International Food Research Journal 17: 63-69 (2010)

Extending 'Kampuchea' guava shelf-life at 27°C using 1-methylcyclopropene

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Abstract: 'Kampuchea' guavas were treated with 300, 600 and 900 nL L^{-1} 1-methylcyclopropene (1-MCP) for 0, 3 and 6 h, and stored at 27°C with 70% relative humidity. The C* values, soluble solids concentration, titratable acidity and pH of these fruits were not affected by both the 1-MCP concentrations and exposure duration while h° values and flesh firmness were affected by these treatments. The L* values, vitamin C content and weight loss were affected by the concentrations of 1-MCP, but not by the exposure duration. Less weight loss and disease incidence in fruit treated with 600 and 900 nL L^{-1} 1-MCP. Fruit exposed to 6 h 1-MCP showed lowest disease incidence compared to other exposure duration in 5 days of storage. Treating Kampuchea guava fruit with 600 nL L^{-1} 1-MCP and exposure duration of 6 h was able to retain fruit colour, flesh firmness and delayed disease development for 5 days.

Keywords: postharvest, storage, disease incidence, firmness, weight loss

Introduction

Guava (*Psidium guajava* L.) is a climacteric fruit (Mercado-Silva *et al.*, 1998; Bassetto *et al.*, 2005). It is highly perishable as it ripens rapidly. Its shelf-life ranges from 2 to 3 days at the room temperature (Bassetto *et al.*, 2005). In Malaysia, retailing of guava fruit is usually carried out without refrigeration. Marketable life is significantly limited by the abrupt softening during post-harvest handling. Thus, prolonging the shelf-life of guavas at tropical temperature of 27°C is highly desirable so as to improve its commercialisation because delivering fruits with consistent eating quality is currently a major issue and being the focus of considerable research (Golding *et al.*, 2005).

Recently, 1-methylcyclopropene (1-MCP) has been added to the list of options for extending the shelf-life and quality of plant products (Vicente *et al.*, 2005). 1-MCP is a synthetic cyclic olefin capable of blocking ethylene action (Sisler and Serek, 1997; Blankenship and Dole, 2003; Kubo *et al.*, 2003; Trinchero *et al.*, 2004; Bassetto *et al.*, 2005; Oritz *et al.*, 2005). The compound is used at low rates, and it has a non-toxic mode of action (Blankenship and Dole, 2003). The effectiveness of 1-MCP in extending the shelf-life of fruits varies with species and variety, ripening stages, and exposure temperature, concentration and duration. Bassetto *et al.* (2005) found that by exposing 'Pedro Sato' guava, a Brazilian guava cultivar, to 1-MCP at 300 nL L^{-1} for 6 or 12 h and at 900 nL L^{-1} for 3 h, prolonged the storage period by 24 h.

To our knowledge, no study has been carried out using 'Kampuchea' guavas, a South-East Asia guava cultivar. Therefore, the objective of this study is to determine the combinations of 1-MCP and exposure duration efficacy for prolonging the shelf-life of Kampuchea guavas at 27°C.

Materials and Methods

Plant materials

Kampuchea guavas were bought from the Puchong Wholesale Market, Selangor, Malaysia. After harvesting in the morning, the fruits normally reached wholesale market within 6 h at the evening

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(Fong, Per. Comm.) Once purchased, the fruits were immediately brought to laboratory and kept under 27°C until following 0700 morning to carry out the experiment. Guavas of the uniform colour, shape, size (350-400 g), disease and defect free were selected for the experiment.

1-MCP application and storage

Guava fruits were treated with Ansip-F® (Lytone Enterprise, Inc. Taiwan R.O.C.) tablets, containing 0.009% 1-MCP active ingredient (equivalent to 900 µL L^{-1} for 100 L). The nominal 1-MCP concentrations used were 300, 600 and 900 nL L^{-1}, respectively. The application of 1-MCP was performed by placing the fruits in a 15 L box with a 0.035 mm thick polyethylene (PE) bag and exposing them to 1-MCP gas for 0, 3 and 6 h, respectively at 27˚C with the relative humidity (RH) of 70%. Distilled water (40°C) with a volume of 17.6 mL was added into a beaker containing 1.10 g of crushed Ansip-F® tablets. The beaker was swirled for a few seconds before placing it into a 55 L container. It was then covered immediately, sealed with Vaseline and tied up in a 0.035 mm thick PE bag to avoid gas leakage. The container was left for 3 h before withdrawing the 1-MCP. After the various treatment durations, the 15 L boxes were opened and fruits were kept under the same room condition. Each 15 L box consisted of 15 fruits and daily analyses were carried out using 2 fruits, starting from day 0 until 5.

Quality characteristic assessments

Colour determination

The skin colour was determined using a Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan), using Illuminate C (CIE, 1976) and results were expressed as lightness (L*), chroma (C*) and hue (h^o). The L* value ranges from 0 = black to 100 = white; whereas h^o is the 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 the stem-end, mid-region and tip-end of a face of guava fruit and considering the mean value of the three measurements.

Firmness determination

The flesh firmness was evaluated using the Bishop Penetrometer FT 327 (Alfonsine, Italy). The forces required for an 11-mm flat surface probe to penetrate the 1-cm cut surface in two opposite locations of equatorial region to a depth of 5 mm were recorded. The penetration force was expressed in kg cm^{-2}.

Soluble solids concentration (SSC) determination

Ten gram of fruit peel and pulp was macerated and the tissue was homogenised with 40 mL of distilled water 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.

Titratable acidity (TA) and pH determination

The remaining juice from the SSC determination was used to measure the TA by titrating with 0.1 mol L^{-1} NaOH using 1% phenolphtalein as indicator. The results were calculated as a percentage citric acid [(mL NaOH x 0.1 mol L^{-1}/weight of sample titrated) x 0.064 x 100] using Ranganna (1977) method.

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 metre was calibrated with buffer at pH 4.0 and 7.0 before used.

Vitamin C content determination

Ten gram of guava flesh was well homogenised with 3% cold metaphosphoric acid using a kitchen blender. 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 Ranganna (1977) method.

Weight loss determination

The weight loss during storage was determined by the weight differences at days 0, 1, 2, 3, 4 and 5, which were then compared with day 0, and expressed in percentage (fresh weight basis). Fruit was weighed using a weighing scale.

Disease incidence determination

Disease appeared on the surface of the fruits was assessed from day 0 until 5. The severity of the disease was assessed according to the percentage of disease area affected per fruit. The percentage score was then related to a 5-point scale, where 0 = 0% area affected, 1 = 1-5% area affected, 2 = 6-15% area affected (mild), 3 = 16-30% area affected (moderate) and 4 = 31-100% area affected (severe).

Statistical analysis

The experimental design was a randomised complete block design with a factorial arrangement of treatments (3 concentrations x 3 exposure duration x 5 storage days) and 3 replications. Data was analysed using the analysis of variance (ANOVA). When ANOVA gives the F values showing significance ($p \leq 0.05$), the differences within each factor were determined by the least significant difference using the Statistical Analysis System for Windows v6.12. Data for the disease incidence was transformed into $\log_{10}$ prior to analysis.

Results and Discussions

The L* and h° values of Kampuchea guava fruit were significantly affected by 1-MCP concentration (Table 1). Fruits treated with 900 nL L^{-1} 1-MCP had lower L* values as compared to the fruits treated with 300 nL L^{-1} 1-MCP. A contrary finding was found in h° values where fruit treated with 900 nL L^{-1} 1-MCP had higher h° values as compared to the fruit treated with 300 nL L^{-1} 1-MCP. This indicated 1-MCP could retain the skin colour of guava by retaining lightness and greenish-yellow colour. The L* and C* values of guava skin were not affected by exposure duration but the h° values was significantly increased by 6 h 1-MCP exposure as compared to 0 h (Table 1). The h° values is the colour seen by eyes and it is an important criteria in determining fruit quality. The results showed that by exposing Kampuchea guava to 6 h 1-MCP could retain its greenish-yellow colour. As storage days progressed, the skin L* values of guava fruit decreased significantly while C* and h° values retained (Table 1). This finding indicated that the lightness of skin decreased with no changes in colour intensity as storage days progressed. There were no significant interactions between concentration x exposure duration, concentration x storage day, exposure duration x storage day, and concentration x storage day x exposure duration (Table 1).

The flesh firmness of Kampuchea guava exposed to 900 nL L^{-1} 1-MCP was significantly firmer than fruit exposed to 300 nL L^{-1} 1-MCP (Table 2). Similar result was reported in 'Hass' avocados (Woolf *et al*., 2005) and Pedro Sato guava (Bassetto *et al*., 2005) where fruits treated with higher concentration of 1-MCP were firmer than those treated with lower concentration of 1-MCP. The flesh firmness increased significantly with increased of 1-MCP exposure duration (Table 2). The flesh firmness decreased significantly over 5 days of storage (Table 2). This finding was in agreement with Bassetto *et al*. (2005) where flesh firmness decreased dramatically by about 88% within 9 days of storage at 25°C regardless of 1-MCP concentration and exposure duration except those treated with 900 nL L^{-1} for 6 or 12 h. Fruit of Rendaiji persimmon (Oritz *et al*., 2005) and 'La France' pear (Kubo *et al.,* 2003) treated with 1-MCP showed normal softening as control fruit. This indicated that treatment of 1-MCP did not slow down the softening process in these fruits. The response of fruits towards 1-MCP differ among fruit types. According to Bashir and Abu-Goukh (2003), unripe guava fruits are usually hard in texture, starchy and acidic in taste and sometimes astringent. After ripening, they become soft, sweet, non acidic, less astringent and highly flavoured. A large number of physiological, biochemical, and structural changes occur during the ripening of fruit which include the degradation of starch or other storage polysaccharides, the production of sugars, the synthesis of pigments and volatile compounds, and the partial solubilization of cell wall (Dhawan *et al*., 2003).

Kampuchea guava fruits treated with different level of concentrations and exposure duration of 1-MCP did not affect the SSC of the fruits (Table 2). This result is in agreement with 1-MCP-treated Pedro Sato guava (Bassetto *et al.*, 2005), oranges, apricots, plums, custard apple, mango and apples (Oritz *et al.*, 2005) and 'Bartlett' pears (Bashir and Abu-Goukh, 2003) where 1-MCP did not affect fruits SSC. The SSC of Kampuchea guava fruits increased as the treatment progressed from day 0 to 2, and then followed by a decrease at day 5 (Table 2). During the storage at 25°C, the SSC of the mature green 'Media China' guava fruits increased, followed by a decrease in the overripe fruit (Golding *et al.*, 2005). The increase in SSC could be attributed to the conversion of starch to sugar, and a later decrease due to the use of this sugar by respiration.

Similar to SSC, the titratable acidity (TA) of Kampuchea guava fruits was also not significantly affected by 1-MCP treatment and exposure duration (Table 2). As storage days progressed from day 0 to 1, the TA of the guava fruits increased significantly, followed by a significant decrease on day 2, and then level off thereafter. The decrease of TA during storage is due to the utilization of these compounds as respiratory substrates, and as carbon skeletons (from their carboxyl groups, -COOH) for the synthesis of new compounds (e.g, flavour compounds) (Zomajski, 1997). This indicated metabolic process of guava fruit could not be stopped by 1-MCP treatment.

There was no difference in the pH of the Kampuchea guava fruits exposed to three levels

Table 1. Main and interaction effects of three concentrations (C) of 1-MCP, three exposure duration (T), and six storage days (D) on the skin colour (L*, C* and h°) of 'Kampuchea' guava

Factor	Skin Colour		
	L*	C*	h°
Concentrations (C), nL L^{-1}			
300	65.25 a[z]	38.87 a	110.95 b
600	63.99 ab	39.06 a	112.18 ab
900	62.82 b	39.25 a	113.14 a
Exposure duration (T), h			
0	64.24 a	38.90 a	111.35 b
3	63.76 a	39.00 a	111.92 ab
6	64.06 a	39.29 a	113.00 a
Storage days (D)			
0 (Before 1-MCP treatment)	65.74 a	38.72 a	112.20 a
1 (After 1-MCP treatment)	65.16 a	38.92 a	111.49 a
2	64.69 ab	39.00 a	112.14 a
3	62.70 cd	39.22 a	112.01 a
4	63.74 bc	39.34 a	111.87 a
5	62.10 d	39.17 a	112.83 a
Interaction			
C x T	NS	NS	NS
C x D	NS	NS	NS
T x D	NS	NS	NS
C x T x D	NS	NS	NS

L* = lightness, C* = chroma and h° = hue angle.
NS Non-significant at $p \leq 0.05$.
[z]Mean separation within columns and factors followed by the same letter are not significantly by LSD at $p \leq 0.05$.

of concentration and exposure duration of 1-MCP (Table 2). However, the pH showed an increase as the storage days progressed from day 2 to 3. The increase in the pH indicated that more ion hydrogen was being released from the fruits, due to the low metabolic processes at the later days of storage as compared to the earlier days. As a result of low metabolic processes guava fruits delayed the release of ion hydrogen starting from day 3 with significant increase of pH as shown in Table 2.

The content of vitamin C in the Kampuchea guava fruits treated with 300 nL L^{-1} was significantly higher than those treated with 900 nL L^{-1} of 1-MCP (Table 2). The exposure time of 1-MCP was found not to affect the content of vitamin C (Table 2). As storage days progressed from day 3 to 4, an increase in vitamin C content was observed. Singh and Pal (2008) reported 'Allahabad Safeda' guava treated with 1-MCP at concentrations of 300 or 600 nL L^{-1} for 12 and 24 h had higher vitamin C contents than control fruit. The contents decreased substantially during fruit ripening, but were relatively high in 1-MCP-treated fruit at the ripe stage. The response of Allahabad Safeda and Kampuchea guavas towards 1-MCP could probably due to variation in cultivar. There were interaction effects on the vitamin C content of Kampuchea guava fruit between the exposure duration x storage day (Table 2). The vitamin C content of 0 and 600 nL L^{-1} 1-MCP-treated fruit did not show significant differences over the 5 days of storage (Figure 1). However, fruits that were exposed to 3 h 1-MCP had higher vitamin C content after 3 days of storage at

Table 2. Main and interaction effects of three concentrations (C) of 1-MCP, three exposure duration (T) and six storage days (D) on flesh firmness, soluble solids concentration (SSC), titratable acidity (TA), pH, vitamin C content, weight loss and disease incidence of 'Kampuchea' guava

Factor	Firmness (kg cm^{-2})	SSC (%SSC)	TA (%citric acid)	pH	Vitamin C (mg $100\ g^{-1}$)	Weight loss (%)	Disease incidence (%)
Concentrations (C), nL L^{-1}							
300	37.67 b[z]	5.52 a	4.53 a	4.03 a	44.30 a	5.48 a	0.96 a
600	38.09 ab	5.46 a	4.80 a	4.05 a	42.49 ab	4.68 b	0.56 b
900	38.90 a	5.54 a	4.80 a	4.04 a	38.45 b	4.79 b	0.48 b
Exposure duration (T), h							
0	37.01 c	5.57 a	4.72 a	4.04 a	43.14 a	5.25 a	1.02 a
3	38.27 b	5.52 a	4.76 a	4.04 a	40.84 a	4.95 a	0.59 b
6	39.38 a	5.43 a	4.65 a	4.04 a	41.25 a	4.75 a	0.39 b
Storage days, (D)							
0 (Before 1-MCP treatment)	39.91 a	5.41 bc	4.69 b	4.00 b	39.52 b	0.00 f	0.00 d
1 (After 1-MCP treatment)	39.40 ab	5.26 c	5.59 a	4.00 b	41.31 b	2.68 e	0.07 d
2	38.70 bc	5.74 a	4.50 b	3.98 b	40.25 b	4.01 d	0.48 c
3	38.29 c	5.70 ab	4.29 b	4.06 a	41.18 b	6.32 c	0.85 b
4	36.78 d	5.52 abc	4.76 b	4.10 a	45.91 a	7.49 b	1.19 a
5	36.23 d	5.41 bc	4.41 b	4.09 a	42.29 ab	9.38 a	1.41 a
Interaction							
C x T	NS	NS	NS	NS	NS	NS	NS
C x D	NS	NS	NS	NS	NS	NS	NS
T x D	NS	NS	NS	NS	*	NS	*
C x T x D	NS	NS	NS	NS	NS	NS	NS

[NS],* Non-significant or significant respectively at $p \leq 0.05$.

[z]Mean separation within columns and factors followed by the same letter are not significantly by LSD at $p \leq 0.05$.

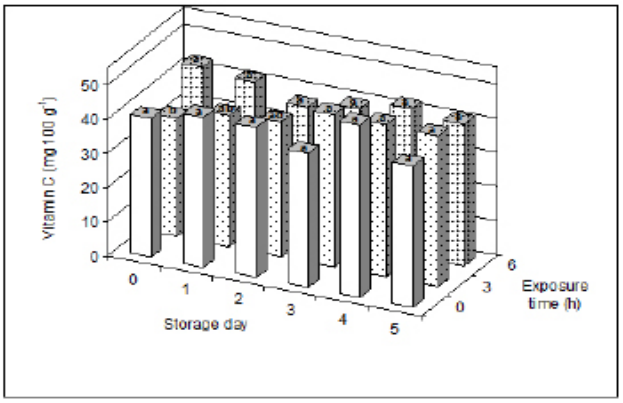

Figure 1. Effects of storage day x exposure duration on vitamin C content of 'Kampuchea' guava. Means separation pertaining to each exposure duration is by LSD at $p \leq 0.05$

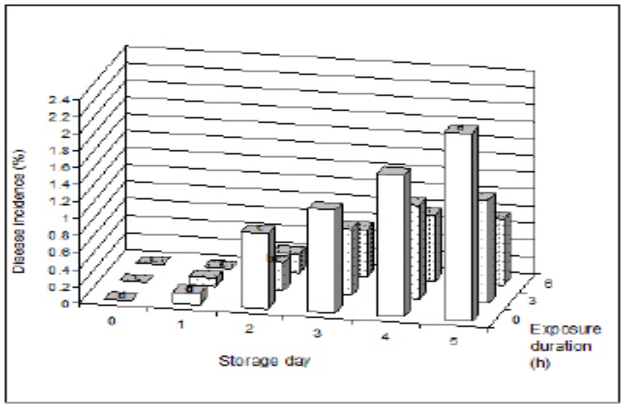

Figure 2. Effects of storage day x exposure duration on disease incidence of 'Kampuchea' guava. Means separation pertaining to each exposure duration is by LSD at $p \leq 0.05$

27°C/RH 70%.

The weight loss in Kampuchea guava fruit was delayed following the 600 and 900 nL L^{-1} 1-MCP treatment as compared to the fruit treated with 300 nL L^{-1} (Table 2). Nevertheless, the exposure time did not affect the fruit weight loss. A total of 9.38% weight loss was observed when the fruits were kept in 27°C/RH 70% room for 5 days. Exposing 1-MCP to Rendaiji persimmon fruits showed a lower loss in its weight as compared to the control fruit (Oritz *et al*., 2005). This could probably due to the reduced or delayed fruit respiration rate by 1-MCP treatment which thus, reduced the loss of water which is a measure of weight loss (Blankenship and Dole, 2003). The higher weight loss in Kampuchea guava fruits treated with 300 nL L^{-1} than other concentration could be due to higher respiration rate, causing more weight loss in the fruit treated with 300 nL L^{-1}.

The disease incidence in Kampuchea guava fruits occurred regardless of the 1-MCP concentrations used (Table 2). Similar finding was also reported in Pedro Sato guava where fruits were affected by *Botryodiplodia*, despite the 1-MCP concentrations used (Bassetto *et al*., 2005). However, fruit treated with at least 600 nL L^{-1} 1-MCP showed significant reduce disease incidence as compared to those exposed to 300 nL L^{-1} (Table 2). Similarly, fruit exposed to at least 3 h 1-MCP showed significant reduce disease incidence as compared to control fruit (Table 2). This could be further noticed clearly in Figure 2, with a significant interaction between the exposure duration x storage day. As for control fruit, the incidence of disease occurred dramatically from 0 to 0.89% within 2 days of storage and increased to 2.2% by day 5. Kampuchea guava fruit exposed to 6 h 1-MCP showed disease incidence of 0.78% by storage day 5, which was the lowest among three exposure times. The longer the fruits being exposed to 1-MCP, the lesser the incidence of disease occurred. A similar finding was also reported in Indian jujube treated with 600 nL L^{-1} 1-MCP for 12 h at 21-32°C, of which the stem-end rots incidence was reduce (Zhong and Xia, 2007). Post-harvest decay of the peach fruit was reduced by the treatment with 1-MCP and the progress of disease in fruit inoculated with *Penicillium expansum* was also reduced (Liu *et al*., 2005). 1-MCP delayed disease development in Kampuchea guava by maintaining fruit resistance due to retard ripening. Delayed ripening in 1-MCP treated fruit associated with reduced ethylene production might have increased its resistance to infection and lesion development resulting in lower decay incidence (Watkins, 2006).

Conclusions

Treating Kampuchea guava fruit with 600 nL L^{-1} 1-MCP and exposure duration of 6 h was able to retain fruit colour, flesh firmness and delayed disease development for 5 days. Others eating quality were not affected by 1-MCP treatment. 1-MCP could be used in combinations with other suitable post-harvest treatments to extend the shelf-life of Kampuchea guava fruits. Some researchers (Zhong and Xia, 2007) concluded that 1-MCP had additive beneficial effects on the ripening inhibition when in combination with other post-harvest treatments such as waxing, controlled atmosphere and PE bags, as compared to

those commodities treated with 1-MCP alone. The current knowledge is still inadequate to enable us to draw a clear conclusion on whether 1-MCP is more effective in inhibiting the ripening of fruit when it is used with and without any combination with other post-harvest treatments. This therefore leads to a greater potential in continuous research to be carried out on 1-MCP in extending the shelf-life of guava fruits.

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