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Improving the Quality and Shelf Life of Guava Fruits Using 1-Methylcyclopropene

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Authors' contributions

This work was carried out in collaboration between both authors. Author FSD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author RS managed the analyses of the study, draw figures and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Storage of guava fruits by using refrigerators as post-harvest treatment is commercially acceptable but is expensive, especially in developing countries. So, the present investigation was carried out with the objective to compare the efficacy of 1-MCP and their most effective concentrations for the shelf-life enhancement of guava fruits without any deterioration in fruit quality in the winter season at both cold and room-temperature storage conditions. Horticultural mature guava fruits were treated with 150, 300, and 600 ppb, and then stored at room temperature at 21°C, RH 45%, or cold storage at 6°C, RH 85%. The Results showed that the highest concentration of 1-MCP (600ppb) significantly ($P<0.05$) preserved fruit firmness, and organoleptic quality attributes. In addition, the fruit weight loss, decay percentage, titratable acidity (TA), total soluble solids (TSS), and fruit color development were significantly preserved compared to other treatments under both cold and room storage conditions. Generally, 1-Methylcyclopropene (1-MCP) could maintain the quality of guava fruit combined with cold temperatures for 24 days. While 150 and 300 ppb 1-MCP preserved the

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quality of fruits for up to 20 days compared to untreated fruits for 16 days. Otherwise, treated fruits with 600ppb of 1-MCP kept at room storage temperature preserved fruits quality for up to 20 days compared with untreated fruits for up to 12 days stored at room storage condition. Hence, 1-MCP as post-harvest treatments preserved the overall quality parameters and enhanced the shelf life of guava fruit even after two weeks of storage at ambient temperature and three weeks after cold storage. Otherwise, 1-MCP could be an alternative to cold storage, as it is more economical than cold storage, especially in developing countries.

Keywords: Guava fruit; 1-MCP; shelf life; fruit quality; physical and chemical properties.

1. INTRODUCTION

“Guava fruits (*Psidium guajava*) belong to the Myrtaceae family, are widely cultivated in tropical and subtropical countries, and are gaining popularity worldwide” [1]. “For instance, in Palestine, guava is mainly cultivated in the northern districts of the geographical area. Recently, guava fruit cultivation on has been increased rapidly in the West Bank from 250 to 300 hectare in 2021, and production has been increased from 15 to 20 tons [2]. Guava fruit exhibits a climacteric pattern of respiration and ethylene production so is highly perishable in nature and suffers a great extent of post-harvest losses. It can be harvested at the early physiology maturity stage and stored for few days at room temperature to ripen” [3]. “Generally, several physiological, biochemical, and structural changes occur during fruit ripening, such as the degradation of starch to sugars, synthesis of pigments, volatile compounds, and partial solubilization of cell walls” [4]. In addition, the quality of climacteric fruits is highly affected by post-harvest conditions, such as transportation and storage during ripening [5]. Climacteric fruit ripening could be controlled by several post-harvest methods, such as reducing the respiration rate and ethylene synthesis, storing fruits at low temperatures, and coating them with various natural substances [6]. “Recently, 1-methylcyclopropene (1-MCP) has been employed to increase the shelf-life of some horticultural commodities. By binding to the ethylene receptors, 1-methylcyclopropene acts as an efficient ethylene antagonist and its effects can persist for a long time” [7]. “It can, therefore, slow down the ripening process as well as senescence of fruit” [8]. “1-MCP is being described as a breakthrough shipping and storage technology that can maintain the fresh-picked quality of the commodity” [8]. 1-MCP delayed fruit ripening, maintained quality and extended shelf-life of apple, avocado, banana, tomato [8], and mango [9]. “The response of the fruit to 1-MCP depends upon a number of variables, including cultivar, maturity stage, concentration, temperature, duration, application technique and exposure and storage environment” [8]. Previous results have shown that post-harvest treatment with 1-MCP and packing material prolongs shelf life, reduces spoilage, and improves guava fruit quality by delaying the onset of senescence during storage [10]. Post-harvest application of 1-MCP, which could delay lignin and cellulose accumulation and delay senescence in common beans [11], loquat fruit [12], pears [13], guava fruit [14], and plums [15]. In addition, post-harvest application of 1-MCP can inhibits the expression of ETR2, and EIL1, and act as an inhibitor of ethylene synthesis [16]. It has been demonstrated that the inhibition of the ethylene action delays ripening and senescence in several species of fruits, such as apples [17], and pears [18]. This study aims to explore the effect of 1-MCP on guava fruit ripening, on prolonging shelf-life and quality during the post-harvest storage periods at cold and room-temperature storage conditions.

2. MATERIALS AND METHODS

2.1 Fruits Materials

Guava fruits were hand harvested at the commercial stage (horticultural maturity), were immediately transported to the post-harvest laboratory of the National Agriculture Research Center (NARC), Qabatia-Jenin. Guava fruits free from damage, uniform size, color, and cleaned were selected for further treatments.

2.2 Post-Harvest Treatments

2.2.1 1-MCP preparation and treated fruits

- The 1-MCP application procedure was followed as it was earlier published by [15]. Samples were kept at 1 ◦C before 1-MCP treatment. Three groups were treated with 1-MCP gas on the 4rd, 6th, and 8th day after harvest in an air-tight chamber at 1°C for 24h.

- The fruits were divided into four sets, each set contains 90 fruits. First set was treated with 600 ppb 1-MCP for 2 minutes. The second set for fruits treated with a moderate concentration of 300 ppb. The third set for fruits treated with a low concentration 150 ppb. The fourth and the fifth sets of untreated (control) fruits were immersed in distilled water for 1 minute. Each set was duplicated for storage at room (21°C, RH 45%), and the other in cold storage (6°C, RH 85%). Fruits packed in boxes (5% ventilations) with newspaper.

2.2.2 Analysis of quality parameters

2.2.2.1 Fruits weight loss (%)

20 fruits were used for each treatment, by tracking weight change from interval (zero days) and every four days by a digital balance (Analytical Digital Balance Single Pan). The result was calculated as a percent (%) through using this equation [19]. Weight loss (%)= ((initial weight – final weight) / initial weight) x100.

2.2.2.2 Firmness measurement (N)

Two fruits per replicate from each treatment were used to measure firmness using a digital penetrometer (Lutron FR -5120, QA Supplies LLC, Norfolk, VA, USA), with 4 mm plunger. Two readings were carried out on opposite sides along fruit equatorial region, and the results were expressed in Newton (N).

2.2.2.3 Total soluble solid (◦Brix)

Total soluble solids of fruits were measured using a digital refractometer (Milwaukee MA871 model, NC, USA). °Brix content was taken from three fruits per replicate. The results were expressed in degrees °Brix.

2.2.2.4 Titratable Acidity (TA)

The TA, recalculated as per citric acid content, by titrating 10 ml of sample of frozen tissue, which had been macerated in 25 mL of distilled water using polytron (Kinematica TM, Luzern, Switzer-land) and by titration to pH 8.2 with 0.1N NaOH using an automatic titrator (716 DMS Titrino, Metrohm,Herisau, Switzerland).

2.2.2.5 Ripening index (TSS/TA)

The ripening ratio was calculated as the ratio of measured TSS to TA of guava fruit juice as described by Sati and Qubbaj [20] using the following formula: Ripening index = (measured TSS/ measured TA)

2.2.2.6 Fruit color development

Three fruits per replicate were used to measure the color development on guava fruits, using colorimeter device Hunter-scale value (L, a*, b*, hue, and chroma) scale (KONICA MINOLTA) for tracking develop in color of guava fruits.

a. L-scale: indicated brightness.
b. a-scale: indicated develop color of fruits from green to red color.
c. b-scale: indicated develop color of fruits from yellow to blue color.
d. hue: expresses the color changes of the guava fruits.
e. Chroma index: analyzes the color value of the guava fruits.

2.3 Data collection and Statistical Analysis

A factorial experiment based on a complete randomized design with three replicates was set up. The collected data were statistically analyzed using analysis of variance (ANOVA) at $P \leq 0.05$ with Statistic version 10 (Stat Soft, Poland). The student-Newman- Keuls (SNK) range test was used for evaluating the difference in means at 5% probability. Figures were plotted using Sigma Plot version 8.0 (Systat, Chicago, IL, USA).

3. RESULTS AND DISCUSSION

The effect of 1-MCP as a post-harvest treatment had a significant influence on the quality and shelf life of guava fruits at low and high storage temperatures compared with untreated (control) fruits. the interaction effect of treated fruits with 1-MCP stored at low temperature, had a significant ($p<0.05$) effect on prolong shelf life up to 24 days, compared to fruit stored at high temperature up to 12 days. In addition, fruits treated with the highest concentration of 1-MCP (600 ppb) and stored at high temperature showed a significant ($p < 0.05$) effect on preserved quality and prolong shelf life of fruits, compared to untreated (control) fruits at low storage temperature (Table 1, appendix).

3.1 Weight Loss

The results showed gradual increase in percent of weight loss in all treatments at both storage temperatures (Fig. 1). Otherwise, all fruits treated with different concentration of 1-MCP showed a significant (P<0.05) reduced percent of weight loss, compared with untreated (control) fruits. Particularly for fruits treated with 600 ppb of 1-MCP had significantly reduced percent of weight loss, compared with other treatments at the end of storage (Fig. 1). This in agreement with earlier reports in banana [21] and mango [9]. The interaction effects of storage temperature, 1-MCP, and storage time were significant on fruit weight loss, as 600 ppb of 1-MCP combined with room temperature (20°C) significantly maintained fruit weight, and this effect was not significantly different when uncoated fruits were kept at (6°C) (Fig. 1). The reduction on weight of fruits might be due to transpiration processes during the ripening process [20]; as shown in the current study, untreated (control) fruits recorded a highest percent of weight loss, and that refer to higher rates of respiration and transpiration [20]. Otherwise, the retention of higher fruit weight due to application of 1- MCP was due to their stimulatory effect on fruit metabolism. These could be probably due to the reduced or delayed fruit respiration in 1-MCP treated fruits through reduced the percent of water losses. These results agree with the findings of Ullah et al. in nectarines [22].

3.2 Firmness

Fruit firmness is one of the most important indicators of fruit quality. The results showed that fruit firmness gradually decreased in all treatment (Fig. 2). Generally, fruits treated with different concentrations of 1-MCP significantly preserved fruit firmness, compared with untreated (control) fruits at both storage temperatures (Fig. 2). On the other hand, fruits treated with high concentration of 1-MCP (600 ppb) and kept at room temperature (20 °C) preserved fruit firmness more than the untreated (control) fruits at cold temperature (6°C) (Fig. 2). The current study indicated that 1-MCP at different concentrations was preserved firmness of fruit at both storage temperatures; it's probably associated with reduction in the activity of pectinolytic enzymes induced by smaller ethylene action [19]. Similar results were observed in apple [23], banana [24] and [21], mango [12], and papaya [25].

3.3 Total Soluble Solid (°Brix)

The current study shows gradual increase in the TSS with different treatment and at different days of storage (Fig. 3). However, no significant difference between treatment after 4 days from storage. While, after 8 days from storage and until the termination of experiments, fruits treated with the highest concentration (600 ppb) of 1-MCP showed lower TSS content compared within other treatments (Fig. 3). This is in agreement with earlier findings in banana [21], and mango [9]. Furthermore, no significant (P ≤ 0.05) differences were found between fruits treated with 600 ppb of 1-MCP kept at room temperature (21°C) and untreated (control) fruits at cold storage (6°C). The increase in TSS during storage may be due to breakdown of complex organic metabolites into simple molecules or hydrolysis of starch into sugar [26]. Similar reports were also shown in banana fruits [27]. Highest value of TSS was also reported in yellow pitahaya fruits [28]. Whereas the lower TSS due to treatment of fruits with 1-MCP, is working on delays fruit ripening through inhibitor ethylene synthesis. In addition, the amount of sugars usually increases along with fruit ripening through biosynthesis processes or degradation of polysaccharides [24].

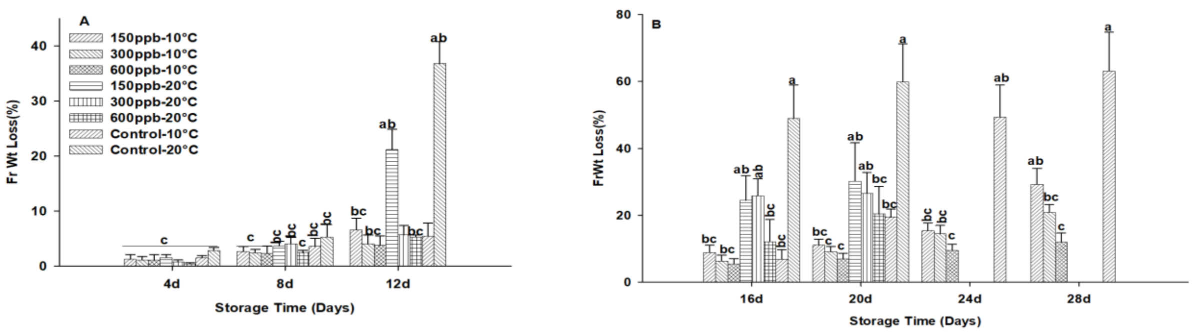

Fig. 1(A and B). Effect of different concentration of 1-MCP (150, 300 and 600ppb) on the fruit weight loss trait of guava fruits during storage at low temperature (6 °C) and high temperature (21 °C)

Each value represents the mean of three biological replicates (± standard division) . The means followed by the same letter are significantly different (SNK test, P ≤ 0.05)

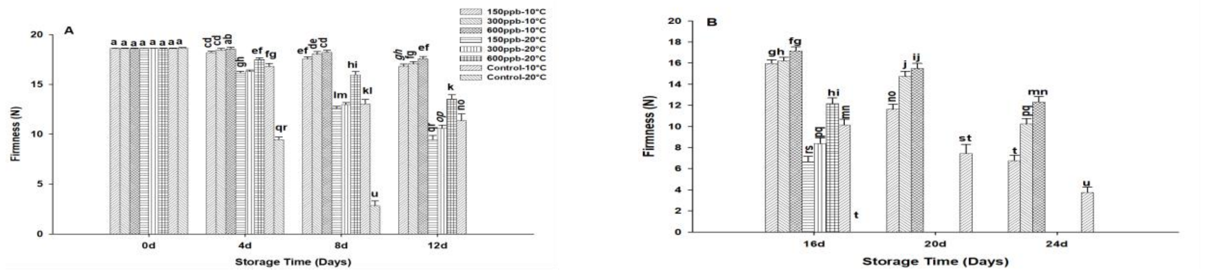

Fig. 2(A and B). Effect of different concentration of 1-MCP (150, 300 and 600 ppb) on the firmness (N) of guava fruits during storage at low temperature (6 °C) and high temperature (21 °C)

Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are significantly different (SNK test, P ≤ 0.05)

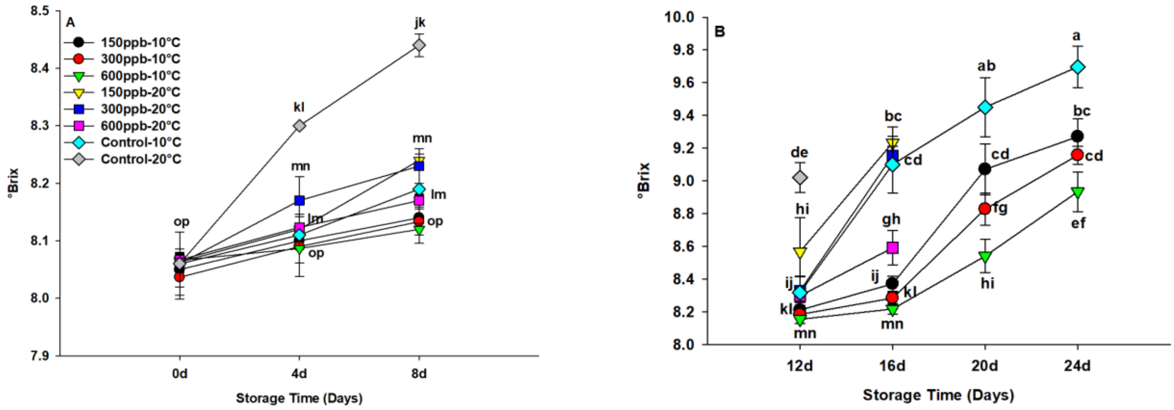

Fig. 3(A and B). Effect of different concentration of 1-MCP (150, 300 and 600 ppb) on the Brix content of guava fruits during storage at low temperature (6 °C) and high temperature (21 °C)

Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are significantly different (SNK test, P ≤ 0.05)

3.4 Titratable Acidity (TA)

The current study showed a gradual and progressive decrease in acidity at treatments during both storage temperatures. Titratable acidity in guava fruits increased up to the climacteric peak and declined thereafter [29]. Similar results were reported during ripening of mango [30]. The results showed maximum percent of TA was observed in fruits treated with 600 ppb 1-MCP at cold storage. Whereas the minimum (0.42%) was recorded in untreated (control) fruits at high temperature storage (Fig. 4). The progressive decline might be due to utilization of acid in metabolism (reference). Post-harvest application of 1-MCP delayed the decline in concentrations of TA. These delayed reductions in TA levels are attributed to the delayed ripening process in treated fruits with 1-MCP [31]. A similar results pattern was found in banana [21], mango [12], and pear fruits [21].

3.5 Ripening Index

During the storage time, the ripening index increased with increase storage time in all treated and untreated fruits (Fig. 5). However, untreated (control) fruits, TSS: TA ratio had a significant (p≤0.05) sharp increase from 4 days of storage till the deterioration of fruits. On the other hand, different concentration of 1-MCP had minor changes in TSS: TA ratio after 8 days of storage till the deterioration of the fruit at both storage temperatures (Fig. 5). No significant difference was found between fruits treated with 600 ppb of 1-MCP kept at room temperature (21°C) and untreated (control) fruits at cold storage (6°C) (Fig. 5). The result indicated that treated fruits with different concentration of 1-MCP delayed fruit ripening. This agrees with different reports that 1-MCP delayed fruit ripening, maintained quality and extended shelf-life of apple, avocado, banana, tomato [30], banana [21], and mango [9]. In addition, 1-MCP as post-harvest treatments found to reduce the ethylene rate production, thus delaying the utilization of organic acids, and delay ripening fruit [27].

3.6 Fruits Color Development

The development of fruits color was primarily evaluated by using hunter scale value (l*, a*, b*, hua, and chrom) scale. h-angle, which indicate the brightness, color saturation and the hue angle of the peel, respectively. As shown in (Fig. 6d). The l* value gradually increased with fruit ripening for the untreated (fruits) control (Fig. 6a). Whereas no significant difference was observed between fruits treated with highest concentration (600 ppb) of 1-MCP at room storage with untreated (control) fruits at cold storage (Fig. 6a). The chroma value of fruit increased with fruit ripening, with a high significant difference was observed between the different concentration of 1-MCP at both storage conditions (Fig. 6e). While the h-angle gradually decreased with fruit ripening in all treatments with a significant difference between fruits. Accelerated in develop of fruits color refer to loss of green skin color, due to chlorophyll molecule breakdown by the chlorophyllase enzyme activity [19,32,33]. “The increase in the activity of this enzyme is generally associated with ethylene production during fruit ripening” [27]. “The product binds to the ethylene binding site in cells, inhibiting ethylene action on the physiologic processes of ripening” [21]. Therefore, loss of green color resulting from the normal ripening process was delayed by the application of 1-MCP. Green color retention in fruits treated with 1-MCP has also been observed in chinese pear [28], bananas [21], mango [9], and avocado [34].

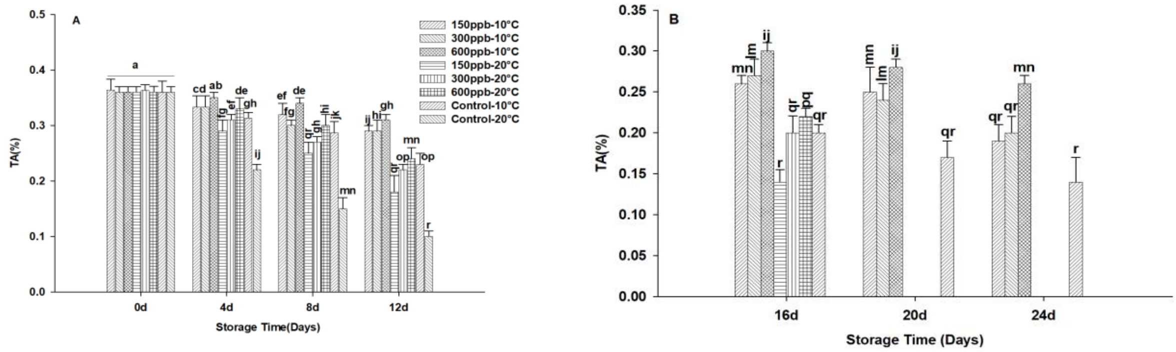

Fig. 4(A and B). Effect of different concentration of 1-MCP (150, 300 and 600ppb) on the titratable acidity of guava fruits during storage at low temperature (6 °C) and high temperature (21 °C)

Each value represents the mean of three biological replicates (± standard division) . The means followed by the same letter are significantly different (SNK test, p ≤ 0.05)

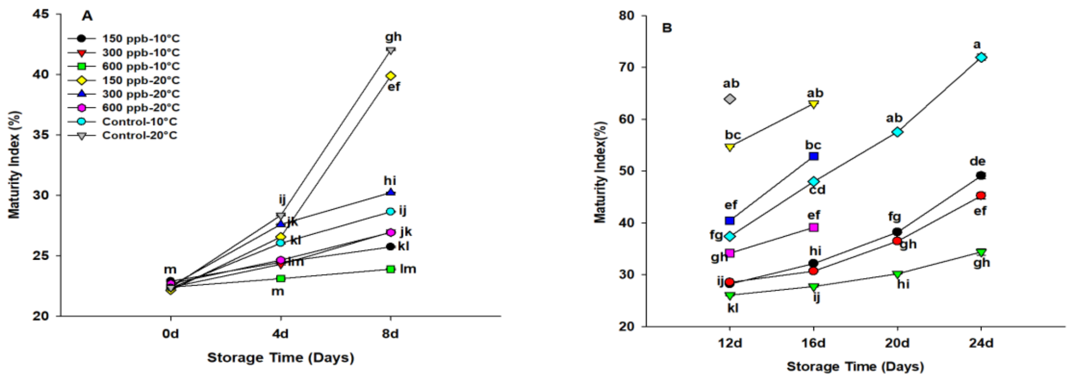

Fig. 5(A and B). Effect of different concentration of 1-MCP **(150, 300 and 600 ppb) on the maturity index (%) of guava fruits during storage at low temperature (6° C) and high temperature (21 °C)**

Each value represents the mean of three biological replicates (± standard division). The means followed by the same letter are significantly different (SNK test, P ≤ 0.05)

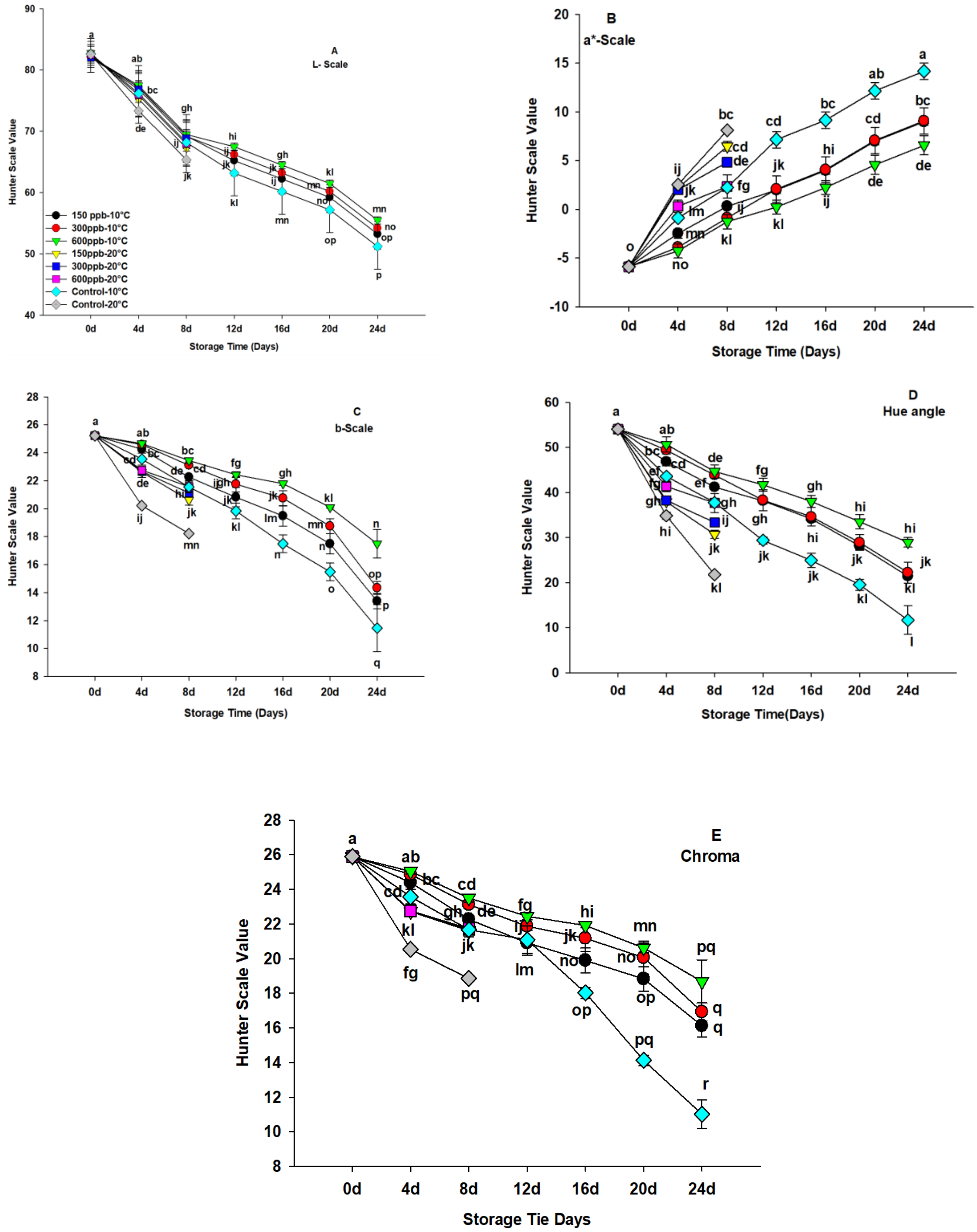

Fig. 6(A, B, C, D, and E). Effect of different concentration of 1-MCP (150, 300 and 600ppb) on the color development (L, a, b, hue and chroma) scale of guava fruits during storage at low temperature (6° C) and high temperature (21°C)

Each value represents the mean of three biological replicates (± standard division) . The means followed by the same letter are significantly different (SNK test, P ≤ 0.05)

4. CONCLUSION

1-MCP as post-harvest treatment was preserved quality of fruits and prolong shelf life of guava fruits as compared with untreated (control) fruits. In addition, the overall fruit quality was maintained up to 24 days at cold (6 °C) storage, and up to 20 days at room (20°c) storage as compared with untreated fruits only for 12 days. 1-MCP as a post-harvest treatment then stored at the room storage condition had no significant difference in fruit firmness and acceptable organoleptic quality with untreated fruits stored at low-temperature conditions. These results indicated that 1-MCP to be effective, highest dose levels of 1-MCP (600 ppb) were best to maintain the quality of guava fruits during storage.

CONSENT

All authors declare that ‘written informed consent was obtained from the patient for publication of this case report and accompanying images.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 1. Variance analysis of the effect of 1-MCP and storage temperature on quality attributes of guava fruits

S.O.V	Mean Square (MS)										
	df	Weight	Firmness	a*scale	l*scale	b*scale	Hue	Chrom	TA	TSS	Ripening index
Temperature (T)	1	3821.8*	1715.7*	180.33*	51118.4*	5163.6*	1574.3*	5975.1*	0.45677*	323.70*	3050.07*
Coating (C)	3	4025.8*	285.23*	72.087*	24.0*	26.96*	332.3*	7.44*	0.02941*	1.918*	477.20*
Storage time (D)	6	1715.7*	655.27*	313.85*	1464.7*	1427.28*	6684.0*	1336.48*	0.23192*	72.281*	1220.48*
T × C	3	802.4	4.27*	32.636*	7.4	8.72*	94.70*	3.46*	0.00103*	5.590*	698.99*
T × D	6	10004.3*	94.31*	211.424*	6091.8*	517.04*	1170.9*	603.70*	0.04731*	115.59*	4050.82*
C × D	18	223.09*	16.89*	3.526*	1.3	1.31*	25.80*	1.53*	0.00321*	4.008*	216.37*
T × C × D	18	1069.6*	14.58*	4.689*	2.6	2.56*	36.50*	0.59*	0.00224*	5.170*	328.56*
ERROR	110	241.71	0.46	1.601	3.3	0.16	10.90	0.14	0.00040	0.005	21.28
C.V (%)		109.2	5.78	93.86	3.64	2.63	12.10	2.33	8.73	1.03	16.24

*ns not significant, and * significant at 5% levels*

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