

Physiological and physico-chemical changes in 1-methylcyclopropene-treated guava (*Psidium guajava* L. cv. Queso de Bola) fruit stored at ambient condition

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Abstract

The marketability of guava fruit is influenced by its quality attributes desired by consumers such as crispiness and crunchiness, green peel color, absence of defects, and better taste. ‘Queso de Bola’ guava fruits were treated with 600 nL L⁻¹ of 1-methylcyclopropane (1-MCP) for 12 hrs then stored at ambient condition (29±2°C, 60-80% RH). Reduced respiration rate with 1-MCP treatment was observed only starting on the 5th day of storage. Ethylene production, however, was not suppressed. The continuous decline in polygalacturonase activity with 1-MCP treatment coincided with firmness retention of the fruit until the 15th day. Higher firmness of 1-MCP-treated fruits than control fruits was further supported by higher sensory scores for crispiness and crunchiness particularly towards the later part of storage. 1-MCP treatment did not prevent peel browning as shown by similar polyphenol oxidase activity and pattern of change in total phenolic content. Total soluble solids, titratable acidity, and pH were not affected by 1-MCP treatment and did not markedly change during storage. Ascorbic acid content decreased in both treatments until day 6 followed by a slight increase with 1-MCP treatment exhibiting higher levels than the control. In general, 1-MCP treatment prolonged the marketability of guava by 3-4 days which was attributed to the maintenance of firmness, retention of green peel color, and reduced disease incidence.

1. Introduction

Guava (*Psidium guajava* L.) is commercially cultivated in tropical and subtropical countries. The fruit is characterized by thick, white or pink and crispy flesh with slight sweet to bland taste. In the Philippines, ‘Queso de Bola’ is one of the locally-grown guava varieties and is popularly known as “guapple”. It is considered as one of the emerging underutilized fruits with a huge potential as fresh and processed products both for local and export market due to its nutraceutical values (Gill, 2016; Mamede *et al.*, 2016).

Guava is highly perishable with a shelf-life of six days at ambient condition when harvested at the green mature stage (Azzolini *et al.*, 2005). For fresh consumption, ‘Queso de Bola’ guava is most desirable at the green and firm unripe stage with a crispy flesh. After harvest, the fruit ripens fast turning the crisp flesh into a soft one. Associated with ripening is the development of the distinct guava aroma (Gill, 2016) that is not desirable

to the Filipino consumers. Moreover, the fruit also becomes readily susceptible to decay and peel browning.

There are several techniques to delay the ripening of fruits like low temperature storage and atmosphere modification. However, guava is susceptible to chilling injury (Singh and Pal, 2008) and cold storage facilities are not readily available in developing countries. Low temperature storage in combination with modified atmosphere packaging (MAP) can keep the fruit for about 2-3 weeks (Mitra *et al.*, 2012). The problem with MAP, however, is the fast development of decay due to high relative humidity within the pack. Given the limitations of the aforementioned techniques, 1-methylcyclopropene (1-MCP) is a potential treatment to extend the marketability of fresh fruit even under ambient condition (Lurie, 2007). Watkins (2008) further reported that the full benefits of 1-MCP maybe perceptible only under the abusive condition of high temperature which exists in the tropics and where retail marketing of guava fruits is usually under these

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conditions. 1-MCP inhibits ethylene perception by competitively and irreversibly binding to ethylene receptors (Sisler and Serek, 2003) thus preventing ethylene-dependent responses such as softening, volatile production, and pigment changes (Huber, 2008). As an ethylene antagonist, 1-MCP has been extensively used in apples (Watkins and Nock, 2012) and pear (Liu *et al.*, 2013), two crops wherein retention of firmness is desired. Favorable responses have been reported also for climacteric fruits like banana (Zhu *et al.*, 2015), avocado and mango (Hofman *et al.*, 2001), durian (Amornputti *et al.*, 2014) and papaya (Manenoi *et al.*, 2007). In guava, 1-MCP delayed fruit softening, retarded peel color change, inhibited respiration and ethylene production resulting in prolonged storage life (Singh and Pal, 2008).

This study aimed to determine the physiological and physico-chemical changes of 'Queso de Bola' guava fruit subjected to optimized 1-MCP treatment then stored at ambient condition ($29\pm2^{\circ}\text{C}$, 60-80% RH).

2. Materials and methods

2.1 Source and preparation of guava fruit

Mature, defect-free, and medium-sized (400-800 g) guava fruits were harvested at approximately 120 days from anthesis in Lomboy Farm, an orchard in Guimba, Nueva Ecija which is located in the central part of Luzon, Philippines. Fruits were individually wrapped in polystyrene fruit cups, packed in plastic crates lined with newspaper, and transported by land to the Postharvest Horticulture Training and Research Center (PHTRC) at UP Los Baños. Upon arrival in the laboratory, fruits were again sorted as to freedom from mechanical damage which might have been incurred during field handling and transport. Prior to 1-MCP treatment, the fruits were dipped in $125 \mu\text{L L}^{-1}$ Amistar (a.i., azoxystrobin) for disease control and then air-dried.

2.2 1-Methylcyclopropene treatment

The preliminary study on optimization of 1-MCP concentration and exposure duration indicated that 1-MCP treatment at 600 nL L^{-1} for 12 hr was the most effective combination in maintaining the desirable quality attributes of guava at ambient condition (data not shown), hence this was the concentration used in the present study.

Fruits were placed in treatment chamber (24-L plastic container) with an amber bottle containing a pre-weighed amount of 1-MCP inside. Following the manufacturer's recommendation, 2 mL distilled water was added to the 1-MCP powder to release the gas and the chamber was immediately closed. The headspace gas inside the treatment chambers was homogenized at regular time interval during 1-MCP treatment.

Before opening the treatment chambers, gases were withdrawn for measurement of the changes in CO_2 and O_2 concentrations after the 12-hour 1-MCP exposure. Headspace gases were measured using a gas chromatograph (GC). The treatment chambers were then opened and guava fruits were packed in corrugated cartons and kept at ambient condition until the fruits reached visual quality rating (VQR) of 5 (fair, defects moderate; limit of marketability).

2.3 Respiration rate and ethylene production

Respiration rate and ethylene production were determined using the static system. Three fruits per treatment were placed individually in respiratory glass jars with one fruit in a jar and then sealed for one hour. Duplicate headspace gas samples of 1-mL each were withdrawn using an air-tight syringe at the time of enclosure (at 0 hr) and after 1 hr. CO_2 production was measured using a GC (Shimadzu GC-2014; Kyoto, Japan) equipped with thermal conductivity detector (TCD) and Porapak QS column set at 100°C and N_2 as the carrier gas. For ethylene production, gas sample was injected to gas chromatograph (Shimadzu GC-2014; Kyoto, Japan) with Porapak QS column set at 100°C and equipped with flame ionization detector (FID).

2.4 Fruit quality assessment

The changes in visual quality, peel color, peel browning, weight loss, disease incidence and severity were evaluated every other day during storage at ambient condition. For visual quality assessment, defects that occur after harvest such as shriveling, disease, and peel discoloration were considered and the following rating was used: 9-8 = excellent, field fresh, 7-6 = good, defects minor, 5-4 = fair, defects moderate, limit of marketability, 3 = poor, defects serious, 2 = limit of edibility, and 1 = non-edible under usual conditions. The change in peel color was determined by taking L^* , a^* , and b^* readings on opposite sides along the equatorial region of the fruit using Konica Minolta Color Reader (CR10). Peel browning and disease severity were rated based on fruit area discoloration or infection, respectively, using the following rating: 1 = none, 2 = 1-10%, 3 = 11-25%, 4 = 26-50%, and 5 = >50%.

2.5 Physico-chemical changes evaluation

Subjective firmness was measured every other day through finger feel method using the following index: 5 = very firm, 4 = firm, 3 = yielding, 2 = soft, and 1 = very soft. Objective firmness determination was also done every three days. Fruit firmness was measured on opposite sides along the equatorial region of the

unpeeled fruit using an Aikoh Digital Force Gauge penetrometer.

Weight loss of eight fruits per replicate was determined by obtaining the difference between the initial weight and weight at a specific time and then divided it by the initial weight. Weight loss was expressed in percent to reflect the cumulative change over time.

For total soluble solids (TSS) and titratable acidity (TA) determination, 50 g of the mid-portion of the fleshy pulp was homogenized with 50 mL distilled water for 2 min then filtered with small wad of cotton. TSS content was measured using Atago PAL-1 digital handheld refractometer while TA was measured by titrating a 2-mL aliquot by a standard base (0.1 N NaOH).

2.6 Ascorbic acid content

Ascorbic acid content was determined using the 2,6-dichlorophenol indophenol titration method as described by Ranganna (1986). Standardization was done by titrating 25 mg ascorbic acid solution dissolved in 100 mL 0.4% oxalic acid. Mixed sample of 50 g of sliced fruits and an equal amount of distilled water was homogenized for 2 mins and centrifuged at 8,000 rpm for 10 min at 10°C using Thermal Scientific Sorval ST40R Centrifuge. A 2 mL aliquot from the homogenized mixture was diluted to 10 mL with 0.4% oxalic acid solution then titrated using 0.04% aqueous indophenol solution. Vitamin C content was reported as mg ascorbic acid per 100 g of fruit pulp.

2.7 Polygalacturonase activity

Activity of polygalacturonase (PG) was determined viscosimetrically using the modified method of Chan *et al.* (1981). Ten grams of fruit was homogenized in 30 mL of 1M NaCl solution for 2 min and centrifuged at 8,000 rpm for 10 mins at 5°C using Thermal Scientific Sorval ST40R Centrifuge. After filtering through a small wad of cotton, 5 mL of the extract was added to 10 mL 1% pectin (dissolved in 0.1M acetate buffer at pH 5.0). After introducing into a 1-mL pipet, the solution was immediately released measuring the time of the flow from top to bottom mark and measurement was repeated after 30 min.

2.8 Polyphenol oxidase activity

Polyphenol oxidase (PPO) activity was assayed with cathecol as substrate according to the optimized procedure of Del Valle (1974). The assay was performed using 0.5 mL of 8 mM cathecol and 1 mL 0.2M acetate buffer (pH 5.2) solution added to the sample test tubes containing 0.1 mL of the enzyme extract. The increase in

absorbance at 420 nm at 25°C was recorded within 5 min. One unit of enzyme activity was defined as the amount of enzyme that caused a change of 0.001 in absorbance per min.

2.9 Total phenolic content

Determination of total phenolic content (TPC) was based on the modified method of Turnos (1993). Ten grams of pulp were sliced thinly, extracted by boiling with 50 mL 70% ethanol, homogenized for 2 mins, and centrifuged at 8,000 rpm for 10 mins at 10°C using Thermal Scientific Sorval ST40R Centrifuge. Distilled water (0.9 mL) and 0.25N Folin-Ciocalteau reagent (2.0 mL) was added to a 0.1 mL extract from the homogenate. The resulting solution was allowed to stand for 5 mins followed by the addition of 2 mL saturated sodium carbonate with slight agitation. After an hour, absorbance was measured at 760 nm using a Secomam UV spectrophotometer. TPC was standardized against gallic acid and expressed as $\mu\text{g g}^{-1}$ of gallic acid equivalent (GAE).

2.10 Sensory evaluation

Crispiness and crunchiness are some of the desirable textural attributes of guava. Guava slices of approximately 0.3 cm in thickness were subjected to sensory evaluation with 12 untrained panelists. Crispiness was rated using the following scale: 1 = leathery, 3 = neither, and 5 = crispy. Crunchiness was rated as: 1 = very soft, 2 = soft, 3 = neither, 4 = crunchy, and 5 = very crunchy. Overall acceptability was rated as follows: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither dislike or like, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely.

2.11 Experimental design

The experiment was laid out in Completely Randomized Design (CRD) with two treatments in triplicate. Each replicate consisted of eight fruits. Parametric data were subjected to ANOVA using SAS version 9.1. Differences between treatment means were compared using LSD at 5% level of significance. Non-parametric data were subjected to Kruskal-Wallis test.

3. Results and discussion

3.1 Headspace gas levels in treatment chambers

Headspace gas levels were measured to determine if the change in O₂ and CO₂ concentrations inside the treatment chamber will have an effect on the binding of 1-MCP and if there will be a residual effect of the modification of atmosphere on subsequent physico-chemical changes of the fruit. After 12 hrs of exposure to

1-MCP gas, the CO_2 increased to 1.16 - 1.30% while O_2 decreased to 12.21 - 13.93% in chambers with or without 1-MCP. Based on the results presented in the following discussions, these modifications in the gas levels did not affect the physical attributes of the fruit. Blankenship and Dole (2003) indicated that up to 10% CO_2 in the treatment chamber did not inhibit the binding effectiveness of 1-MCP in apples.

3.2 Respiration rate and ethylene production

Earlier reports indicated that 1-MCP treatment often results in suppressed or delayed respiratory climacteric and ethylene production (Blankenship and Dole, 2003; Watkins, 2008; Dang *et al.*, 2017). In this study, respiration rate of 1-MCP-treated fruit was higher than the control during the first 3 days (Figure 1) followed by a sharp decline on the 5th day. From this day onwards, suppressed respiration rate with 1-MCP treatment was observed except on the 15th day when there was a sharp increase which was attributed to the onset of slight decay. Until the 13th day at ambient condition, 1-MCP-treated guava fruits did not ripen and remained firm similar to the observed delayed ripening for 7 to 8 days of the climacteric type guava variety Ben Dov treated with 500 nL L^{-1} 1-MCP (Porat *et al.*, 2009). In the case of control fruits, the initially lower respiration rate started to increase and exhibited the typical climacteric pattern of respiration. An abrupt increase in respiration rate of the control fruits was observed after a week of storage which peaked at $28.71 \text{ mg CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$ on the 9th day which coincided with the sudden decline in firmness and peak activity of PG.

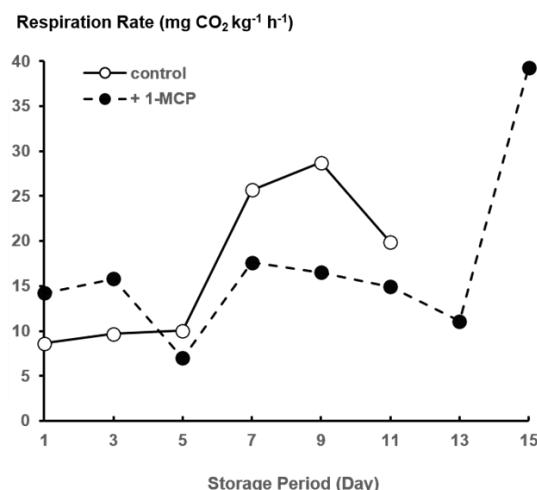


Figure 1. Respiration rate ($\text{mg CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$) of 'Queso de Bola' guava fruits treated with 600 nL L^{-1} 1-MCP for 12 hrs and then stored at ambient condition ($29 \pm 2^\circ\text{C}$, 60-80% RH). Each point represents the mean of three replicates

Ethylene production on the other hand, was not affected by 1-MCP treatment. A significant increase in ethylene production of the control fruit was observed

only on the 3rd day of storage reaching $0.25 \text{ nL g}^{-1} \text{ h}^{-1}$ while those of 1-MCP-treated fruits remained relatively stable until day 5 at $0.16 \text{ nL g}^{-1} \text{ h}^{-1}$ (Figure 2). On day 7, ethylene production of 1-MCP-treated fruits became higher than the control fruits which persisted until day 9 although differences were not significant. The increase in ethylene production of 1-MCP-treated fruits on the 13th day was due to the onset of decay.

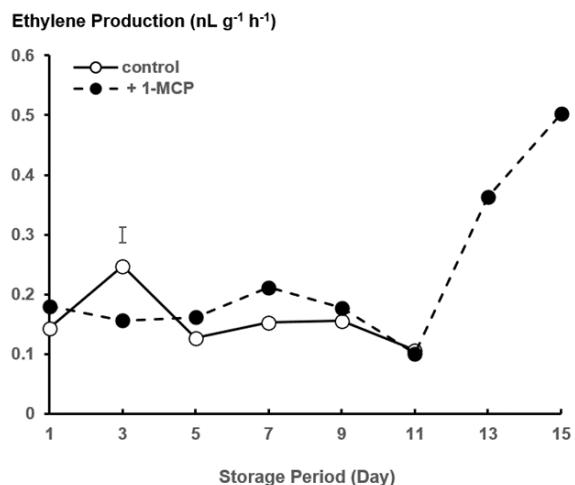


Figure 2. Ethylene production ($\text{nL g}^{-1} \text{ h}^{-1}$) of 'Queso de Bola' guava fruits treated with 600 nL L^{-1} 1-MCP for 12 hrs and then stored at ambient condition ($29 \pm 2^\circ\text{C}$, 60-80% RH). Vertical bar indicates LSD at 5% level of significance. Each point represents the mean of three replicates

3.3 Fruit firmness and polygalacturonase activity

In this study, the prominent effect of 1-MCP was the retardation of the loss of firmness similar to the reports of Bassetto, Jacomino, Pinheiro *et al.* (2005) in 'Pedro Sato' guava. During storage at ambient condition, 1-MCP-treated fruits were consistently firmer than control fruits (Figure 3A). On the 9th day, 1-MCP-treated fruits were still firm while the control fruits were already yielding to slight finger pressure (rating of about 3.5). It took 13 days at ambient condition for 1-MCP-treated fruits to reach the same rating. Thus, with 1-MCP treatment, loss of firmness was delayed by 4 days.

The obtained subjective firmness values can be supported by the objective measurement of firmness using a penetrometer. During the first 6 days, control fruits were slightly firmer than the 1-MCP-treated fruits although differences were not significant (Figure 3B). On the 9th day, however, firmness of control fruits sharply declined from 10.12 N to 6.48 N while that of the 1-MCP-treated fruits exhibited only a slight decline from 9.68 N to 9.19 N. From then on, the decrease in firmness was slow. 1-MCP-treated fruits maintained high firmness values (7.23N) for 15 days at ambient condition. It took only about 9 days for control fruits to reach almost the same firmness value.

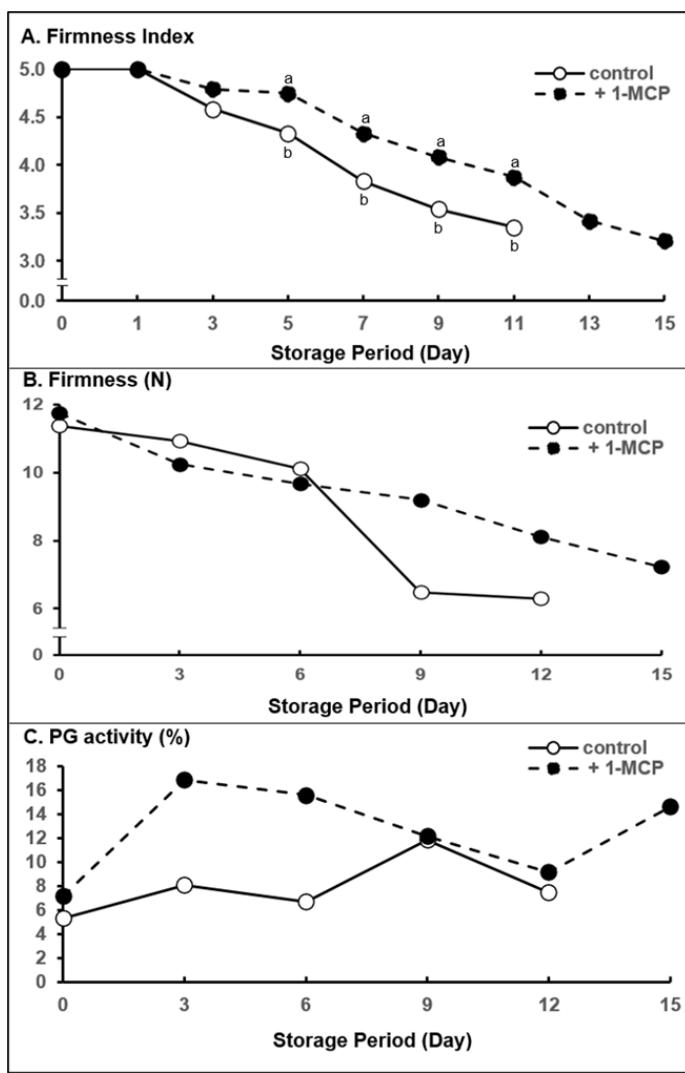


Figure 3. (A) Firmness index, (B) objective firmness (N), and (C) polygalacturonase activity (%) of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH). Firmness index was analyzed using Kruskal-Wallis Test. For objective firmness and PG activity, each point represents the mean of three fruit samples during destructive sampling

Softening is characterized by progressive depolymerization of pectin and hemicelluloses, polysaccharides in the cell wall associated with the

activity of hydrolytic enzymes such as pectin methyl esterase (PME) and polygalacturonase (PG) (Braga *et al.*, 2018). Jain *et al.* (2003) reported that among the enzymes involved in textural changes of guava fruits, PG plays a major role and that PME plays a little role throughout ripening forming only pectic substances for PG. Moreover, Abu-Goukh and Bashir (2003) reported that white and pink-fleshed guava fruits had increased PG activity during ripening accompanied by a loss in flesh firmness. In this study, however, firmness of 1-MCP-treated fruits was retained even with higher PG activity than control fruits. Compared with the control, however, PG activity of 1-MCP-treated fruits continuously decreased during storage which coincided with the retention of fruit firmness (Figure 3C). According to Ali *et al.* (2004), differential softening among tropical fruits cannot be attributed solely to either difference in the modification of cell wall pectin or to PG activity. The observed increase in PG activity on day 15 on the other hand, coincided with the stage when fruits already yielded to finger pressure.

3.4 Peel Color

Compared to the native Philippine guava, 'Queso de Bola' guava fruit does not change color from green to yellow but only from green to light yellow color. Thus, a non-destructive method was used in determining color change based on the International Commission on Illumination using a color meter that measures color space *L** (lightness), *a** (+ for red, - for green) and *b** (+ yellow, - blue) which gives less variable results and measures little differences (Barrett *et al.*, 2010).

The brightness of peel color of 1-MCP-treated and control fruits decreased during storage as indicated by the decreasing *L** values (Table 1). With regards to *a** values, peel of control fruits was greener than 1-MCP treated fruits. However, the intensity of green color slowly decreased during storage as indicated by

Table 1. Peel color of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH)

Treatment	Storage Period at Ambient (d)					
	0	3	6	9	12	15
<i>L*</i>						
1-MCP	67.83a	65.02a	64.28a	63.17a	63.78a	62.93
Control	67.02a	64.83a	64.47a	63.90a	63.13a	-
<i>a*</i>						
1-MCP	-3.68b	-1.35a	0.35a	-0.03a	1.55a	1.17
Control	-2.00a	-0.67a	-0.07a	0.20a	-0.27a	-
<i>b*</i>						
1-MCP	42.53a	41.78a	42.92a	43.38a	43.42a	43.22
Control	41.90a	40.65a	42.62a	41.15a	43.12a	-

Means within columns for each color parameter followed by the same letter are not significantly different at 5% level, LSD. Each data represents the mean of six readings taken from three replicates. No values were indicated on the 15th day since the experiment was already terminated

increasing a^* values. 1-MCP-treated fruits had higher b^* values than control fruits but differences were not significant. Regardless of treatment, guava fruits hardly exhibited loss of green color during storage.

3.5 Visual quality

Visual quality in this study refers to the external physical attributes of guava like the absence of defects (shriveling, disease) and discoloration like peel browning. Starting on the 3rd day, visual quality rating declined abruptly with control fruits reaching the limit of marketability (VQR 5) on day 9 (Figure 4). On the other hand, 1-MCP-treated fruits were still marketable until day 12. The decline in VQR was due to disease (Figure 5) and peel browning (Figure 6A). Fruit shriveling was not apparent in both treatments until the 15th day at ambient condition even with 14% weight loss.

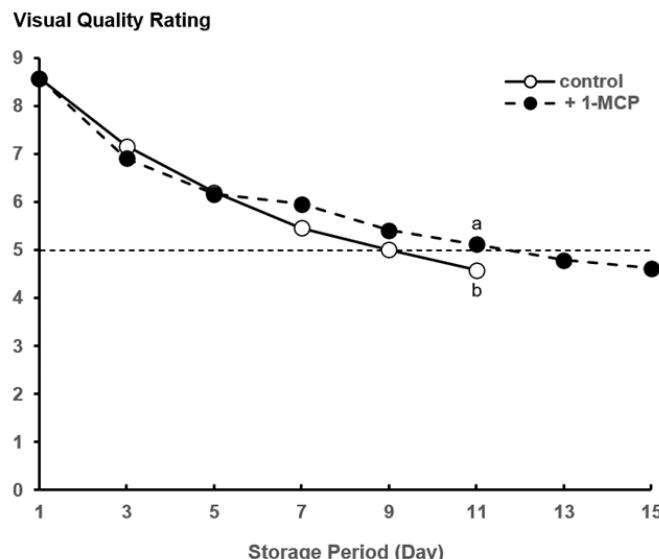


Figure 4. Visual quality rating of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH). Data was analyzed using Kruskal-Wallis test. Horizontal dashed line indicates the limit of marketability

Observed symptoms of disease in guava fruits were similar to the reports of Magarro (2018) and Bental (2010). There were soft, sunken and circular brown rot symptoms caused by *Geotrichum* sp., dry brown rot caused by *Calonectria* sp., and irregularly shaped brown soft rot caused by *Lasiodiplodia* sp. Manifestation of disease symptoms was delayed by about 5 days in 1-MCP-treated fruits with less than 5% infected fruits (Figure 5). There was also a slow rate of disease development in 1-MCP-treated fruits reaching only less than 10% on day 7 and 33.33% on the 13th day until the end of storage. On the other hand, control fruits manifested disease symptoms as early as the 3rd day of storage with 16.67% infected fruits. Disease incidence continued its fast increase on the 5th day with 29.17%

infected fruits. The occurrence of disease, however, in the control fruits did not progress beyond day 5. Although disease incidence reached 30%, the severity of infection was very slight with less than 10% of the fruit surface infected (severity rating of 1.5). The reduction in disease incidence and severity was also observed in 'Allahabad Safeda' guava fruits treated with 1-MCP which had four- to five-fold reduction in the incidence of decay caused by *Rhizopus* sp. (Singh and Pal, 2008).

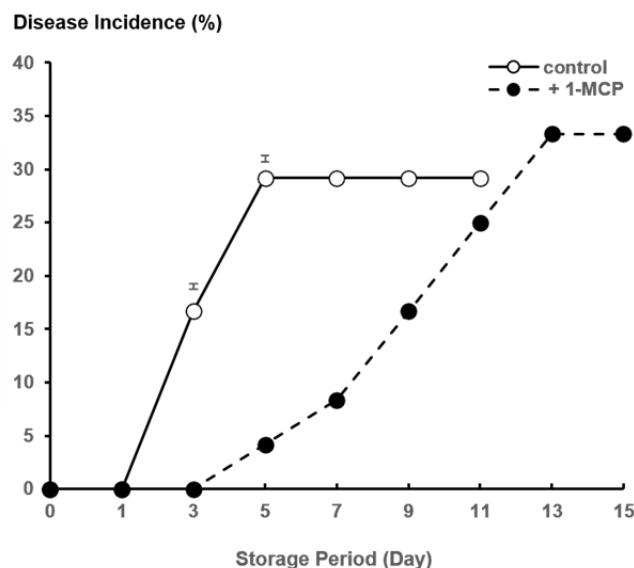


Figure 5. Disease incidence (%) of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH). Bars indicate LSD at 5% level of significance. Each point represents the mean of three replicates consisting of eight fruits per replicate

3.6 Peel browning, PPO activity, and total phenolic content

Peel browning of guava fruits occurs even before harvest. Singh (2010) stated that guava fruits have delicate skin that is vulnerable to bruising and mechanical injuries. In this study, the decline in the visual quality of fruits was mainly due to browning. Even with increasing severity of peel browning during storage, the pulp of the fruits regardless of treatment maintained its white color. Some of the guava fruits regardless of treatment had already slight peel browning before 1-MCP treatment (Figure 6A). 1-MCP treatment did not reduce the incidence of peel browning in guava fruits. The rate of browning with respect to duration of storage was almost the same for both 1-MCP-treated and control fruits. As early as the 5th day at ambient condition, fruits had moderate peel browning.

Browning results from cellular damage during enzymatic oxidation of phenolic compounds by PPO which are originally sequestered in different compartments (Wang *et al.*, 2017). The occurrence of

peel browning, however, cannot be related to the activity of PPO which is in contrast to the report of Zhang and Zhang (2008) in pomegranate peel. In 'Queso de Bola' guava fruits, PPO activity was relatively low in both treatments until the 9th day of storage (Figure 6B). Initially, PPO activities after harvest in 1-MCP-treated and control fruits were 0.37 unit mL⁻¹ min⁻¹ and 0.38 unit mL⁻¹ min⁻¹, respectively and remained fairly stable until the 9th day. The maximum activity of PPO in both treatments was observed on the 12th day when fruits were showing moderate peel browning.

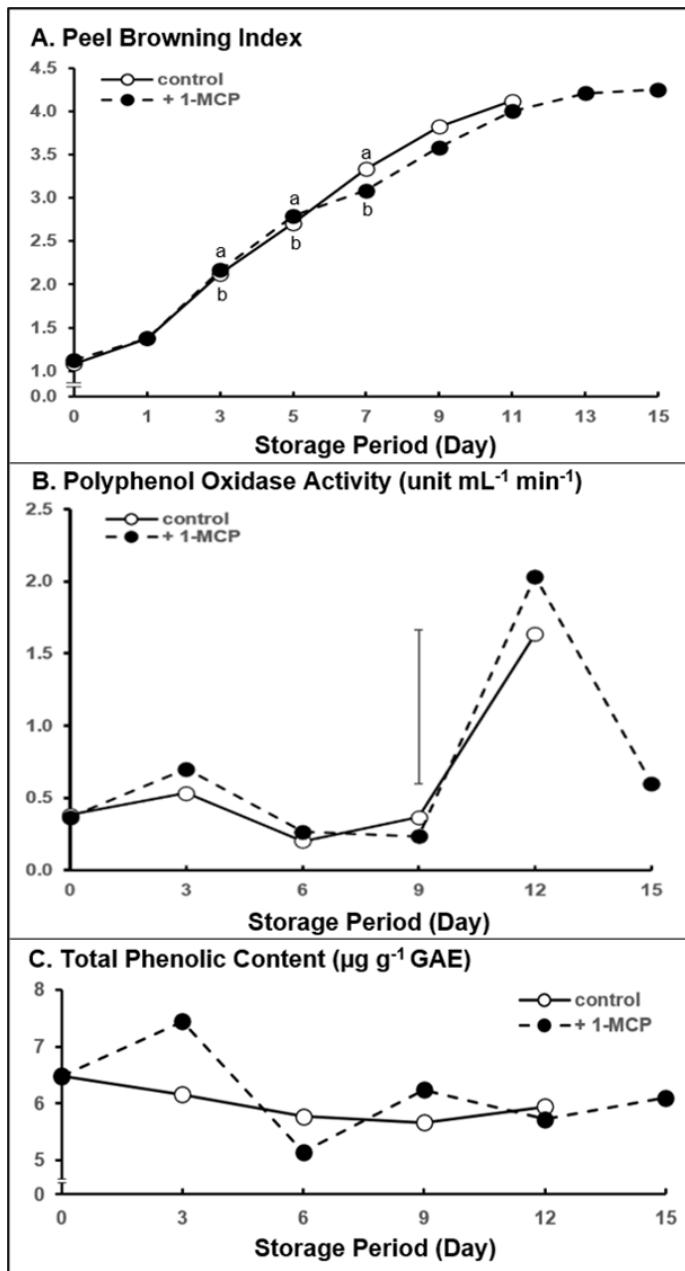


Figure 6. (A) Peel browning index, (B) polyphenol oxidase activity (enzyme unit mL⁻¹ min⁻¹), and (C) total phenolic content (μg g⁻¹ GAE) of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH). Peel browning index was analyzed using Kruskal-Wallis test. For PPO and TPC, each point represents the mean of three fruit samples during destructive sampling. Bar indicates LSD at 5% level of significance

With regard to total phenolic content (TPC), there was no definite pattern of change throughout storage of 1-MCP-treated fruits (Figure 6C). The initially 6.49 μg g⁻¹ GAE increased to 7.45 μg g⁻¹ GAE on day 3 followed by an abrupt decrease on day 6 and then an increase which remained relatively stable at about 6.00 μg g⁻¹ GAE until day 15. On the other hand, TPC of the control fruits was slowly decreasing until the 9th day of storage from 6.48 μg g⁻¹ GAE to 5.67 μg g⁻¹ GAE and slightly increased to 5.95 μg g⁻¹ GAE on the 12th day when its maximum PPO activity was also observed.

3.7 Total soluble solids, titratable acidity, and pH

Bassetto *et al.* (2005) reported that 1-MCP lowered the TSS values of 'Pedro Sato' guava fruits. Except at day 3, 1-MCP-treated fruits had also lower total soluble solids (TSS) values during storage than control fruits (Table 2) although differences were not significant. However, TSS values of all fruits did not markedly change during storage and ranged from 6.20 to 8.13° Brix. This high TSS value was obtained in the control fruits that manifested a rapid decline in softening on day 9.

Titratable acidity (TA) values of fruits on the other hand, slightly increased in both treatments during storage (Table 2) which is similar to the report that 'Pedro Sato' guava treated with 1-MCP maintained higher acidity levels during storage (Bassetto *et al.*, 2005). As in TSS, there was no significant difference in TA among fruits although 1-MCP-treated fruits had slightly higher TA values than the control.

Similar to TSS and TA, 1-MCP did not significantly affect the pH values of guava fruits.

3.8 Ascorbic acid content

Initially, control fruits had higher ascorbic acid content than 1-MCP-treated fruits (Table 2). During storage, however, 1-MCP-treated fruits maintained higher ascorbic acid content than control fruits starting on the 3rd day until the last day of storage. In 1-MCP-treated fruits, the highest ascorbic acid content of 127.42 mg 100 g⁻¹ was obtained on the last day of storage. Control fruits had low ascorbic acid content of 82.09 mg 100 g⁻¹ on the last day. Accordingly, ascorbic acid is responsible for the scavenging of the reactive oxygen species (Chiari *et al.*, 2012) thus delaying senescence which in the case of guava manifests as peel browning. However, peel browning occurred in both 1-MCP-treated and control fruits. Thus, peel browning cannot be correlated to ascorbic acid content.

Table 2. Physico-chemical changes of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH)

Treatment	Storage Period at Ambient (d)					
	0	3	6	9	12	15
TSS (°Brix)						
1-MCP	6.20a	7.20a	7.13a	7.60a	7.53a	7.50
Control	6.26a	7.07a	7.53a	8.13a	7.83a	-
TA (%)						
1-MCP	0.17a	0.17a	0.19a	0.22a	0.16a	0.27
Control	0.13a	0.17a	0.17a	0.16a	0.20a	-
pH						
1-MCP	4.30a	4.32a	4.36a	4.27a	4.46a	4.47
Control	4.34a	4.35a	4.17b	4.28a	4.37a	-
Ascorbic Acid (mg 100 g ⁻¹)						
1-MCP	101.84a	121.95a	95.62a	122.35a	115.50a	127.42
Control	110.21a	104.76a	74.99a	99.70a	82.09b	-

Means within columns for each parameter followed by the same letter are not significantly different at 5% level, LSD. Each point represents the mean of three replicates. No values were indicated on the 15th day since the experiment was already terminated

Table 3. Sensory characteristics of 'Queso de Bola' guava fruits treated with 600 nL L⁻¹ 1-MCP for 12 hrs and then stored at ambient condition (29±2°C, 60-80% RH)

Treatment	Storage Period at Ambient (d)					
	0	3	6	9	12	15
Crispiness						
1-MCP	4.17a	4.08a	3.92a	3.25a	3.75a	3.75
Control	4.08a	4.00a	3.33a	3.50a	2.83a	-
Crunchiness						
1-MCP	2.75a	2.92a	2.92a	2.42a	2.83a	2.75
Control	2.92a	3.33a	2.67a	2.92a	2.00b	-
Overall Acceptability						
1-MCP	6.33b	6.83a	6.83a	6.42a	6.83a	6.67
Control	7.50a	6.50a	6.92a	6.83a	7.00a	-

Data was analyzed using the Kruskal-Wallis test. No values were indicated on the 15th day since the experiment was already terminated

3.9 Sensory evaluation

Crispiness and crunchiness are some of the desired quality attributes of 'Queso de Bola' guava fruits. According to Chauvin *et al.* (2008), crispiness is defined as "one sound event perceived as a sharp, clean, fast, high pitched sound and evaluated with the incisors and lips open". On the other hand, crunchiness is a "multiple lower pitched sound perceived as a series of small events and evaluated with the molar and lips closed". Generally, crispiness of fruits decreased during storage at ambient condition regardless of the treatment (Table 3). 1-MCP-treated fruits were crispier than control fruits which were more notable on day 12. As to the crunchiness, fruits regardless of treatments were rated by the panelists as neither crunchy nor soft (rating of 2.42 to 3.33) throughout the evaluation period except for the soft texture observed in the control fruits on day 12. Overall acceptability of fruits ranged from 6.33 to 7.50 (like slightly to like moderately) with the control fruits slightly preferred by the panelists than the 1-MCP-treated fruits.

4. Conclusion

1-MCP treatment at 600 nL L⁻¹ for 12 hrs prolonged the marketability of 'Queso de Bola' guava by 3-4 days longer than control fruits which were attributed to the maintenance of firmness, retention of green peel color, and reduced disease incidence.

1-MCP slowed down the decline in firmness thus maintaining the crisp texture desired by consumers. However, the relationship between retention of firmness and suppressed polygalacturonase activity and ethylene production brought about by 1-MCP treatment as reported in other studies was not established in this study.

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