



ORIGINAL ARTICLE

Extending the Shelf life of TomEJC Mango through Application of 1-Methylcyclopropene

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Abstract

Mango cultivar TomEJC (TJC) has a substantial potential as a fresh food commodity with its high quality; however this cultivar requires a specialized postharvest handling. This study was conducted to extend the shelf life of TJC mango through application of 1-MCP. Four treatments (1 ppm for 12 h and 24 h, 2 ppm for 12 h and 24 h) were tested with a control; stored at 14 °C and 85-90% RH. The changes in flesh colour, pulp firmness, total soluble solids (TSS), pH, weight loss and rate of respiration and ethylene production were measured during the storage of four weeks. Application of 1-MCP showed a significant effect ($p < 0.05$) on flesh colour, firmness, TSS, pH, rate of respiration, and rate of ethylene production. Results showed significant differences ($p < 0.05$) in L* (lightness from black to white), a* (redness to greenness), and b* (yellowness to blueness) values of flesh between control and treatments. The control and 2 ppm for 24 h treatment reached the flesh colour at ripening within 16 days; while, the least rate of colour changed was resulted by 2 ppm 12 h treatment. TSS and pH of fruit pulp increased during the storage period, while the flesh firmness decreased. Further, the same properties of treatment 2 ppm 12 h, resulted the least rates of changing. According to the sensory evaluation and TSS, treating TJC mango with 1-MCP was found to be successful in delaying of ripening and subsequently it extends the shelf life of mango approximately 10 days than the untreated mango. The study showed that the application of 2 ppm of 1-MCP for 12 h the shelf life of TJC mango for period of four weeks in cold storage (14 °C and 85-90% RH) without deteriorating the quality of fruits.

Keywords: 1-MCP, Ethylene, Respiration rate, Shelf life, TJC mango

1. Introduction

Mango (*Mangifera indica*) is one of the most popular fruits in the world, and often called the 'King of Fruit' in Asian countries (Singh et al. 2013). It is popular among the people due to its delicate taste, excellent fragrance and nutritional value. India is the country where mango was originated. Though it is not an endemic crop, it is widely grown in many parts of Sri Lanka. The land extent is 28,440 ha and 493.5 million fruits production in 2018 (Department of Census and Statistics). Different mango varieties grown in Sri Lanka include *TomEJC* (TJC), *Betti*, *Kohu*, *Villard*, *Karthacolomban* and are cultivated in different districts such as *Kurunegala*, *Gampaha*, *Ratnapura*, *Matale*, *Hambantota*, *Moneragala*, *Puttalam* and *Matara*. Among those mango cultivars, TJC (TomEJC) mango has more consumer demand and higher price in the local market as well as international market due to its excellent taste, golden-orange colour, and large fruit size. And this fruit is available considerable time of the year. TJC mango is majorly exported to countries like Maldives, Middle East, Singapore and EU (Asian Development Bank 2017).

Mango is a climacteric fruit and the ripening is initiated by autocatalytic ethylene production and an increase in the rate of respiration. With the commencement of the ripening process, cell wall degrading enzymes may cause the fruit softening (Hewajulige et al. 2018). Due to the perishable nature of mango, it has more opening for the spoilage before it reaches to the consumers. Currently, the fresh mango fruit supply is expanded in the world market. But

fruit availability is limited due to the short shelf life. One of the reasons for the postharvest losses in perishables are early ripening due to increased temperature, weight loss due to increase in the respiration process and susceptibility to diseases such as anthracnose and pest infestation, improper transportation methods and the storage conditions as well (Sonune et al. 2011). According to the Asian Development Bank (2017), post-harvest loss of 'TJC' mango is about 10-20%. Therefore, currently, the export and international trade of mango have become limited. And also, there is a necessity to extend the shelf life of the mango to maintain the quality until consumption. Extending of shelf life up to about a month will help the possibility for export. If the freshly harvested fruit is kept at ambient conditions, ripening will increase rapidly within a few days thus, usage of low-temperature storage will be more effective.

According to Reid et al. (2008), effective agents have been found for control ripening, senescence etc. For increasing the shelf life of horticultural commodities, 1-Methylecyclopropene (1-MCP) has been used. It is available in powder form and releases in gaseous form when mixed with a dilute base. It acts as an efficient ethylene antagonist and its effects can exist for a long time (Khedr 2016). Several significant factors have to be considered when using 1-MCP such as concentration of 1-MCP, cultivar, maturity, temperature, duration, application technique and exposure and storage environment as the response of the fruit to 1-MCP depends upon these (Beaudry and Watkins 2003; Pelayo et al.

2003). 1-MCP is a better ethylene inhibitor which has been used to reduce the postharvest losses. It binds to the ethylene receptors with 10-fold greater affinity than ethylene and it is active at much lower concentrations compared with ethylene (Blankenship and Dole 2003). It helps to extend the shelf life of the mango until those are transported to the local or international market. Therefore, the present study was conducted to evaluate the effectiveness of 1-MCP on extending the shelf life of 'TJC' mango.

2. Materials and Method

Plant material

TJC' mango fruits at early maturity stage were purchased from Ellawala Horticulture Pvt. Ltd., *Galkiriyagama*. At this stage, it was 0.9 °Brix and as mentioned by Nambi et al. (2015), peel colour was similar to maturity stage one. Laboratory analysis was done at the Research and Development Centre, National Institute of Post-Harvest Management (NIPHM), *Jayanthi Mawatha, Anuradhapura*.

Application of 1-Methylcyclopropene to mango fruits

Selected fruits were washed by clean water. After air drying, mangoes were divided into five lots. Two lots were treated with 1 ppm 1-MCP gas concentration and each lot was kept for 12 h and 24 h periods respectively. Other two lots were treated with 2 ppm 1-MCP gas concentration for 12 h and 24 h periods as before and all lots were kept in airtight glass chambers and the control sample was put into the chamber without exposing to 1-MCP. Each

treatment was replicated three times. Hundred mango fruits were used for each treatment. All the experiments were conducted at ambient conditions of 29 ± 4 °C and 68 ± 5 % RH. After exposing to 1-MCP, the fruits were stored in the cool room at a temperature of 14 °C and 85-90 % Relative Humidity (RH).

Determination of physicochemical parameters

The flesh colour, physiological weight loss, Total Soluble Solids (TSS), pH, pulp firmness, respiration rate, ethylene production and total sugars of 1-MCP treated 'TJC' mango and the untreated samples were measured at the initial stage and at four-day intervals during the four weeks of storage period.

Flesh colour: The flesh colour of mango was measured using a colour difference meter (Model: Minolta, CR 400) and readings were recorded as L*, a*, b* values where L* indicates the lightness and extends from 0 (black) to 100 (white) while a* indicates redness (+) to greenness (-) and b* indicates yellowness (+) to blueness (-) respectively. The measurements at the stem end, mid-region and floral end of each face of the peel and flesh were measured and a mean value was obtained.

Physiological weight loss: The weight of fruits was measured by using a top-loading electronic balance (Model: SHIMADZU, BL-2200H). The percentage of weight loss was obtained according to the Khedr (2016).

$$\text{Weight loss \%} = \frac{(\text{Initial weight} - \text{Weight of sampling day})}{\text{Initial weight}} \times 100$$

Total soluble solids (TSS): Pulp from the middle of mango was chopped using a mortar and pestle and squeezed through muslin cloth. Total soluble solid contents were measured using a Refractometer (ATAGO, Model PAL-1) and readings were reported as °Brix.

Pulp firmness: Pulp firmness was measured using penetrometer (Model: CS 1-2, Italy) according to the method of Roy, (2012). It was placed perpendicular to the peeled mango and measured the proximal, middle and distal portion of samples and average was taken. Readings were expressed in N.

Respiration rate and ethylene production: Respiration rate and ethylene production were measured by analysing carbon dioxide emission rate and ethylene concentrations using gas chromatography (Model: SHIMADZU GC- 2014) fitted with 1 m long Porapak-N column (inner diameter 2 mm, 80/100 mesh). As reported by Nissanka et al. (2005), mango fruit samples from each treatment were placed in air-tight glass containers of a constant volume at ambient condition for one h. Headspace gas sample of 1 ml was injected into gas chromatography to measure ethylene and CO₂ concentration. Thermal Conductivity Detector (TCD) was the detector used for the CO₂ determination and Flame Ionization Detector (FID) was used to detect ethylene. Injector, column, FID, and TCD detector temperatures were 100°C, 40°C, 150°C and 150°C respectively. Helium (He) was the carrier gas used in the flow rate of 37ml per min.

pH: pH was measured in the juice extracted by treated and control mango samples by using the pH meter (Model: 290, Thermo Orion) at 4-day intervals.

Sensory Evaluation: Sensory Evaluation was done on fifteenth day after the treatment according to the five-point hedonic scale using 30 untrained panellists. Peel and flesh appearance, odour, taste, and overall acceptability were organoleptic characteristics analysed by Friedman method.

Statistical analysis:

The experimental design was Two Factor Factorial. All the experimental data were analysed using ANOVA in SAS package 9.0. Non parametric data were analysed using Friedman test. Mean separation was done by Tukey's method.

3. Results and Discussion

Effect of 1-MCP on pulp colour reference to L* value

The 'L' value indicates the lightness which extends from 0 (black) to 100 (white). Fig. 1 shows the change of L value in the pulp colour during the storage period.

The pulp colour of all the mangoes became the light yellow with storage time. L* values were significantly different ($p < 0.05$) between control and treatments. Control sample and mangoes exposed to 2 ppm for 24 h treatment had a higher reduction in the lightness than the other treatments at the end of storage period. All the treatments except control and mangoes exposed to 2 ppm for 24 h showed the least change in L* value during storage. According to

Macnish et al. (1997) higher concentration and exposure time of 1-MCP saturate the greater degree of ethylene binding sites of fruits. The development of the pulp colour is due to physicochemical changes such as an increase in carotenoid pigments. And also colour development can be influenced by the internal gas including levels of CO₂ and ethylene. High level of CO₂ inhibits ethylene production (Hoa et al. 2002). Watkins (2006) reported that 1-MCP decrease the chlorophyll degradation that is responsible for colour changes of fruits during the ripening.

Effect of 1-MCP on pulp colour reference to a* value

The 'a' value indicates the turning of fruits from green (-) to red (+). The change in a* value of the treated samples and control is shown in Fig. 2. The initial a* value of the control increased rapidly during 16 days in storage, while the treatments of 12 h 1 ppm, 12 h 2 ppm and 24h 1 ppm showed the least change during the whole storage period. Control samples reached fully yellow colour at the end of 16 days of storage period. Turning to redness was slow in the 1-MCP treated samples than the control sample. The a* values of the treated samples and control were significantly ($p < 0.05$) different during the storage period.

Effect of 1-MCP on pulp colour reference to b* value

The 'b' values indicate the turning fruits from yellowness to blueness. Positive (+) values are towards yellowness while negative (-) values are towards blueness. A significant difference ($p < 0.05$) was observed in the control sample

than the other treatments. The control sample was almost turned to yellow at the end of the 16 days in storage while other treatment showed the least change in the b* value (Fig. 3). Turning to yellow in flesh colour is slow with 1-MCP, indicating the effect of 1-MCP in turning the ripening process.

Pulp firmness

Fig. 4 shows the changes in pulp firmness of treated and untreated samples of mango during the storage period under cold storage.

Higher values indicate the firmness and lower values indicates the softness of the pulp. A significant difference ($p < 0.05$) of pulp firmness was observed between the treated and untreated samples. The initial firmness of mango fruits before treatment was around 108 N. However, at subsequent days of treatment, significant differences ($p < 0.05$) were observed among the treatments. The firmness decreased in all the treatments with the storage period. Mangoes exposed to 2 ppm dose for a period of 12 h showed a lower rate of reduction in firmness compared to the other treatments indicating effectiveness of this treatment in retarding the rate of ripening. The ripening of mango fruits is characterized by softening of pulp due to cell wall digestion by pectinesterase, polygalacturonase and other enzymes (Hoa et al. 2002). And also softening is accompanied by a reduction in the size of hemicelluloses, loss of galactose side chains and solubilisation and depolymerisation of pectin (Mane 2017). The reduction in firmness during the storage period is considered as a natural process of ripening of almost all fleshy fruits

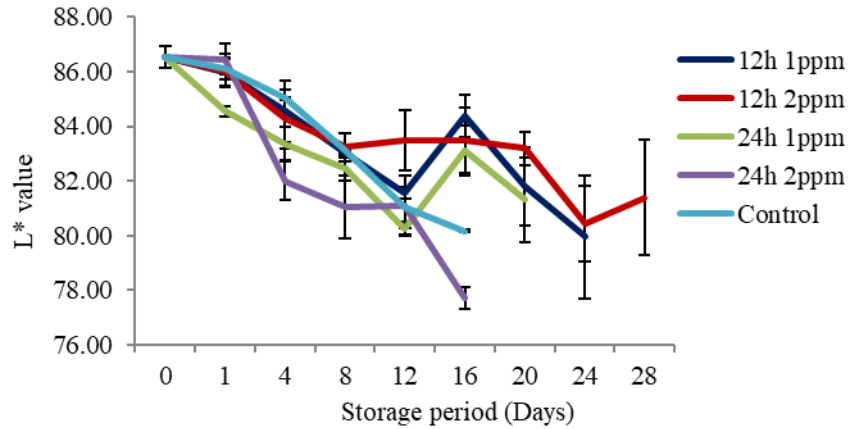


Figure 1: Effect of 1-MCP on the L* value of the TJC mango treated with different dosages in cold storage (14°C, 85-90% RH)
L* value: lightness, black (0) to white (100)

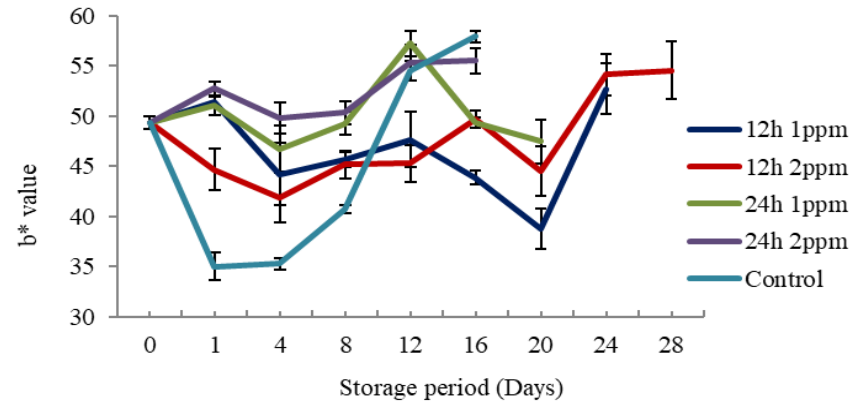


Figure 3: Effect of 1-MCP on b* value of the TJC mango treated with different dosages in cold storage (14°C, 85-90% RH)
b* value: yellowness to blueness

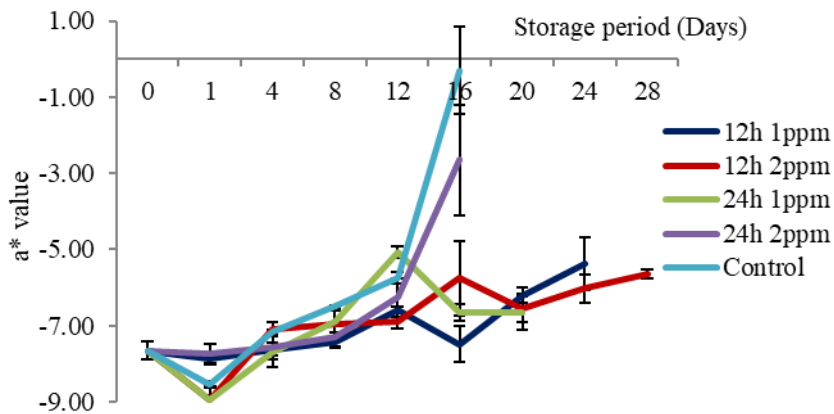


Figure 2: Effect of 1-MCP on a* value of the TJC mango treated with different dosages in cold storage (14°C, 85-90% RH)
a* value: green (-) to red (+)

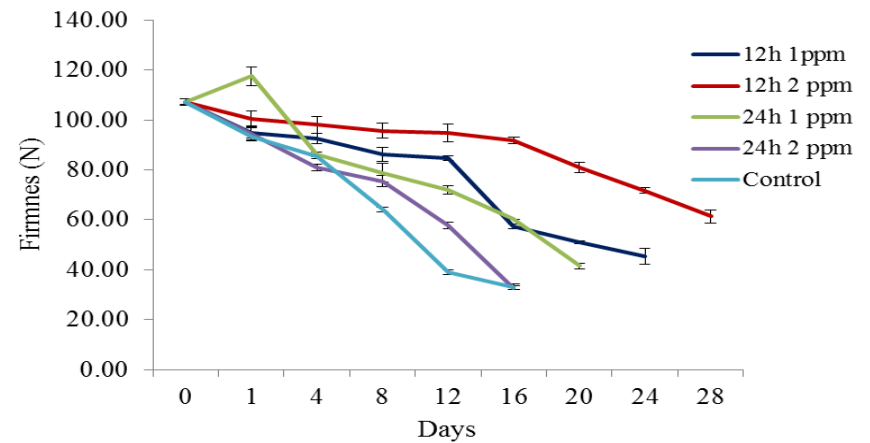


Figure 4: Effect of 1-MCP on pulp firmness of the TJC mango treated with different dosages in cold storage (14°C, 85-90% RH)

due to biochemical changes of the cellular structure (Brady 1987).

pH of fruits

Mango fruits treated with 1-MCP showed a significant effect ($p < 0.05$) on pH compared to control during cold storage (Fig. 5). Application of 1-MCP is effective in maintaining lower pH than the control sample. According to the results, the pH values gradually increased with the storage period in all stored samples. The control sample showed a higher pH value during the 12 to 16 days in storage while treated samples showed lower pH values. Samples treated with 12 h 1 ppm and 12 h 2 ppm showed lower values of pH than the other treatments and also less variation. As reported by Islam et al. (2013), oxidation of acid compounds during storage fruits results higher pH values.

Total Soluble Solid (TSS)

Fig 06 shows the changes in TSS of treated and untreated samples of mango during the storage period under cold storage.

There was significantly lower ($p < 0.05$) total soluble solid content in 1-MCP treated mango than the control sample. 1-MCP treatment resulted in a slower increment of total soluble solid content. The control sample showed a significant increase in TSS at the end of 16 days in storage than the treated samples. It indicates that the control reached to fully ripening stage and 1-MCP treated mango has not reached to the fully ripening stage at the end of 16 days.

The increase in TSS during storage may possibly due to the breakdown of complex organic metabolites into simple molecules or

due to hydrolysis of starch into sugars (Wills et al. 1981). During the ripening process, starch hydrolysed into simple sugars, where glucose, fructose and sucrose are dominant in ripe fruits (Ito et al. 1997). Mango is a climacteric fruit which has a tendency to have high soluble solid concentration until a maximum is reached at full ripe stage (Durigan et al. 2004).

Respiration rate

Fig. 7 shows the changes in respiration rate of treated and untreated samples of mango during the storage period under cold. A significant difference ($p < 0.05$) was observed in the rate of respiration between the treated samples and the control sample. Significantly higher peak was observed in the control sample and the lowest peak revealed by 12 h 1 ppm treatment. However, the control sample was reached to ripening stage rapidly than the 1-MCP treated samples. Generally, the increase or decrease in the rate of respiration depends on the changes in storage conditions and the physiological status of the fruit (Kader 1992; Fennir et al. 2003). Reduced oxygen and high CO₂ levels reduce the rate of respiration and lead to slow ripening (Mathooko 1996). 1-MCP inhibit the ethylene action thereby reduce the respiration rate and ATP concentration required to provide energy used in the catabolic process during ripening (Abeles et al. 1992).

Ethylene production

Table 1 presents ethylene production by mango fruits of different treatments during the storage period. A significant difference ($p < 0.05$) was observed between the treated samples and

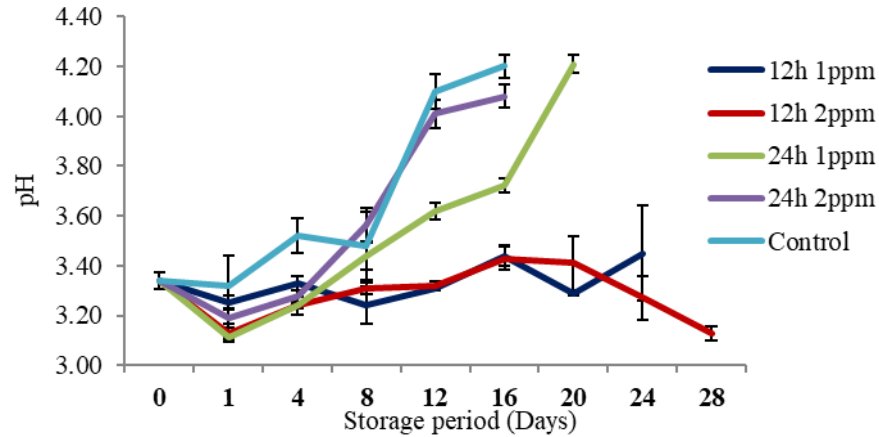


Figure 5: Effect of 1-MCP on pulp firmness of the TJC mango treated with different dosages in cold storage (14 °C, 85-90% RH)

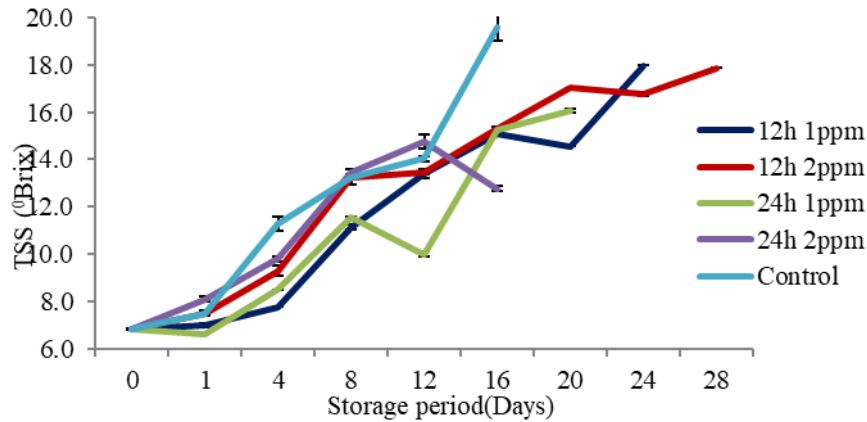


Figure 6: Effect of 1-MCP on TSS of the TJC mango treated with different dosages in cold storage (14 °C, 85-90% RH)

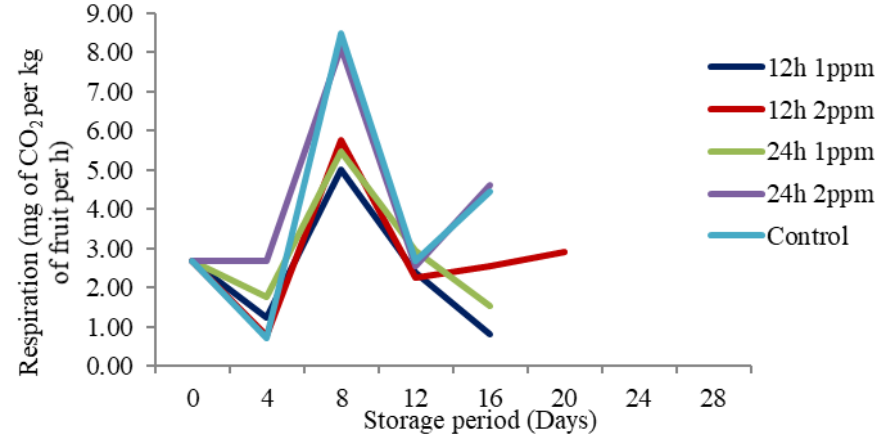


Figure 7: Effect of 1-MCP on the respiration rate of the TJC mango treated with different dosages in cold storage (14 °C, 85-90% RH) storage.

the control sample (Table 1). The ethylene production of mango is usually maximum with the onset of the climacteric peak of fruit ripening like other climacteric fruits (Mane 2017). According to the results, the control sample at the 16 days in storage showed significantly higher ethylene production than the other treatments. At the same day, least ethylene production was observed in 12 h 1 ppm treatment. This is due to the suppression of ethylene production of mango fruits by 1-MCP (Wang et al. 2009).

Table 1: Effect of 1-MCP on ethylene production of the TJC mango treated with different dosages in cold storage (14 °C, 85-90% RH)

Days after storage	Treatment and concentration of ethylene (uL kg ⁻¹ h ⁻¹)				
	12 h 1 ppm	12 h 2 ppm	24 h 1 ppm	24 h 2 ppm	Control
0	ND	ND	ND	ND	ND
8	ND	0.60 ± 0.05 ^b	0.51 ± 0.01 ^b	1.21 ± 0.10 ^a	ND
16	0.18 ± 0.70 ^b	0.19 ± 0.08 ^b	0.21 ± 0.02 ^b	0.40 ± 0.33 ^{ab}	0.70 ± 0.32 ^a
24	0.40 ± 0.07 ^a	0.23 ± 0.04 ^b	*NA	*NA	*NA
28	*NA	0.39 ± 0.04 ^a	*NA	*NA	*NA

Note: Data are presented as mean value ± SD, * Fruits discarded due to over-ripening
 ND: Not detected by the Gas chromatography
 Values with same letters are not significantly different ($p \leq 0.05$)

Table 2: Effect of 1-MCP on physiological weight loss of the TJC mango treated with different dosages in cold

Days after storage	Treatment and weight loss (%)				
	12 h 1ppm	12 h 2 ppm	24 h 1ppm	24 h 2 ppm	Control
4	2.19 ± 0.47 ^a	1.11 ± 0.74 ^a	1.83 ± 0.34 ^a	3.33 ± 1.95 ^a	1.33 ± 0.07 ^a
8	3.43 ± 0.49 ^{bc}	2.19 ± 0.81 ^c	3.41 ± 0.40	4.71 ± 0.198 ^b	2.47 ± 1.98 ^c
12	6.19 ± 2.48 ^a	5.50 ± 3.42 ^a	5.52 ± 0.83 ^a	6.03 ± 0.240 ^a	3.57 ± 2.46 ^a
16	8.81 ± 2.67 ^a	7.23 ± 4.45 ^a	7.33 ± 0.94 ^a	8.13 ± 2.5 ^a	6.09 ± 2.51 ^a

storage (14 °C, 85-90% RH)

Note: Data are presented as mean value ± SD
 Values with same letters are not significantly different ($p \leq 0.05$)

Physiological weight loss

The results showed that there is no significant difference among the different treatments. The weight loss can take place due to respiration, transpiration of water through the peel and due to other biological changes. But in cold storage, RH is high therefore evaporation loss is lower and respiration may cause to the weight loss. According to Ali et al. (2010) respiration causes a weight reduction because a carbon atom is lost from the fruit in each cycle.

Organoleptic properties of mango fruits

Consumers purchase the fruits and vegetables based on appearance and freshness. There are significant differences in taste and texture and overall acceptability of mango treated with 1-MCP compared to control. The organoleptic evaluation confirmed that there was an effect in the application of 1-MCP than the untreated sample. The highest preference was achieved by the control sample because the control sample had started its ripening at the 12 days after treatment. The least preference was observed in treated ripening compared to

control sample. However, among treatments, 24 h 1 ppm 1-MCP application showed better preference.

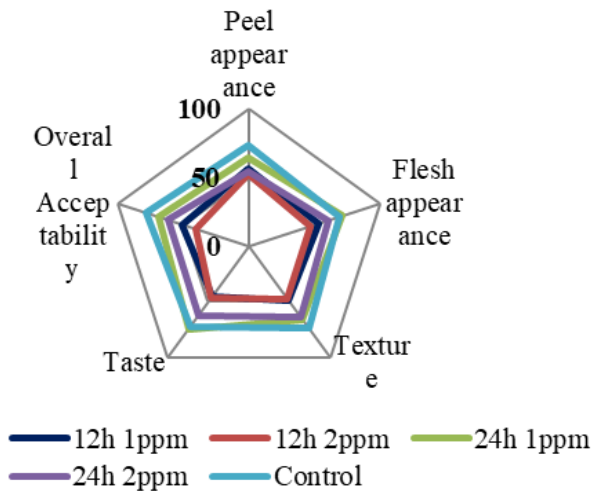


Figure 8: Sums of rank of sensory attributes for 1-MCP treated and control mango after 12 days in storage (14 °C, 85-90% RH)

Shelf-life evaluation

Results from the experiment showed that the application of 1-MCP had a positive effect in delaying the softness, reducing the ethylene production, reducing pH and TSS. And also it was found that 1-MCP treated mango had 4 to 12 days of longer storage life compared to control. TJC mango treated with the dosage of 2 ppm for 12 h exposure period had the longest shelf life of 28 days. Jiang and Joyce (2000) have earlier reported that application of 1-MCP between 1 and 100 ppm is effective for mango fruits and low concentrations do not extend the shelf life effectively. However, 1-MCP delayed ripening of mango successfully treated even with low concentrations when fruits are stored at 14°C but high concentrations may cause fruit to be unacceptable for consumption.

4. Conclusion

The research confirms that the application of 1-Methylcyclopropene (1-MCP) delayed the ripening of 'TJC' mango stored at low-temperature conditions (14°C and 85-90% RH). In fact, 1-MCP suppresses most of the physicochemical changes associated with mango ripening. Treating 'TJC' mango with 2 ppm 1-MCP for 12 hours extended its shelf life up to four weeks under low temperature.

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