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PENERBITAN PEGAWAI

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carambola* L.) when treated with ascorbic
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Abstract: 'B 10' carambola of ripening stage (RS) 3 and 4 were minimally processed (MP) and then dipped in 0, 15 and 30 mg L⁻¹ ascorbic acid (AA). The 1-cm-thick slices were then dried, packed into cling-wrapped-foam tray and stored at 7 °C for 0, 3 and 5 days. Skin colour (*L**, *C** and *h°*), flesh firmness, soluble solids concentration, vitamin C content, titratable acidity, pH, degree of browning, polyphenoloxidase (PPO) activity and sensory attributes of MP carambola treated with AA were determined. AA treatment had significant effect in decreasing cut surface browning degree but no significant effect on all the selected quality characteristics of the MP carambola. In the sensory evaluation, flesh colour, sweetness, flavour and overall taste were significantly affected by AA treatment especially at 15 mg L⁻¹. The RS of fruit significantly affected skin colour (*C** and *h°*), pH and sensory attributes of colour and flavour of the MP carambola. As storage day (SD) progressed, skin colour (*C** and *h°*), flesh firmness and vitamin C content, cut surface browning, PPO activity and all the sensory attributes of MP carambola decreased significantly. Flesh firmness of the MP carambola was affected by the interaction between AA × SD. Sensory attributes of MP carambola were affected significantly by AA × RS. All the sensory attributes of MP carambola positively correlated to each other but negatively correlated with browning degree. PPO activity positively correlated with browning degree.

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Keywords: browning; PPO activity; sensory attributes; colour; firmness

INTRODUCTION

Malaysia exported USD8.3 million worth of carambola to EU, East Asia, Middle East and ASEAN. When cut transversely the fruit is star-shaped and could be served as an interesting addition to salads. The increase in living standards and the demands from employment and activities place a premium on time, including food shopping and preparation time. These have increased the demand of convenient and fresh-like products, which has led to a relatively new area of food service in Malaysia, i.e. minimally processed (MP) foods.

MP carambola is produced by cleaning, washing, trimming, slicing and packaging the fruit. It is a new form of product intended to meet the needs of consumers for convenience and fresh-like quality. However, such MP fruits have a short post-cutting life because the mechanical injury during processing increases the change in colour (browning), tissue softening, as well as loss of nutrient and flavour.¹ Browning has been attributed to the action of polyphenoloxidase (PPO) on the natural phenolic substances or compounds of the fruits.² The browning is due to the destruction of fruit cellular compartmentation which allows the phenolic

substrates to be accessible to PPO, which catalyse phenolic oxidation. The appearance of MP fruit is therefore defective, and the organoleptical properties and nutritional quality are reduced.

Inhibitors of enzymatic browning such as ascorbic acid (AA) and its isomer, erythroic acid, cinnamic acids, sodium chloride, L-cysteine, ethanol and sulfites, have been used in food processing. However, non-toxicity, wholesomeness and the effects on taste, flavour and texture restrict the use of browning inhibitors. The use of sulfites such as sulfur dioxide and sulfurous acid is limited because of their toxicity. AA is a reducing agent that reduces the substrates back to polyhydroxy compounds. To the best of our knowledge, no work has been carried out using AA to inhibit enzymatic browning in MP carambola. The objective of this study was therefore to assess the effects of AA and ripening stages on the quality characteristics of MP carambola.

MATERIALS AND METHODS

Plant materials

'B10' carambola at ripening stage (RS) 3 and 4 were obtained from Fruitland Import and Export, Serdang

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Lama, Selangor, Malaysia. Fruits weighing 160–190 g, which were well-formed, uniform in size, free from blemishes and discolouration (spotless and no edge browning) were selected. The fruits were packed in boxes and pre-cooled at 10 °C in a cold room for 24 h. Then the fruits were washed manually with 10 °C distilled water to remove dirt on the fruit, the edges were trimmed off using a sharp kitchen knife, sliced transversely into slices 1 cm thick and were randomly selected for different treatments. The slices were dipped in 0, 15 and 30 mg L⁻¹ of 4 °C AA solution for 2 min. Then they were dried using kitchen towel for 2 min, placed on TP2 polystyrene foam trays (18 cm × 10 cm), cling-wrapped with polyethylene cling food wrap film (thickness 0.08 mm) and stored at 7 °C for 0, 3 and 5 days. Each tray consisted of five slices of MP carambola.

Determination of skin colour

Skin colour was determined using a Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan) using the Illuminate C (CIE, 1976) and results were expressed as lightness (*L**), chroma (*C**) and hue (*h*°). The *L** value is ranging from 0 = black to 100 = white. The *h*° is an angle in a colour wheel of 360°, with 0°, 90°, 180° and 270° representing the hues red, yellow, green and blue, respectively, while *C** is the intensity or purity of the hue. Measurements were carried out at two opposite locations of every slice of the MP carambola.

Determination of flesh firmness

Flesh firmness was evaluated using the Bishop Penetrometer FT 327 (Alfonsine, Italy). The force required for an 11 mm probe to penetrate the cut surface in two opposite locations to a depth of 5 mm was recorded. The penetration force was expressed in newtons.

Determination of soluble solids concentration

One wing was cut from each slice of MP carambola, and a total of 15 slices for each storage day (SD) were macerated with a chopping knife. Ten grams of the macerated tissue was homogenised with 40 mL of distilled water by using a kitchen blender. The mixture was filtered with cotton wool. A drop of the filtrate was then placed on the prism glass of refractometer (Model N1, Atago Co. Ltd., Tokyo, Japan) to obtain the %SSC. The readings were corrected to a standard temperature of 20 °C by adding 0.28% to obtain %SSC at 27 °C.

Determination of titratable acidity and pH

The remainder of the juice from the SSC determination was used to measure titratable acidity (TA) by titrating with 0.1 mol L⁻¹ NaOH using 1% phenolphthalein as indicator. The results were calculated as a percentage oxalic acid:

$$\frac{\text{mL NaOH} \times 0.1 \text{ mol L}^{-1}}{\text{weight of sample titrated}} \times 0.045 \times 100.$$

The pH of the juice was measured using a glass electrode pH meter model Crison Micro pH 2000 (Crison Instruments, S.A., Barcelona, Spain). The pH meter was calibrated with buffer at pH 4.0 and 7.0 before being used.

Determination of vitamin C content

One wing was cut from each slice of MP carambola and total of 15 wings for each SD were macerated with a chopping knife. Ten grams of the macerated tissue was well homogenised with 3% cold metaphosphoric acid. The volume was made up to 100 mL and filtered with cotton wool. Then 5 mL of the aliquot was titrated with 2,6-dichlorophenol-indophenol solution to a pink colour. The vitamin C content was determined according to the Ranganna³ method.

Determination of cut surface browning degree

A subjective hedonic score for cut surface browning, based on a scale of 0–5 (0 = none, 1 = trace, 2 = slight, 3 = moderate, 4 = severe and 5 = extremely severe) was used to assess the cut surface browning degree of MP carambola.

Determination of PPO activity

PPO was extracted by homogenising 100 g of tissue in 300 mL cold 0.2 mol L⁻¹ sodium phosphate buffer, pH 6.8, containing 1.5% polyvinylpyrrolidone (molecular weight 44 000). The homogenate was centrifuged for 15 min at 16099 × *g* and 4 °C using a refrigerated centrifuge (Sorvall RC-5B, Dupont Instruments, Waltham, Massachusetts, US). The pellet was discarded and the supernatant (crude extract) that contained the enzyme was used to assay PPO activity.

The crude extract was assayed for PPO activity according to the modified procedure of Galeazzi *et al.*⁴ with catechol as substrate. PPO activity was expressed as the increase in absorbance at 410 nm per 10 s with a spectrophotometer (Shimadzu UV-1201, Kyoto, Japan). The initial linear portion of the activity curve was used to express the enzyme activity (U min⁻¹ mL⁻¹). One unit of PPO activity (U) was defined as the amount of the enzyme that increased the absorbance by 0.001 min⁻¹ under the conditions of the assay.

Sensory evaluation

Sensory evaluation was carried out by 10 untrained panelists with ages between 20 and 35 years. Panelists were required to evaluate the acceptability of flesh colour, sweetness, texture, flavour and overall taste of MP carambola at 0, 3 and 5 days. The sensory evaluation of MP carambola were scored on a structured hedonic scale of 9 = like extremely and 1 = dislike extremely.

Statistical analysis

Fifteen trays were prepared for each single dipping with five trays for each SD. The experiment was

replicated four times except for PPO activity and TA determination which were replicated three times. The experimental design was a randomised complete block design with a factorial arrangement of treatments (3 AA levels \times 2 RSs \times 3 SDs). Data were analysed using analysis of variance (SAS Institute, Cary, NC) and means were separated by LSD. Correlation analysis by using Pearson's correlation matrix was also performed.

RESULTS AND DISCUSSION

Skin colour

The AA treatments had no significant effect on the skin colour of MP carambola as evidenced by the non-significant *F*-test of the L^* , C^* and h° values (Table 1). RSs did not produce significant effects on L^* values of the skin colour. The C^* values of carambola skin in RS 4 was significantly more saturated compared to the RS 3 by about 10% (Table 1). In contrast to the other values of skin colour, the h° values of carambola skin in RS 3 was significantly higher than RS 4. As ripening progressed, h° values of RS 4 fruit decreased by 9.35% from stage 3. The increase in the value of C^* , accompanied by a decrease in the value of h° of the carambola indicated that the skin colour of the fruit at RS 4 was less green and more yellow as compared to RS 3.

The skin colour of the MP carambola was measured at 0, 3 and 5 days of storage at 7°C and the results are shown in Table 1. Higher C^* values indicated a less green and more yellow skin colour of the fruit

Table 1. Main and interaction effects of three levels of ascorbic acid (AA), two ripening stages (RS) and 3 storage days (SD) on skin colours (L^* , C^* and h°) of minimally processed carambola

Factor	Skin colour ^z		
	L^*	C^*	h°
Ascorbic acid, mg L ⁻¹ (AA)			
0	46.91	21.84	100.77
15	47.40	22.47	100.66
30	47.18	22.26	100.85
<i>F</i> -test significance	NS	NS	NS
Ripening stage (RS)			
3	46.70	21.10 ^{b,y}	105.70 ^a
4	47.63	23.28 ^a	95.82 ^b
<i>F</i> -test significance	NS	*	*
Storage day (SD)			
0	47.81	20.93 ^c	101.65 ^a
3	46.98	21.94 ^b	100.60 ^b
5	46.70	23.70 ^a	100.03 ^b
<i>F</i> -test significance	NS	*	*
Interaction			
AA \times RS	NS	NS	NS
AA \times SD	NS	NS	NS
RS \times SD	NS	NS	NS
AA \times RS \times SD	NS	NS	NS

^z L^* = lightness, C^* = chroma and h° = hue angle

^y Mean separation within columns and factors by LSD at $P \leq 0.05$.

NS,* Non-significant or significant at $P \leq 0.05$, respectively.

which were found to increase significantly with SD. The h° values decreased significantly from SD 0 to 3 (Table 1). However, the h° values of the carambola at SD 3 was not significantly different from SD 5. The significant increase of C^* values and decrease of h° values as SD progressed resulted in more yellow skin colour of the MP carambola.

From the results of this study, it is obvious that MP carambola showed significant skin colour changes from green to yellow during the 5 days of storage at 7°C. This means that MP carambola lost its visual green colour of the skin and ripened. Wounding of plant tissues has long been known to induce ethylene production.⁵ Shredded lettuce has been reported to lose its visual green colour as indicated by a more positive a^* value occurring during 10°C of storage for 10 days.⁶ Possibly the storage temperature is not low enough to retard ethylene production. As these products are placed in sealed packages, ethylene can accumulate and cause undesirable changes in quality.⁷ The process of hand-tearing spinach into small pieces produced 0.4 mg L⁻¹ ethylene, which was sufficient to cause degradation of chlorophyll *a*. Ethylene hastened the loss of membrane integrity during senescence resulting in chlorophyll changes and loss of visual green colour. Thus, in MP carambola the production of wound-induced ethylene after trimming and slicing will increase chlorophyllase activity, which degrades chlorophyll.¹

Flesh firmness

There was no significant difference in flesh firmness of the MP carambola when treated with three different concentrations of AA (Table 2). Flesh firmness of RS 3 was significantly firmer by 14.11% compared to RS 4. As ripening progressed, flesh firmness decreased. Similar results were reported in B10 carambola where flesh firmness decreased as ripening progressed.^{8,9}

When flesh firmness of the MP carambola was measured at different SD of 0, 3 and 5, flesh firmness decreased significantly as SD progressed (Table 2). The control fruit had significantly higher force values than those stored for 3 and 5 days. Flesh firmness stored for 3 days was significantly higher by 6.69% than 5 days of storage. Rocha and Morais¹⁰ found that the firmness of MP apple decreased 50% after 7 days of storage at 4°C. The firmness of tomato slices decreased slightly during storage especially at the lower temperatures of 2–8°C.¹¹ Peeling and cutting causes moisture loss, reduces endogenous protection from the loss of turgor, increases loss of cell sap and transpiration.

There was a significant interaction effect of AA and SDs on flesh firmness of the MP carambola (Fig. 1). Flesh firmness of carambola dipped in distilled water (control) did not show significant differences over the 5 days of storage. Carambola dipped with 15 mg L⁻¹ of AA had a higher force value at SD 0 than SD 3 and 5. When the carambola was dipped in 30 mg L⁻¹ of

Table 2. Main and interaction effects of three levels of ascorbic acid (AA), two ripening stages (RS) and 3 storage days (SD) on firmness, soluble solids concentration (SSC), vitamin C, pH and titratable acidity (TA) of minimally processed carambola

Factor	Firmness (N)	SSC (%SSC)	Vitamin C (mg 100 g ⁻¹)	pH	TA (%oxalic acid 100 g ⁻¹)
Ascorbic acid, mg L ⁻¹ (AA)					
0	5.35	8.01	19.27	4.28	0.71
15	5.39	7.86	19.58	4.28	0.69
30	5.45	7.87	21.55	4.28	0.67
F-test significance	NS	NS	NS	NS	NS
Ripening stage (RS)					
3	5.81 ^{a,z}	7.79	19.49	4.23 ^b	0.68
4	4.99 ^b	8.04	20.77	4.34 ^a	0.70
F-test significance	*	NS	NS	*	NS
Storage day (SD)					
0	5.79 ^a	7.81	22.00 ^a	4.27	0.83 ^a
3	5.38 ^b	7.89	19.93 ^b	4.29	0.65 ^b
5	5.02 ^c	8.04	18.46 ^c	4.29	0.58 ^b
F-test significance	*	NS	*	NS	*
Interaction					
AA × RS	NS	NS	NS	NS	NS
AA × SD	*	NS	NS	NS	NS
RS × SD	NS	NS	NS	NS	NS
AA × RS × SD	NS	NS	NS	NS	NS

^z Mean separation within columns and factors by LSD at $P \leq 0.05$.

NS,* Non-significant or significant at $P \leq 0.05$, respectively.

AA the flesh firmness was significantly higher at SD 0 than 5. In general, the flesh firmness of MP carambola dipped with AA decreased as SDs increased. AA treatment of the MP carambola did not affect flesh firmness (Table 2) since AA functions as a reducing agent, an antioxidant and a metal sequestering agent but not as a structure-strengthening agent.¹²

SSC, pH and titratable acidity

The SSC is not significantly affected by AA treatment, RS and SD (Table 2). Similar result was obtained in MP apples.^{10,13} In MP cantaloupe, harvest maturity

affect SSC of produce.¹⁴ Wan and Lam¹⁵ reported no significant increase in the SSC of B10 carambola as the fruit matured. However, in the study on skin colour of B10 carambola, SSC increased significantly as fruit matured from stage 1 to 3, but the increase was not significant from RS 5 to 9.⁹

The AA treatment and SDs had no significant effect on the pH of carambola juice while the RS had a significant effect on the pH (Table 2). The juice pH increased significantly as ripening progressed from stage 3 to 4 making the fruit less acidic. This is in agreement with the findings of Vines and Grierson¹⁶ on carambola whereby the pH increased from 2.3 in the mature green fruits to 3.8 in the mature yellow fruits. Juice pH of the MP carambola depends on the concentration of free H⁺ ions.¹⁷ The increase in pH throughout maturation was due to metabolic processes in the fruit that resulted in the decrease of organic acids.¹⁸ The decrease of organic acids will decrease free H⁺ ions and consequently increases the pH.

The AA treatment and RS had no significant effect on TA of MP carambola (Table 2). The TA of MP carambola increased significantly as SDs progressed (Table 2). Similar finding was reported in MP mango slices where TA increased during storage at 13 and 23 °C.¹⁹ Organic acids that are prevalent during the harvest stage of carambola are primarily soluble oxalic and malic acids.²⁰ Oxalic acid is the major organic acid in carambola and the levels are higher in sour cultivars from 0.5–1.0 g 100 g⁻¹ fresh weight when compared with those of sweet type 0.07–0.17 g 100 g⁻¹ fresh weight.²¹

The high SSC during ripening was due to the hydrolysis of starch into sugar by phosphorylase

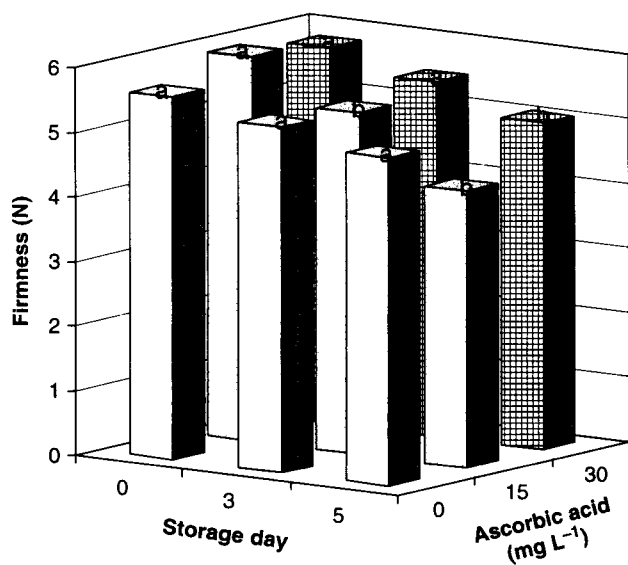


Figure 1. Effects of storage day × ascorbic acid on flesh firmness of minimally processed acarambola. Means separation pertaining to each concentration of ascorbic acid is by LSD at $P \leq 0.05$.

enzymes in the fruit or sugars was being synthesised in the leaves and transported into the fruit.²² The increase of SSC could also be due to the decrease in TA as organic acids were converted into sugars or being utilised during respiration.¹⁷ However, there was no significant correlation between SSC and TA of MP carambola (Table 3). Thus, the findings in the present study are in accordance with the fact that few organic acids were converted into sugar. In addition, the absence of starch or sugar accumulation from the hydrolysis of starch in carambola also affected SSC.

The carambola juice pH was significantly and negatively correlated with the SSC (Table 3). The increase in the pH was associated with a decrease in the SSC of carambola. When strawberries were fed with labelled fructose through the peduncle, labelled citric acid soon appeared in the fruit.²³ Since metabolic processes require organic acids, the available sugars in the fruit were converted to organic acids. The conversion of sugar to organic acids decreased the SSC. The organic acids were used in the metabolism and this reduced free H⁺ ions, resulting in an increase of the pH.

Vitamin C content

Differences in AA treatment and RS did not affect the vitamin C content of MP carambola (Table 2). The vitamin C content was significantly highest at SD 0 followed by days 3 and 5 indicating a decreasing trend as SD increased. The decrease in vitamin C content was 9.41% on the third day of storage compared to 7.38% at the end of the SD. This is similar to the findings on broccoli florets where the vitamin C content decreased during storage at 5 °C for 6 days.²⁴ This could be due to the autoxidation of vitamin C by ascorbate oxidase. During any post-harvest storage period of over-ripe and damaged fruits and vegetables, the significant loss of the vitamin C content was due to oxidative changes induced by enzymes especially ascorbate oxidase.²⁵

Even though the MP carambola was dipped in AA solution at a temperature of 4 °C, the content of vitamin C did not increase significantly (Table 2). This could be due to the low temperature of AA solution used for dipping reduced the absorption of vitamin C by the fruit tissues. In addition, the dipping period

Table 3. Correlation coefficients (*r*) for soluble solids concentration (SSC), vitamin C content (Vit C), pH, degree of browning (DB) and polyphenoloxidase activity (PPO) of minimally processed carambola treated with ascorbic acid

	SSC	Vit C	pH	DB	PPO
SSC	–				
Vit C	–0.09	–			
pH	–0.65*	0.50*	–		
DB	0.16	–0.28*	0.02	–	
PPO	–0.08	–0.15	0.35*	0.63*	–

For correlation coefficients, *n* = 72 except PPO, *n* = 54.

* Significant at *P* ≤ 0.05.

might not be sufficient for vitamin C to penetrate into the fruit tissues thus affecting the vitamin C content. However, little is known about the mobility mechanism of vitamin C in fruit tissues.

Degree of cut surface browning

The browning of MP carambola began from fruit margin then progressed to the cut surface. The AA treatment and the SD affected the browning degree of the MP carambola significantly (Table 4). The RS and all the interaction effects did not affect the browning degree of MP carambola significantly. The cut surface browning degree of MP carambola dipped in 0 mg L⁻¹ AA was 9.46 and 6.76% significant higher than those dipped in 15 and 30 mg L⁻¹ of AA, respectively (Table 4). However, the cut surface browning degree of MP carambola treated with 15 mg L⁻¹ AA was not significantly different from the 30 mg L⁻¹ treated sample. This indicated that the AA treatment reduced the cut surface browning of MP carambola. The AA might have reduced *o*-quinones back to phenolic substrates and thus retarded browning oxidation.²⁶ The browning of apple cores were inhibited by using 0.5% AA.²⁷

The RSs did not affect the cut surface browning degree of MP carambola (Table 4). This finding is in agreement with several apple cultivars where maturity did not appear to influence the development of browning.²⁸ As SDs progressed, the cut surface browning degree increased significantly from SD 0 to 5 (Table 4). SD 0 did not show any browning but

Table 4. Main and interaction effects of three levels of ascorbic acid (AA), two stages of maturity indices (MI) and three storage days (SD) on the degree of browning and polyphenoloxidase (PPO) activity of minimally processed carambola treated with ascorbic acid

Factor	Degree of browning	PPO activity ^z (U min ⁻¹ mL ⁻¹)
Ascorbic acid, mg L ⁻¹ (AA)		
0	5.0 ^{a,y}	609.59
15	4.2 ^b	442.11
30	4.4 ^b	531.99
<i>F</i> -test significance	*	NS
Ripening stage (RS)		
3	4.3	483.39
4	4.7	572.41
<i>F</i> -test significance	NS	NS
Storage day (SD)		
0	0 ^c	389.77 ^c
3	3.1 ^b	528.65 ^b
5	5.0 ^a	665.28 ^a
<i>F</i> -test significance	*	*
Interaction		
AA × RS	NS	NS
AA × SD	NS	NS
RS × SD	NS	NS
AA × RS × SD	NS	NS

^z Data are means of three replicate samples.

^y Mean separation within columns and factors by LSD at *P* ≤ 0.05.

NS, * Non-significant or significant at *P* ≤ 0.05, respectively.

browning increased to 85 and 125% as SDs progressed to day 3 and 5, respectively. The browning of 'Golden Delicious' apple slices¹⁸ and 'Kent' mango slices¹⁹ also showed similar result where browning increased with the duration of storage. In this study, although MP carambola had been dipped with AA solution, the inhibition effect of cut surface browning was only temporary. This is because the AA is not a stable acid since it is prone to oxidation and the reaction is irreversible.²⁶ Thus, as SD progressed, AA was used up in the reduction process and the browning reaction was then reinitiated.²⁹

PPO activity

The PPO activity was not affected by AA treatment, RS and the interactions (Table 4). The increase or decrease of the PPO activity as ripening progressed depends on the type of fruit and stage of ripening. In sapota flesh, the PPO activity increased in the later stages of ripening.³⁰ This is due to the disappearance of PPO inhibitors in the sapota tissue during ripening.³¹ In mangoes, the PPO activity increased to a peak level during ripening; thereafter, the activity decreased.³²

The PPO activity of MP carambola increased significantly as SDs progressed (Table 4). The PPO activity at SD 5 had the highest activity compared to the other SDs of evaluation. The activity at SD 5 was significantly higher than SD 0 by 41.41% and SD 3 by 20.54%, respectively. The increase of the PPO activity could be due to the insufficient concentration of the ascorbic acid, which at low concentration might act as a pro-oxidant.³³ When using low concentration of ascorbic acid as an anti-browning agent, the ascorbic acid would only be stable at low pH.¹² This is due to the fact that the oxidation of ascorbic acid is pH dependent, where oxidation is rapid at neutral and higher pH, and slow at acidic pH.³⁴ This report is in line with this study where the acidity was not low enough to inhibit the PPO activity as SDs progressed. In addition, the PPO activity of MP carambola was also positively correlated with pH (Table 3), confirming that the PPO activity increased with the increase of pH.

The PPO activity of MP carambola was positively correlated with degree of browning (Table 3), reflecting that the activity of PPO increased as the degree of browning increased. This finding is similar to the result of a study on apple^{35,36} and peach³⁷ where a strong positive correlation was obtained between the PPO activity and the degree of browning.

Sensory attributes

The treatment of 15 mg L⁻¹ AA affect sensory attributes of MP carambola as shown in Table 5. Panelists prefer the colour of RS 4 fruit to RS 3 fruit, but not its flavour. As SD progressed, the rating for all the sensory attributes of MP carambola decreased significantly. Given that the score 5 is the limit of acceptance from the consumer point of view, the MP carambola should not be stored for more than 5 days.

Table 5. Main and interaction effects of three levels of ascorbic acid (AA), two ripening stages (RS) and 3 storage days (SD) on sensory attributes of minimally processed carambola treated with ascorbic acid

Factor	Colour	Sweet-ness	Texture	Flavour	Overall taste
Ascorbic acid, mg L ⁻¹ (AA)					
0	5.2 ^{b,z}	4.8 ^b	5.6	4.8 ^b	5.2 ^b
15	6.0 ^a	5.6 ^a	6.0	5.6 ^a	6.2 ^a
30	5.5 ^b	5.1 ^{ab}	5.8	5.1 ^b	5.8 ^{ab}
F-test significance	*	*	NS	*	*
Ripening stage (RS)					
3	5.0 ^b	5.2	5.9	5.4 ^a	5.8
4	6.3 ^a	5.0	5.6	5.0 ^b	5.6
F-test significance	*	NS	NS	*	NS
Storage day (SD)					
0	7.1 ^a	6.9 ^a	7.2 ^a	7.1 ^a	7.8 ^a
3	5.6 ^b	4.5 ^b	5.6 ^b	4.4 ^b	4.8 ^b
5	4.5 ^c	4.6 ^b	4.8 ^c	4.5 ^b	5.0 ^b
F-test significance	*	*	*	*	*
Interaction					
AA × RS	*	*	*	*	*
AA × SD	NS	NS	NS	NS	NS
RS × SD	NS	NS	*	NS	NS
AA × RS × SD	NS	NS	NS	NS	NS

^z Mean separation within columns and factors by LSD at $P \leq 0.05$. NS, *Non-significant or significant at $P \leq 0.05$, respectively.

In apple, the shelf life of cut apple was limited to 3 days due to severe surface browning.¹⁰

There was a significant interaction between AA × RS for all the sensory attributes of MP carambola treated with AA (Table 5). Data from sensory evaluation was well correlated with the objective evaluation of firmness and PPO activity and degree of browning (Table 6), showing the importance of browning on acceptance of MP carambola.

CONCLUSION

The AA used as dipping solution for MP carambola did not affect the physical and chemical quality characteristics, but improved the sensory attributes. During the sensory evaluation, it was obvious that the sensory panelists preferred MP carambola that had been dipped with AA especially at 15 mg L⁻¹. The significant effect of AA in preventing browning showed that the visual quality of MP carambola could be improved by dipping it in AA solution. The MP carambola dipped in 30 mg L⁻¹ of AA produced better visual quality than 15 mg L⁻¹ of AA. However, the AA did not affect the PPO activity. This is because PPO is a relatively difficult enzyme to extract and purify.^{30,32,33} This enzyme also acts on a great number of substrates and catalyses more than one reaction. In individual species, PPO can occur in multiple forms. Furthermore, the physiological role of this enzyme is not well understood and the enzyme has a complex role in food processing. The characteristics of PPO also vary with the type of fruits. There are

Table 6. Correlation coefficients (*r*) for soluble solids concentration (SSC), flesh firmness (Firm), sensory attributes [flesh colour (Col), sweetness (Swt), flesh texture (Tex), flavour (Fla) and overall taste (Ovt)], browning degree (DB) and PPO activity (PPO) of minimally processed carambola treated with ascorbic acid

	Firm	Col	Swt	Tex	Fla	Ovt	DB	PPO
Firm	–							
Col	0.15	–						
Swt	0.09	0.28*	–					
Tex	0.29*	0.34*	0.42*	–				
Fla	0.38*	0.35*	0.68*	0.70*	–			
Ovt	0.37*	0.43*	0.64*	0.75*	0.93*	–		
DB	–0.46*	–0.59*	–0.55*	–0.55*	–0.69*	–0.72*	–	
PPO	–0.22	–0.33*	0.20	–0.31*	–0.43*	–0.40*	0.61*	–

For correlation coefficients of SSC, Firm, Col, Swt, Tex, Fla, Ovt and DB, $n = 72$, while PPO, $n = 54$.

* Significant at $P \leq 0.05$.

differences between PPO from different cultivars and also differences in PPO isolated at different stages of maturity of fruits. Thus, the role of AA in inactivating PPO activity of carambola is somewhat complex and unclear. However, the browning reaction is cultivar dependent. Therefore, to control browning, selection of cultivars with a low content of PPO substrates and activity should be a priority. Further work is needed to determine the relative importance of the factors in controlling carambola browning and to fully understand the browning behaviour of the MP carambola.

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