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# Effect of 1-methylcyclopropene, potassium permanganate and silica gel on quality of cantaloupe fruits and carrot roots during mixed load

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## Abstract

This study was carried out during the 2023 and 2024 seasons, to study the effect of 1-methylcyclopropene (1-MCP), potassium permanganate ($KMnO_4$), silica gel, 1-MCP + silica gel and $KMnO_4$ + silica gel compared with control treatment on physical and chemical changes which may occur during mixed load of cantaloupe fruits cv. Primal Galia type and carrot roots cv. Laguna throughout storage at 5°C and 90-95 % relative humidity for 28 days. The results indicated that all treatments were superior to control treatment in maintaining quality attributes and extending the storability of fruits and roots. However, $KMnO_4$ + silica gel was the most effective treatment in reducing weight loss, color change, $O_2$ consumption, $CO_2$ and ethylene production and maintaining the firmness and total soluble solids of fruits and roots. In addition, delaying the ripening of cantaloupe fruits, reducing the increase of total carotenoid content of fruits, reducing isocoumarin accumulation and gave carrot roots without any bitterness until the end of the storage period. Also, gave an excellent appearance and did not exhibit any changes in the appearance of fruits and roots until the end of the storage period. On the other hand, control treatment gave an unsalable appearance of fruits and roots at the end of storage.

**Key words**: Mixed load, 1-methylcyclopropene, potassium permanganate, silica gel, cantaloupe, carrot, storability.

## Introduction

Fresh produce in the postharvest supply chain is often stored and transported with varying ethylene production rates and sensitivities. Ethylene sensitive commodities, such as snap beans, broccoli, and carrots, are often stored with ethylene producing fruits, such as cantaloupe, tomatoes, and bananas, in mixed loads during storage, transport, and retail or open market displays. This close proximity can lead to poor product quality as ethylene producing fruits can result in physiological disorders of ethylene sensitive items, accelerating ripening and senescence. These processes are major factors in the deterioration of fruit quality in the market (Pathak *et al*., 2017).

Cantaloupe is a climacteric fruit that produces increased ethylene and respiration rates during ripening and storage (Flores *et al*., 2007). Rapid ripening and short conservation period, 2 weeks or less (Karchi, 2000), is a result of this. Excessive softening, a yellow-orange rind color, flavor deterioration, reduced sugar content, increased susceptibility to pathogens, and loss of firmness making the fruit more susceptible to bacterial spoilage are all characteristic of overripe cantaloupe. In addition, the fruit loses water, shrivels quickly and accelerates the natural processes of development, ripening and senescence (Fallik *et al*., 2005).

Carrot roots are sensitive to ethylene exposure. Shelf life of carrots is significantly reduced when exposed to exogenous ethylene due to water loss, shriveling, and softening of root tissue, dehydration, loss of firmness, microbial spoilage and loss of sweetness and carotenoid content. Color changes, tissue cavitation, bitterness formation and altered flavor profiles can also be caused by ethylene exposure (Ergun and Hussein, 2018).

Bitterness is a key issue for carrots and is the main reason for the rejection of carrots by consumers (Kreutzmann *et al*., 2008). When carrots are exposed to ethylene, bitterness is induced through synthesis of isocoumarin (8-hydroxy-3-methyl-6-methoxy-3,4-dihydro-isocoumarin) (Seljasen *et al*., 2001), which is associated with bitterness in ethylene treated carrots, and the rate of isocoumarin formation increases with increasing ethylene concentrations (Lafuente *et al*., 1996).

To delay ripening, maintain cantaloupe quality, and reduce isocoumarin formation in carrots during mixed loading, low ethylene levels can be achieved using 1-methylcyclopropene, potassium permanganate, and silica gel.

1-Methylcyclopropene (1-MCP) is a cyclic alkene and seems to be the most practical an ethylene action inhibitor due to its stability, effectiveness at low concentrations, nontoxic properties, environmentally friendly and harmless to the public health (Blankenship and Dole, 2003). 1-MCP can block ethylene biosynthesis and action as it binds irreversibly to ethylene receptors in the plant cell and prevents ethylene from binding (Sisler and Serek, 2003). 1-MCP has been extensively used in postharvest studies to delay ripening, senescence and change of surface color, retain the firmness of fruits, maintain the quality and prolong the postharvest shelf life of 'Galia' melon fruits (Atala and El-Gendy, 2020). In addition, treatment of carrots with 1-MCP before exposure to exogenous ethylene inhibit the effect of ethylene, effectively decreased isocumarin accumulation in carrots and significantly lower sensory scores for bitterness during storage. Furthermore, treatment with 1-MCP prevented the increase in respiration and prevented postharvest quality deterioration and maintained quality attributes of carrots (Kramer *et al*., 2012).

The other technique of ethylene absorption with the use of potassium permanganate sachets ($KMnO_4$) is an alternative in the reduction of the ethylene produced during maturation, prolonging the pre-climacteric phase and the post-harvest life of the fruits (Sanches *et al*., 2019). Several studies have confirmed that the application of $KMnO_4$ can able to remove the ethylene from storage atmosphere by absorbing of ethylene and oxidizing it to carbon dioxide and water (Köstekli *et al*., 2016), reduced respiratory rate, retarded weight loss, delayed fruit ripening, senescence and softening of fruits, maintained quality and prolonged the shelf life of 'Galia' melons (Atala and El-Gendy, 2020).

Another system uses materials with high surface areas that can absorb ethylene either alone or in combination with an oxidizing agent, such as silica gel (Enriquez, 2020). European Union regulations (Ahvenainen, 2003) allow the use of silica gel ($SiO_2$) in food packaging. Silica gel is an absorbent and porous material with amorphous structure, and has hydrophilic properties which prevent the formation of excess moisture inside the package (Pratama and Sonjaya, 2023). Silica gel can be used as an ethylene absorbent to preserve the peel color of bananas, reduce weight loss (especially pulp to peel ratio), reduce decay incidence and maintain total soluble solids and sugar content of fruits (Enriquez, 2020).

Jayarajan and Sharma (2018) showed that a mixture of potassium permanganate ($KMnO_4$) and silica gel controls weight and firmness loss, reduces ethylene evolution and respiration rates and extends the shelf life of nectarines. Like Bhattacharjee and Dhua (2017), also found that a silica gel-permanganate mixture can be used to preserve the postharvest quality of bitter gourd fruits without causing disease.

Therefore, this study attempted to determine the effects of inhibiting, removing, or absorbing ethylene, as well as oxidation of ethylene from the storage environment by 1-MCP, $KMnO_4$, and silica gel on physical and chemical changes that may occur during mixed loading of cantaloupes and carrots during storage at 5°C for 28 days.

## Materials and methods

Cantaloupe fruits (*Cucumis melo* L.) cv. Primal Galia type were harvested at light yellow with green coloring stage and carrot roots (*Daucus carota* L.) cv. Laguna were harvested in the proper stage of marketing (fully mature) on February 22$^{nd}$ and 28$^{th}$ in 2023 and 2024 seasons, respectively, from a private farm at Fayed district, Ismailia Governorate, and transferred to the laboratory of Vegetable Handling Research Department, Horticultural Research Institute, Agricultural Research Center, and uniform fruits and roots in color, size, appearance, with no physical defects or fungal infection were selected and placed in the same carton box (33 cm x 23 cm x 12.5 cm) contained three cantaloupe fruits and three trays of carrot roots and each tray was approximately 250g, each box represented as one experimental unit (Eu) randomly distributed into six groups as follows: 1-methylcyclopropane (1-MCP) sheets contained 5% per box, potassium permanganate ($KMnO_4$) micro-perforated sachets contained 5g per box ($KMnO_4$ is placed on one side of the box to avoid staining the fruits), silica gel micro-perforated sachets (3.5 × 4 cm) contained 10g per box, 1-MCP sheets contained 5% + silica gel micro-perforated sachets (3.5 × 4 cm) contained 10g per box and $KMnO_4$ sachets contained 5g + silica gel micro-perforated sachets (3.5 × 4 cm) contained 10g per box ($KMnO_4$ is placed on one side of the box to avoid staining the fruits), in addition, untreated control.

Samples of all treatments were tightly overwrapped with polypropylene film (30µm thickness). Fifteen Eu were prepared from each treatment and stored at 5°C and 90-95 % relative humidity (RH) for 28 days. The samples were taken randomly in three experimental units and were arranged in a complete randomized design. Measurements were examined immediately after harvest and at 7 days' intervals (0, 7, 14, 21 and 28) of storage for the following characteristics:

**Loss in weight percentage**: It was calculated by the following equation: Loss in weight % = Initial weight of fruit - weight of fruit at sampling date / the initial weight of the fruit ×100.

**The general appearance (score)**: as evaluated using a scale from 9 to 1, where 9= excellent, 7= good, 5= fair, 3= poor and 1= unsalable fruits rating (5) or below were considered as unmarketable.

**Bitterness (score):** Bitterness was detected by a four-member panel using a hedonic scale of 1 to 5, where 1 = no bitterness detected; 2 = slight bitterness, distinguishable from harsh flavor; 3 = moderate bitterness, carrots noticeably bitter; 4 = carrots were very bitter; and 5 = carrots were extremely bitter, unpalatable sample (Lafuente *et al.*, 1996).

**Firmness ($kg/cm^2$):** Cantaloupe fruit firmness was determined at the same two positions on each fruit using a firmness tester, (Pressure Tester) with an 8 mm plunger and carrot roots firmness as recorded by TA- 1000 texture analyzer instrument using a penetrating cylinder of 1mm diameter, to a constant distance (3 and 5mm) inside the pulp of roots and by a constant speed 2mm per sec.

**External surface color:** It was evaluated by a color meter (Minolta CR 200) to measure the lightness (L* value) for cantaloupe fruit and carrot roots.

**Total soluble solids percentage (TSS %)**: It was determined as a composite juice sample by digital refractometer, "Model Abbe Leica" according to AOAC (2000).

**Total carotenoid content (mg/100g fresh weight):** It was determined according to AOAC (2000).

**Isocoumarin content (mg/100g fresh weight)**: It was determined according to Lafuente *et al.* (1996).

**Gas composition inside the packages**: It was measured using F-950 Handheld Ethylene Analyzer that measures 3 critical gases: Ethylene, $CO_2$ and $O_2$ to maintain optimum produce quality at every phase of handling during storage.

**Statistical analysis**: Statistical analysis was performed on the studied traits for each season and pooled analysis was carried out when the errors were homogeneous. The homogeneity of variances for the two seasons was checked by use of Levene (1960) test. The combined data across the two seasons of the study were analyzed.

## Results and discussion

**Weight loss**: The weight loss percentage of cantaloupe fruits and carrot roots during mixed load increased considerably and consistently with the prolongation of storage periods (Table 1). The loss in weight may be attributed to respiration, transpiration and other senescence-related metabolic processes during storage (Mandal *et al.,* 2017). Similar results were reported by Özdemir *et al*. (2018); Saleh *et al*. (2023).

Table 1. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on weight loss percentage of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| | Cantaloupe fruits | | | | | |
| 1-MCP | 0.00s | 0.65q | 1.21k | 2.34f | 3.08d | 1.46C |
| $KMnO_4$ | 0.00s | 0.59q | 1.13l | 2.01g | 2.65e | 1.28D |
| Silica gel | 0.00s | 0.73p | 1.31j | 2.60e | 3.86b | 1.70B |
| 1-MCP+SG | 0.00s | 0.41r | 0.90n | 1.56h | 2.04g | 0.98E |
| $KMnO_4$+SG | 0.00s | 0.34r | 0.74p | 0.97m | 1.23k | 0.65F |
| Control | 0.00s | 0.82o | 1.47i | 3.31c | 4.69a | 2.06A |
| Means | 0.00E | 0.59D | 1.13C | 2.13B | 2.93A | |
| | Carrot roots | | | | | |
| 1-MCP | 0.00r | 0.59n | 1.27i | 1.52h | 1.86f | 1.05C |
| $KMnO_4$ | 0.00r | 0.51op | 0.79lm | 1.11j | 1.34i | 0.75D |
| Silica gel | 0.00r | 0.92k | 1.66g | 2.18e | 2.73c | 1.50B |
| 1-MCP+SG | 0.00r | 0.45p | 0.62n | 0.85kl | 1.06j | 0.60E |
| $KMnO_4$+SG | 0.00r | 0.30q | 0.46p | 0.57no | 0.73m | 0.41F |
| Control | 0.00r | 1.49h | 2.29d | 2.89b | 3.86a | 2.11A |
| Means | 0.00E | 0.71D | 1.18C | 1.52B | 1.93A | |

Means in the same column and row having the same letter are not significantly different at $P$=0.05 level by Duncan's multiple range test.
*1-MCP :1-methylcyclopropane, $KMnO_4$: potassium permanganate, SG: Silica gel

All postharvest treatments reduced the weight loss of fruits and roots during storage as compared with control. After 28 days of storage, $KMnO_4$ + silica gel was the most effective treatment in reducing the weight loss, while control treatment gave the highest values of weight loss. These results were in agreement with Jayarajan and Sharma (2018) and Belwal *et al*. (2023).

The reducing weight loss % during storage may be due to that these materials removes or absorb exogenous ethylene from atmosphere surrounding produce (which produce from cantaloupe fruits), which decreased respiration rate and transpiration and consequently retarded weight loss (Wrzodak and Gajewski, 2015; Köstekli *et al.,* 2016; Jayarajan and Sharma, 2018). Also, these materials significantly delayed the onset of climacteric ethylene production and respiration rate, which diminished the weight loss in fruit during storage (Sammi and Masud, 2007).

**General appearance (GA):** There was a significant reduction in the general appearance (score) of cantaloupe fruits and carrot roots with the prolongation of the storage period (Table 2). These results were in agreement with Özdemir *et al.* (2018) and Saleh *et al.* (2023). Since ethylene released from fruits can promote respiration, the fruit quality characteristics change in their chemical composition, appearance and texture, leading to fruit ripening and senescence (Chanka *et al*., 2024).

All treatments had significantly the highest score of GA as compared with control which recorded the lowest score of GA and deteriorated rapidly. After 28 days of storage, $KMnO_4$ + silica gel treatment showed an excellent appearance and did not exhibit any changes in GA, while 1-MCP + silica gel treatment rated good appearance in cantaloupe fruits but gave an excellent appearance in carrot roots. On the other hand, untreated control had the unsalable appearance of fruits and roots. These results were in agreement with Aday and Caner (2011); Atala and El-Gendy (2020).

Table 2. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on general appearance (score) of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Mean |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| | Cantaloupe fruits | | | | | |
| 1-MCP | 9.00a | 9.00a | 8.33ab | 7.67bc | 6.33d | 8.07B |
| $KMnO_4$ | 9.00a | 9.00a | 9.00a | 7.67bc | 6.33d | 8.20B |
| Silica gel | 9.00a | 9.00a | 7.67bc | 7.00cd | 5.00e | 7.53C |
| 1-MCP+SG | 9.00a | 9.00a | 9.00a | 9.00a | 7.67bc | 8.73A |
| $KMnO_4$+SG | 9.00a | 9.00a | 9.00a | 9.00a | 8.33ab | 8.87A |
| Control | 9.00a | 7.00cd | 5.00e | 3.00f | 1.00g | 5.00D |
| Means | 9.00A | 8.67A | 8.00B | 7.22C | 5.78D | |
| | Carrot roots | | | | | |
| 1-MCP | 9.00a | 9.00a | 9.00a | 7.00cd | 6.33d | 8.07B |
| $KMnO_4$ | 9.00a | 9.00a | 9.00a | 7.67bc | 7.00cd | 8.33B |
| Silica gel | 9.00a | 9.00a | 8.33ab | 6.33d | 5.00e | 7.53C |
| 1-MCP+SG | 9.00a | 9.00a | 9.00a | 9.00a | 8.33ab | 8.87A |
| $KMnO_4$+SG | 9.00a | 9.00a | 9.00a | 9.00a | 9.00a | 9.00A |
| Control | 9.00a | 7.67bc | 6.33d | 4.33e | 1.67f | 5.80D |
| Means | 9.00A | 8.78AB | 8.44B | 7.22C | 6.22D | |

*For treatment and other details Table 1

Jayarajan and Sharma (2018) showed that the use of $KMnO_4$ + silica gel is very effective in controlling the loss in weight and firmness, and can be recommended to enhance the shelf life of nectarine without compromising the quality attributes. Also, 1-MCP treatment has a beneficial effect in delaying ripening and keeping general appearance of cantaloupes (Atala and El-Gendy, 2020). Fan and Mattheis (2000) indicated that ethylene-induced physiological disorders and quality loss in carrots can be prevented by 1-MCP treatment prior to exposure to ethylene.

**Bitterness of carrot roots**: Bitterness score increased gradually with the prolongation of storage period (Table 3) and these are in agreement with Lafuente *et al.* (1996). The increase in bitterness in carrots during storage may be attributed to the formation of isocoumarin, and the greater decrease in the taste quality of carrots might be due to their exposure to greater amounts of ethylene in the atmosphere (Yanmaz *et al.,* 1999). Also, Seljasen *et al.* (2001) found that ethylene-induced formation of isocoumarin was characterized in relation to ethylene-enhanced respiration in whole or cut carrots and showed that a bitter flavor (score of 2) was detected in carrots with about 20 mg isocoumarin/100g peel. Isocoumarin levels of about 50 to 150 mg/100 g peel typically resulted in scores of 2 to 3; scores of >3 was associated with variable but high isocoumarin levels (Lafuente *et al.,* 1996).

All treatments were effective in reducing bitterness as compared with the control treatment. Moreover, $KMnO_4$ + silica gel or 1-MCP + silica gel appeared without any bitterness until the end

Table 3. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on bitterness (score) of carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| 1-MCP | 1.00h | 1.00h | 1.00h | 1.67fg | 2.00ef | 1.33C |
| $KMnO_4$ | 1.00h | 1.00h | 1.00h | 1.67fg | 2.00ef | 1.33C |
| Silica gel | 1.00h | 1.00h | 1.00h | 2.67cd | 3.00c | 1.73B |
| 1-MCP+SG | 1.00h | 1.00h | 1.00h | 1.00h | 1.33gh | 1.07D |
| $KMnO_4$+SG | 1.00h | 1.00h | 1.00h | 1.00h | 1.00h | 1.00D |
| Control | 1.00h | 1.33gh | 2.33de | 3.67b | 4.67a | 2.60A |
| Means | 1.00C | 1.06C | 1.22C | 1.94B | 2.33A | |

*For treatment and other details Table 1

of the storage period. While the appearance of the bitter taste in the control treatment occurred after 14 days of storage and the bitter taste became more apparent in roots after 21 days of storage and the taste of carrots appeared very bitter and unpalatable at the end of the storage period.

Simões *et al.* (2011) found that baby carrots were below the limit of acceptance from the consumer point of view (score = 3), mainly due to the perception of a bitter flavor. One hypothesis suggests that the development of bitterness is related to the accumulation of isocoumarin (Czepa and Hofmann, 2003). Also, Kramer *et al.* (2012) found that treatment of carrot roots with 1-MCP before exposure to ethylene resulted in significantly lower sensory scores for bitterness due to 1-MCP inhibiting the effect of ethylene, where isocoumarin accumulation associated with bitterness in ethylene-treated carrots.

Potassium permanganate or 1-MCP or silica gel treatments resulted in significantly lower scores for bitterness in carrot roots during storage may be due to that these materials remove or absorb exogenous ethylene from atmosphere surrounding produce (which produce from cantaloupe fruits), thus decreasing respiration rate and ethylene production consequently reducing bitterness (Wrzodak and Gajewski, 2015; Köstekli *et al.,* 2016; Jayarajan and Sharma, 2018).

**Firmness**: There was a significant decrease in firmness of fruits and roots with a prolonged storage period (Table 4). These results were similar with Özdemir *et al*. (2018), and Atala and El-Gendy (2020). Ethylene significantly affects fruit firmness by stimulating cell wall hydrolysis, where ethylene release is closely related with the changes in activities of pectin-degrading enzymes such as pectin methylesterase (PME), and polygalacturonase (PG) which are responsible for cell wall degradation and contributes to the softening and quality deterioration of fruit (Fatima *et al*., 2023). In addition, the loss of firmness was closely associated with the breakdown of cell walls or reduction in the middle lamella cohesion due to the solubilization of the pectic substance which causes it to become softer (Wan Zaliha *et al*., 2014). Ripening induced the degradation of pectin and cellulose and the contents of water-soluble pectin gradually increased (Li *et al*., 2022). Also, water loss eventually causes carrot tissue to become soft (Ergun and Hussein, 2018).

All treatments are superior to control in reduce the loss in firmness of fruits and roots. After 28 days of storage, $KMnO_4$ + silica gel was the most effective treatment in reducing the loss of firmness

Table 4. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on firmness (kg/ $cm^2$) of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Mean |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| | Cantaloupe fruits | | | | | |
| 1-MCP | 6.80a | 6.20a-d | 5.32fg | 4.20ij | 3.50k | 5.20D |
| $KMnO_4$ | 6.80a | 6.27a-d | 5.80d-f | 4.70g-i | 4.08i-k | 5.53C |
| Silica gel | 6.80a | 6.08b-e | 4.83gh | 3.60jk | 2.75l | 4.81E |
| 1-MCP+SG | 6.80a | 6.50a-c | 6.10b-e | 5.18f-h | 4.63hi | 5.84B |
| $KMnO_4$+SG | 6.80a | 6.60ab | 6.37a-d | 5.95c-e | 5.55ef | 6.25A |
| Control | 6.80a | 5.80d-f | 4.20ij | 2.85l | 1.90m | 4.31F |
| Means | 6.80A | 6.24B | 5.44C | 4.41D | 3.74E | |
| | Carrot roots | | | | | |
| 1-MCP | 3.88a | 3.13d-g | 2.73h-k | 2.38kl | 2.27l | 2.88D |
| $KMnO_4$ | 3.88a | 3.28b-f | 2.98f-i | 2.70i-k | 2.43kl | 3.06C |
| Silica gel | 3.88a | 3.08d-h | 2.53j-l | 2.18l | 1.67m | 2.67E |
| 1-MCP+SG | 3.88a | 3.45b-d | 3.22c-g | 3.05e-i | 2.88g-j | 3.30B |
| $KMnO_4$+SG | 3.88a | 3.63ab | 3.53a-c | 3.40b-e | 3.25c-g | 3.54A |
| Control | 3.88a | 2.90g-j | 2.27l | 1.73m | 1.08n | 2.37F |
| Means | 3.88A | 3.25B | 2.88C | 2.58D | 2.26E | |

For treatment and other details Table 1

during storage, which recorded the highest values of firmness, while control recorded the lowest values of firmness. These results conform with Jayarajan and Sharma (2018); Chanka *et al*. (2024).

A sharp reduction in firmness in control may be due to cantaloupes being high ethylene producers which causes the degradation of the middle lamella of cell walls and the intracellular of fruits, thus leading to softening and increased firmness loss (Taye *et al*., 2019). However, all treatments were effective in inhibiting, removing, or absorbing and oxidizing exogenous ethylene produced by cantaloupe fruits (Li *et al*., 2011; Sarkar *et al*., 2017; Álvarez-Hernández *et al*., 2019), and slow the respiration rate and ripening process (Fatima *et al*., 2023). 1-MCP also inhibits cell wall degradation, maintains the compactness of cell walls and reduces the hydrolysis of water-soluble pectin, and enzymatic activities such as PG and PME (Taye *et al*., 2019). Thus, reducing softening and maintaining higher firmness during storage.

**Color (L* value):** There was a gradually decrease in lightness (L* value) of fruits and roots with prolonged storage period, which resulted in a darker peel color (Table 5). These results were in agreement with other workers (Özdemir *et al*., 2018; Atala and El-Gendy, 2020).

All treatments had significantly higher L* values as compared with control. After 28 days of storage, $KMnO_4$ + silica gel was the best treatment in reducing the loss of L* value which indicated that lighter peel (high L* value), while the lower L* value recorded in the control which indicated that darker peel (low L* value). These results are in conformity with Sarkar *et al.* (2017); Atala and El-Gendy (2020), and this may be due to these materials significantly delayed color development and peel color change, this was attributed to the removal of ethylene gas from the surrounding of the products (Al Fadil *et al*., 2016; Sarkar *et al*., 2017; Taye *et al*., 2019). Furthermore, Atala and El-Gendy (2020) found that cantaloupe fruits treated with 1-MCP reduced the

Table 5. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on color (L* value) of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Mean |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| | Cantaloupe fruits | | | | | |
| 1-MCP | 61.30a | 60.84a | 60.25a-d | 58.51fg | 55.21j | 59.22C |
| $KMnO_4$ | 61.30a | 60.91a | 60.38a-c | 58.93ef | 55.35j | 59.37C |
| Silica gel | 61.30a | 60.71ab | 59.68b-e | 56.81hi | 53.27k | 58.35D |
| 1-MCP+SG | 61.30a | 61.03a | 60.62ab | 59.25c-f | 57.61gh | 59.96B |
| $KMnO_4$+SG | 61.30a | 61.21a | 61.02a | 60.81ab | 59.43c-f | 60.76A |
| Control | 61.30a | 60.37a-c | 59.18d-f | 56.16ij | 51.32l | 57.67E |
| Means | 61.30A | 60.85A | 60.19B | 58.41C | 55.36D | |
| | Carrot roots | | | | | |
| 1-MCP | 53.14a | 52.41a-c | 50.59ef | 48.17h | 45.22j | 49.91D |
| $KMnO_4$ | 53.14a | 52.53ab | 51.02de | 48.88gh | 46.59i | 50.43C |
| Silica gel | 53.14a | 52.17a-c | 49.69fg | 46.94i | 43.42k | 49.07E |
| 1-MCP+SG | 53.14a | 52.66ab | 52.21a-c | 50.48ef | 48.21h | 51.34B |
| $KMnO_4$+SG | 53.14a | 52.79ab | 52.63ab | 51.48c-e | 50.01f | 52.01A |
| Control | 53.14a | 51.94b-d | 48.44h | 45.46j | 41.18l | 48.03F |
| Means | 53.14A | 52.42B | 50.76C | 48.57D | 45.77E | |

For treatment and other details Table 1

respiration rate, delayed fruit ripening and senescence processes and reduced color change, thus extending the shelf life of fruits due to inhibited production of ethylene (Muharrem *et al*., 2005).

**Total soluble solids**: The total soluble solids (TSS %) content decreases with the prolongation of the storage period of fruits and roots, as shown in (Table 6). These results are in agreement with Koca (2006); Atala and El-Gendy (2020). The reduction of TSS during storage has been attributed to hydrolysis and the utilization of the reducing sugars and acids, which are the main substrates in respiration (Almenar *et al*., 2009).

Table 6. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on TSS% of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Cantaloupe fruits | | | | | Means |
|---|---|---|---|---|---|---|
| | Storage period (day) | | | | | |
| | 0 | 7 | 14 | 21 | 28 | |
| 1-MCP | 11.63a | 11.10b-e | 10.30fg | 8.77j | 7.90l | 9.94D |
| $KMnO_4$ | 11.63a | 11.33a-c | 10.70ef | 9.27i | 8.53jk | 10.29C |
| Silica gel | 11.63a | 10.83de | 9.83gh | 8.17kl | 7.30m | 9.55E |
| 1-MCP+SG | 11.63a | 11.37a-c | 10.90c-e | 10.10g | 9.50hi | 10.70B |
| $KMnO_4$+SG | 11.63a | 11.47ab | 11.23a-d | 10.67ef | 10.13g | 11.03A |
| Control | 11.63a | 10.70ef | 9.40hi | 7.30m | 5.77n | 8.96F |
| Means | 11.63A | 11.13B | 10.39C | 9.04D | 8.19E | |
| | Carrot roots | | | | | |
| 1-MCP | 8.73a | 8.40a-e | 8.13c-g | 7.99e-h | 7.05j | 8.06C |
| $KMnO_4$ | 8.73a | 8.43a-d | 8.00e-h | 7.94f-h | 7.20j | 8.06C |
| Silica gel | 8.73a | 8.37a-f | 8.03d-h | 7.37ij | 6.56k | 7.81D |
| 1-MCP+SG | 8.73a | 8.50a-c | 8.40a-e | 8.17c-g | 7.70hi | 8.30B |
| $KMnO_4$+SG | 8.73a | 8.67ab | 8.63ab | 8.53a-c | 8.27b-g | 8.57A |
| Control | 8.73a | 8.33a-f | 7.87gh | 7.10j | 6.05l | 7.62E |
| Means | 8.73A | 8.45B | 8.18C | 7.85D | 7.14E | |

For treatment and other details Table 1

All treatments maintain TSS % of fruits and roots compared with control. After 28 days of storage, $KMnO_4$ + silica gel was the best treatment in retained more TSS, while control treatment had the lowest value of TSS. These results are agreement with Atala and El-Gendy (2020); Enriquez (2020), and this may be due to these materials inhibit exogenous ethylene, reduce respiration rate and physiological changes during storage (Muharrem *et al*., 2005; Enriquez, 2020; Chanka *et al*., 2024), thus delaying the ripening and senescence and maintaining TSS (Atala and El-Gendy, 2020; Enriquez, 2020).

**Total carotenoids of cantaloupe fruits**: Data in (Table 7) show that there was a significant increase in the total carotenoids content of fruits with the prolongation of storage periods. These results were in agreement with Saleh *et al.* (2023). The color of cantaloupe fruits became yellow to orange with the storage time, which may be due to the breakdown of chlorophyll and synthesis of carotenoids, a pigment contributing to orange color in cantaloupe fruit (Muharrem *et al.,* 2005). Also, Watkins and Nock (2012) reported that cantaloupes are high ethylene producers; ethylene accelerates chlorophyll degradation and the appearance of yellow or orange colors. Ethylene also promotes ripening of the pulp.

All treatments show significantly lowest content of total carotenoids of cantaloupes as compared with control which gave the highest value of total carotenoids as intense yellow. After 28 days of storage, $KMnO_4$ + silica gel was the most effective treatment in reducing the increase of carotenoids content and gave the lowest value of total carotenoids, while the highest ones were obtained from control. These results were in agreement with Belwal *et al*. (2023). $KMnO_4$ treatment documented lower chlorophyll degradation owing to its ethylene oxidizing property which delayed ripening, thereby reducing chlorophyllase activity and inhibiting the synthesis of carotenoids of bitter gourd fruits (Bhattacharjee and Dhua, 2017).

Table 7. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on carotenoids (mg/ 100g fresh weight) of cantaloupe fruits during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| $KMnO_4$ | 3.18m | 3.32j-m | 3.49g-j | 3.73c-e | 3.82cd | 3.51C |
| Silica gel | 3.18m | 3.37i-l | 3.61e-g | 3.89c | 4.09b | 3.63B |
| 1-MCP+SG | 3.18m | 3.30k-m | 3.39h-l | 3.58e-g | 3.71d-f | 3.43D |
| $KMnO_4$+SG | 3.18m | 3.26lm | 3.31k-m | 3.34j-m | 3.45g-k | 3.31E |
| Control | 3.18m | 3.55f-h | 3.86cd | 4.07b | 4.46a | 3.83A |
| Means | 3.18E | 3.36D | 3.54C | 3.74B | 3.90A | |

For treatment and other details Table 1

Muharrem *et al.* (2005) reported that cantaloupe fruits treated with 1-MCP delayed fruit ripening and reduce accumulation of carotenoids, thus extending the shelf life of cantaloupe fruits. Also, Jiang and Fu (2000) found that differential effects of 1-MCP on color development depend on the multiplicity of pigment changes contributing to final fruit color (chlorophyll degradation, selective pigment synthesis or both) and their relative dependency on ethylene responsiveness. Also, they added that 1-MCP acts as high affinity noncompetitive inhibitor of ethylene action.

**Isocoumarin content of carrot roots**: Sensory appearance of carrots is determined by several compounds, while a specific bitter taste depends on the content of phenolic, especially isocoumarin, which associated with bitterness in carrots (Kramer *et al*., 2012). As shown in (Table 8), there was a significant increase in isocoumarin concentrations of carrot roots during mixed load with cantaloupe fruits with prolonged the storage period.

Table 8. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on isocoumarin content (mg/100g fresh weight) of carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| 1-MCP | 0.00k | 0.00k | 5.00ij | 14.00f | 20.00e | 7.80C |
| $KMnO_4$ | 0.00k | 0.00k | 0.00k | 12.00fg | 18.00e | 6.00D |
| Silica gel | 0.00k | 0.00k | 7.00hi | 25.00d | 37.00c | 13.80B |
| 1-MCP+SG | 0.00k | 0.00k | 0.00k | 3.00jk | 8.00hi | 2.20E |
| $KMnO_4$+SG | 0.00k | 0.00k | 0.00k | 0.00k | 3.00jk | 0.60E |
| Control | 0.00k | 10.00gh | 21.00e | 47.00b | 63.00a | 28.20A |
| Means | 0.00E | 1.67D | 5.50C | 16.83B | 24.83A | |

For treatment and other details Table 1

These findings are in agreement with Lafuente *et al*. (1996), and this may be due to isocoumarin accumulation is induced by exposure to low concentrations of ethylene (Fan and Mattheis, 2000). In addition, Lafuente *et al*. (1996) indicated that the more rapid the respiratory rise in response to ethylene, the more rapidly isocoumarin accumulated. The greater the respiratory response to ethylene, the higher the level of isocoumarin formed. Also, the rate of isocoumarin formation generally increased with increasing ethylene concentrations.

All treatments were effective in decreasing the accumulation of isocoumarin in roots compared with control. After 28 days of storage, $KMnO_4$ + silica gel treatment recorded the lowest value of isocumarine content in roots, while, the highest ones were recorded in control. These results are in conformity with Fan and Mattheis (2000); Kramer *et al*. (2012), and this may be due to these materials can inhibits, removes or absorbs ethylene from atmosphere surrounding product (Abu-Goukh, 2013; Enriquez, 2020; Chanka *et al*., 2024), thus reduce the accumulation of isocoumarin in carrot. Furthermore, Fan and Mattheis (2000) reported that treatment with 1-MCP before exposure to ethylene prevented isocoumarin accumulation in carrot roots, due to the accumulation of isocoumarin in carrot can be reduced by avoiding exposure to ethylene and to other stresses that induce ethylene production, where 1-MCP inhibits ethylene action by irreversibly binding to ethylene receptors (Mattheis *et al*., 2003).

**Gas composition inside the packages**: As shown in (Table 9, 10 and 11), there was a significant decrease in $O_2$ % and increase in $CO_2$ % and ethylene concentration (ppm) inside the packages with prolonged the storage period. These findings are in agreement with Ergun and Hussein (2018); Atala and El-Gendy (2020), and these may be due to oxygen consumption and carbon dioxide production of fruits and roots during respiration process (Flores *et al*., 2007; Simões *et al*., 2011). In addition, cantaloupe is a climacteric fruit that exhibit a peak in respiration and a sharp increase in ethylene production during ripening (Flores *et al*., 2007).

Table 9. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on $O_2$ (%) of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| 1-MCP | 20.80a | 19.20e | 17.55g | 16.27h | 13.70k | 17.50D |
| $KMnO_4$ | 20.80a | 19.80cd | 18.27f | 16.70h | 14.40j | 17.99C |
| Silica gel | 20.80a | 19.03e | 16.60h | 14.75j | 12.55l | 16.75E |
| 1-MCP+SG | 20.80a | 19.97b-d | 19.03e | 18.25f | 16.52h | 18.91B |
| $KMnO_4$+SG | 20.80a | 20.45ab | 20.22bc | 19.70d | 18.18f | 19.87A |
| Control | 20.80a | 18.93e | 15.33i | 12.80l | 10.33m | 15.64F |
| Means | 20.80A | 19.56B | 17.83C | 16.41D | 14.28E | |

*For treatment and other details Table 1

Table 10. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on $CO_2$ (%) of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| 1-MCP | 0.03m | 0.67k | 1.77gh | 3.03e | 4.20c | 1.94C |
| $KMnO_4$ | 0.03m | 0.60k | 1.20i | 2.03fg | 2.90e | 1.35D |
| Silica gel | 0.03m | 0.77jk | 2.27f | 4.07c | 5.37b | 2.50B |
| 1-MCP+SG | 0.03m | 0.50kl | 1.10ij | 1.60h | 2.27f | 1.10E |
| $KMnO_4$+SG | 0.03m | 0.20lm | 0.53kl | 0.83jk | 1.20i | 0.56F |
| Control | 0.03m | 1.67h | 3.60d | 5.30b | 7.53a | 3.63A |
| Means | 0.03E | 0.73D | 1.74C | 2.81B | 3.91A | |

*For treatment and other details Table 1

Table 11. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on ethylene concentration (ppm) of cantaloupe fruits and carrot roots during mixed load (combined analysis of two seasons)

| Treatments* | Storage period (day) | | | | | Means |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | |
| 1-MCP | 0.00i | 0.00i | 0.10fg | 0.17e | 0.32d | 0.12C |
| $KMnO_4$ | 0.00i | 0.00i | 0.06g-i | 0.14ef | 0.27d | 0.09C |
| Silica gel | 0.00i | 0.05g-i | 0.15ef | 0.30d | 0.47c | 0.19B |
| 1-MCP+SG | 0.00i | 0.00i | 0.00i | 0.03g-i | 0.09f-h | 0.02D |
| $KMnO_4$+SG | 0.00i | 0.00i | 0.00i | 0.00i | 0.02hi | 0.00D |
| Control | 0.00i | 0.10fg | 0.32d | 0.57b | 0.89a | 0.38A |
| Means | 0.00D | 0.02D | 0.11C | 0.20B | 0.34A | |

*For treatment and other details Table 1

There were significant differences between all treatments and control of the gas composition inside the packages. After 28 days of storage, $KMnO_4$ + silica gel treatment recorded the high levels of $O_2$ and the low levels of $CO_2$ and ethylene inside the package, while, the low level of $O_2$ and the high levels of $CO_2$ and ethylene recorded in control. This was also confirmed by the variations in $O_2$, $CO_2$, and ethylene concentrations over the storage period compared to the initial concentrations. These results are in conformity with Enriquez (2020); Chanka *et al*. (2024), and this may be due to these materials can block, remove, absorb and oxidation exogenous ethylene which produce from cantaloupe fruits, so preventing ethylene production, inhibiting ethylene biosynthesis and action of ethylene and decreased respiration rate, and consequently reduced the consumption of $O_2$ and decreased accumulation of $CO_2$ and ethylene concentrations inside the packages (Taye *et al*., 2019; Enriquez, 2020; Chanka *et al*., 2024).

Furthermore, 1-MCP and $KMnO_4$ reduced 1-aminocyclopropane-1-carboxylic acid (ACC) synthase (ACS) and/or 1-aminocyclopropane-1-carboxylic acid oxidase (ACO) enzymes activities which related to ethylene biosynthesis, resulting in decreased ethylene biosynthesis and consequently ethylene-induced respiration (Wan Zaliha *et al*., 2014). The low level of ACC in climacteric fruit is a limiting factor that regulates ethylene production. ACC starts to accumulate due to increased activity of ACS which is responsible in the conversion of ACC to ethylene; where ACS is the key enzyme of ethylene biosynthesis, being responsible for converting S-adenosyl-L-methionine to ACC, while ACO subsequently oxidizes ACC to ethylene (Li *et al*., 2011). 1-MCP forms a double bond with the receptor metal; thus, 1-MCP has inhibited the transmission of the ethylene signal, inhibiting ethylene action in a signaling pathway and directly preventing ethylene production (Atoo *et al*., 2022).

Mixed load of cantaloupe fruits cv. Primal Galia type and carrot roots cv. Laguna packed with potassium permanganate + silica gel was the most effective treatment for delaying fruits ripening of cantaloupe and maintaining quality of roots and fruits during storage which gave excellent appearance without any bitter taste in roots until 28 days of storage at 5°C and 90-95 % relative humidity.

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