD) test at a significance level of $p \leq 0.05$ using the SPSS software package (SPSS Inc., Chicago, IL, USA).

## Results and discussion

### Flesh color

Flesh color of fresh-cut wax apple fruits was present as $L^*$, WI, BI (Fig. 1) and $\Delta E^*$ (Fig. 2).The increased BI and decreased WI of the fresh-cut fruits of all treatments was detected during storage which was due to the enzymatic browning reaction and the moisture loss from cut surface (Supapvanich et al. 2011). The *A. vera* gel coating could maintained $L^*$ and WI which was approximately 66.42 and 61.92, respectively, and delayed the increase in BI and $\Delta E^*$ of fresh-cut wax apple fruits during storage. Amongst *A. vera* gel coated fresh-cut fruits, those coated with 75 % *A. vera* gel expressed the highest $L^*$ and WI and the lowest BI and $\Delta E^*$ on the cut surface while the contrast results was observed for were present in the uncoated fresh-cut wax apple fruit. Moreover, 75 % *A. vera* gel coating reduced the loss of fresh weight better than other treatments and the high weight loss was found in the uncoated and 100 % *A. vera* coated fresh-cut fruit samples (data not shown). These results suggested that *A. vera* gel coating prevented enzymatic browning reaction and reduced the loss of moisture from the cut surface. Chauhan et al. (2011) and Song et al. (2013) suggested that *A. vera* gel had antibrowning functionality which can prevent apple slices from surface browning for a long duration. Martinez-Romero et al. (2006) also reported that *A. vera* gel coating minimized the changes in hue and browning of sweet cherries stored at cold temperature. Moreover, Chauhan et al. (2015) reported that the combination of *A. vera* gel and shallac coating extended shelf-life of tomato fruit including maintaining the fruit color. Interestingly, we found that fresh-cut wax apple coated with 100 % *A. vera* gel showed higher BI* and lower $L^*$ and WI than those of other *A. vera* gel coatings. These might be related to the dried cut-surface of the 100 % *A. vera* coated fruit. As a plasticizer agent, added water improved property of *A. vera* gel in preventing cut-surface drying of the fresh-cut fruits. The $\Delta E^*$ of the fresh-cut wax apple fruits coated with 100 % *A. vera* gel was similar to the fresh-cut fruits coated with 25 and 50 %.

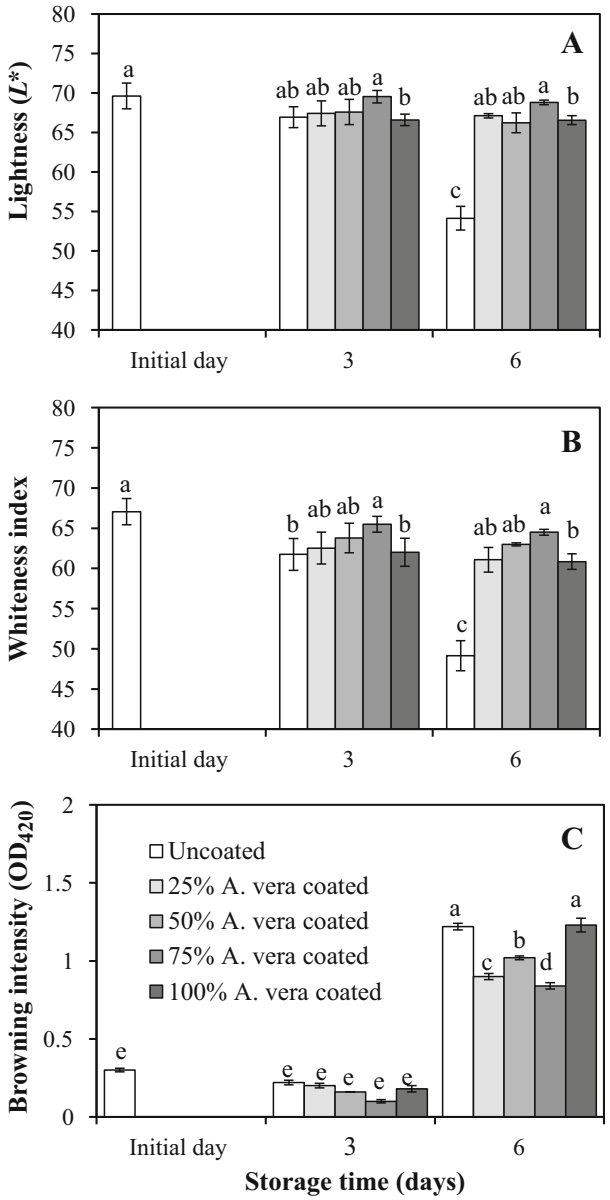


**Fig. 1** Lightness ($L^*$) (**a**) and whiteness index (WI) (**b**) and browning index (BI) (**c**) of fresh-cut wax apple fruit coated with fresh *A. vera* gel held at 4 ± 1 °C for 6 days

## Sensory evaluation

Table 1 shows five hedonic sensorial scores of browning, odor and overall acceptability of the fresh-cut wax apple fruits. The sensory evaluations were investigated on the initial day of storage and at the end of storage. Regarding to previous work and our preliminarily test, the shelf-life of fresh-cut wax apple fruits was about 6 or 7 days at 4 ± 1° C (Supapvanich et al. 2011, 2012). On day 6 of storage, the browning score of fresh-cut fruit coated with 75 % *A. vera* gel was significantly least ($p < 0.05$) at 1.94 ± 0.10 while the highest score of 4.06 ± 0.5 was

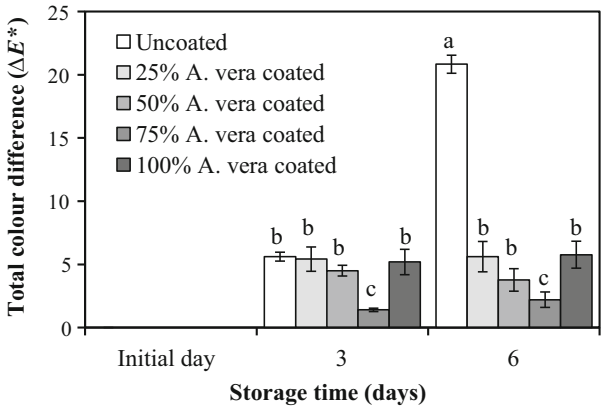


**Fig. 2** Total colour difference ($\Delta E^*$) of fresh-cut wax apple fruit coated with fresh *A. vera* gel held at 4 ± 1 °C for 6 days

observed in uncoated fresh-cut fruit. Odor scores of all fresh-cut on day 6 were lower than that at initial; however, no significant difference amongst the treatments, except 100 % *A. vera* coated fresh-cut fruit, were found. Fresh-cut wax apple fruit coated with 100 % *A. vera* gel received the least odor score, compared with others ($p < 0.05$). In overall acceptability on day 6, fresh-cut fruit coated with 75 % *A. vera* gel presented the highest score and the uncoated fresh-cut fruit had the least core. These show that *A. vera* gel coating could maintain sensorial quality attributes by retarding browning incidence and maintaining overall acceptability of the fresh-cut fruits. These results are consistent with previous works reported by Chauhan et al. (2011) and Song et al. (2013) in which *A. vera* gel-coated apple slices has higher sensorial scores than did the control. In fresh-cut kiwi fruit, Benitez et al. (2013) suggested that *A. vera* coating retarded browning and maintained the fruit sensory quality for a long storage duration.

## Total phenolic and total antioxidant activity

TP content and antioxidant activity of fresh-cut wax apple fruits coated with *A. vera* is presented in Fig. 3. Regarding to the above results, 75 % *A. vera* coating was best in retarding cut surface browning and maintenance of sensorial quality attributes of the fresh-cut wax apple fruits. It is widely recognized that the evolution of TP content and antioxidant activity of fruits during storage could be different depending on the cultivars and climatic and environmental conditions during growth period (Kalt 2005). In the present study, an increase in both TP content and antioxidant activity content was found during storage. There was no significant change difference in increasing TP content of the *A. vera* coated fresh-cut fruits during storage while a significant increase in TP content of the uncoated fresh-cut fruit was found on 6th

**Table 1** Sensorial quality attributes, browning, odor score and overall acceptance scores, of fresh-cut wax apple fruit coated with fresh *A. vera* gel held at 4 ± 1 °C on day 6

| Sensory score | Day 0 | Day 6 | | | | |
|---|---|---|---|---|---|---|
| | | Uncoated | 25 % *A. vera* | 50 % *A. vera* | 75 % *A. vera* | 100 % *A. vera* |
| Browning | 1.00d | 4.06 ± 0.51a | 3.67 ± 0.29a | 2.44 ± 0.25b | 1.94 ± 0.10c | 2.76 ± 0.10b |
| Odor | 5.00a | 4.62 ± 0.30b | 4.14 ± 0.10b | 4.20 ± 0.22b | 4.00 ± 0.10b | 2.04 ± 0.10c |
| Overall acceptability | 5.00a | 1.40 ± 0.07d | 2.40 ± 0.10c | 2.33 ± 0.19c | 3.10 ± 0.09b | 2.05 ± 0.08c |

Data represent ± SD of four replications. The same letter in each row shows no significant difference at $p < 0.05$

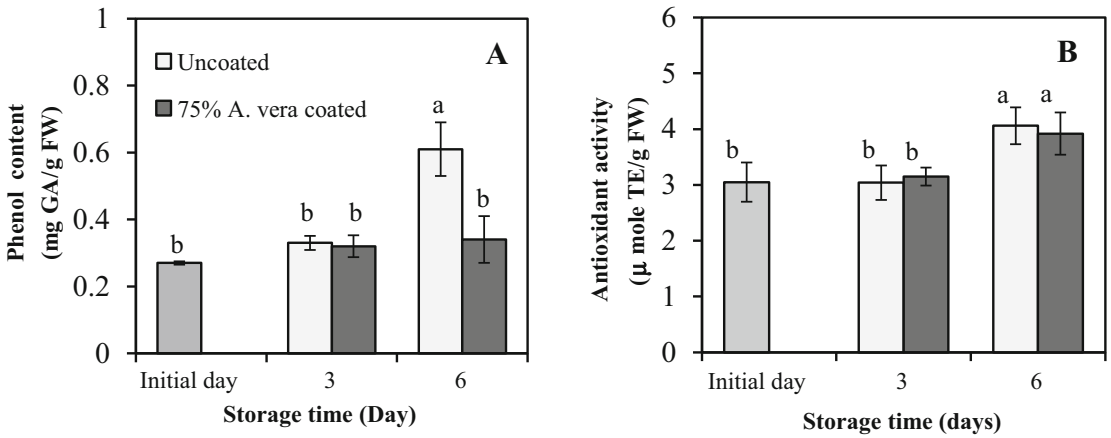


**Fig. 3** Phenolic content and antioxidant activity of fresh-cut wax apple fruit coated with fresh *A. vera* gel held at 4 ± 1 °C for 6 days

day of storage ($p < 0.05$) (Fig. 3a). Similar effects on TP for *A. vera* coated-grapes during cold storage were observed earlier (Serrano et al. 2006). The change of TP content in this present study was related to the highest BI and $\Delta E^*$ and the lowest in WI as shown in Figs. 1 and 2 and also associated with the highest visual browning incidence as shown in Table 1. However, the increase in antioxidant activity of the fresh-cut fruits during storage might not be related to the browning incidence as there was no significant difference in antioxidant activity between 75 % *A. vera* coated fresh-cut fruit and the uncoated fresh-cut fruit (Fig. 3b).

## Polyphenol oxidase and peroxidase activities

Figure 4 shows PPO (A) and POD activity (B) of the fresh-cut fruits treated with 75 % *A. vera* gel and the uncoated sample. Although, on 6th day of storage, PPO activity of 75 % *A. vera* coated fresh-cut fruit was not significantly different to that in the fresh-cut fruits on day 0, the significant increasing activity was found in the control ($p < 0.05$) (Fig. 4a). The increase in PPO activity of the uncoated fresh-cut fruit during storage was concomitant with the increase in browning incidence and the loss of WI of the fresh-cut fruit during storage. Baldwin et al. (1995) addressed that edible coating provide a semi-permeable barrier to gases exchange resulting in the reduction of metabolism, oxidative reaction including browning inhibition. The change of PPO activity was also related to the marked increase in TP content of the uncoated fresh-cut fruits as shown in Fig. 3a. In apple fruit slices, the application of *A. vera* gel coating showed significant reduction in PPO activity (Chauhan et al. 2011). Moreover, we found that 75 % *A. vera* coating induced POD activity in the fresh-cut fruit which was significantly higher than that of the uncoated fresh-cut fruit on day 6 ($p < 0.05$) (Fig. 4b).

POD activity detected in this study is vague on browning incidence of the fresh-cut wax apple fruits during storage. In previous work, we showed that pineapple fruit core extract prevented browning of the fresh-cut wax apples but POD activity of the treated fruit was higher than that of the uncoated fresh-cut fruit while PPO activity of the control was significantly higher than that of the treated fresh-cut fruits (Supapvanich et al. 2012). From these results, we suggest that the main factor relating browning incidence of fresh-cut wax apple fruits during storage is the activity of PPO on phenolic compounds in the fruit. The *A. vera* gel coating could retard PPO activity and the increase in TP content during storage.

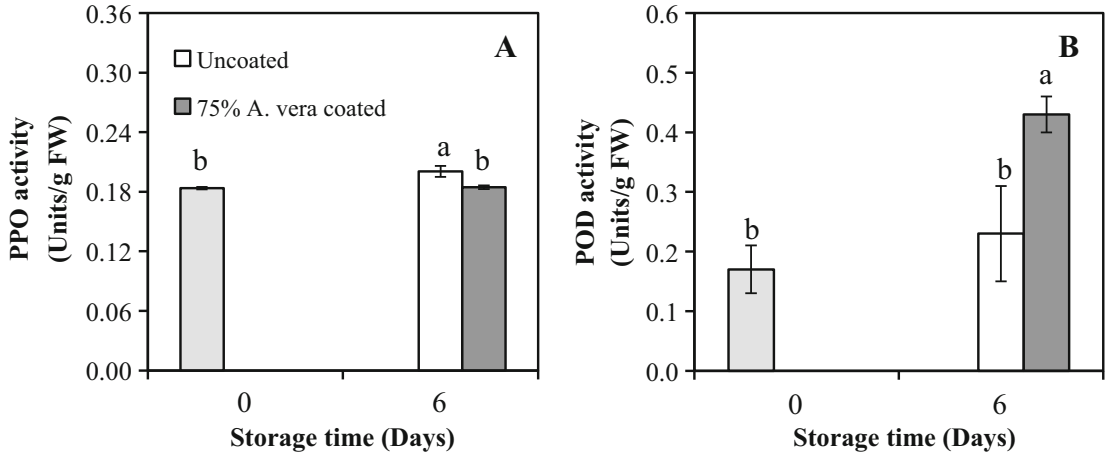


**Fig. 4** PPO (**a**) and POD (**b**) activities of fresh-cut wax apple fruit coated with fresh *A. vera* gel held at 4 ± 1 °C for 6 days

## Conclusion

The *A. vera* gel coating could be an alternative natural coating agent for alleviating browning incidence of fresh-cut fruits. The results show that the use of 75 % (v/v) *A. vera* gel coating maintained flesh-cut surface colour and retarded browning incidence of the fresh-cut wax apple fruits due to delay of an increase in TP content and PPO activity. However, POD activity was induced by *A. vera* gel coating and the change in antioxidant activity might be not related to browning incidence of the fresh-cut fruits during storage.

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