

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 (KMnO₄), silica gel, 1-MCP + silica gel and KMnO₄ + 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, KMnO₄ + silica gel was the most effective treatment in reducing weight loss, color change, O₂ consumption, CO₂ 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 isocoumarin 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 (KMnO₄) 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 KMnO₄ 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 (SiO₂) 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 (KMnO₄) 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, KMnO₄, 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 22nd and 28th 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 (KMnO₄) micro-perforated sachets contained 5g per box (KMnO₄ 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 KMnO₄ sachets contained 5g + silica gel micro-perforated sachets (3.5 × 4 cm) contained 10g per box (KMnO₄ 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/cm²): 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, CO₂ and O₂ 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, KMnO₄: 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, KMnO₄ + 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

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

compared with control which recorded the lowest score of GA and deteriorated rapidly. After 28 days of storage, KMnO₄ + 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).

Jayarajan and Sharma (2018) showed that the use of KMnO₄ + 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, KMnO₄ + 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, KMnO₄ + silica gel was the most effective treatment in reducing the loss of firmness during storage, which recorded the highest values of firmness, while control recorded the lowest values of firmness. These results

Table 4. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on firmness (kg/ cm²) 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

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, KMnO₄ + 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 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).

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

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).

All treatments maintain TSS % of fruits and roots compared with control. After 28 days of storage, KMnO₄ + silica gel was the best

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-c	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

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, KMnO₄ + 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). KMnO₄ 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	
1-MCP	3.18m	3.34j-m	3.54f-i	3.81cd	3.87cd	3.55C
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, KMnO₄ + silica gel treatment recorded the lowest value of isocoumarin 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 O₂ % and increase in CO₂ % 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).

There were significant differences between all treatments and control of the gas composition inside the packages. After 28 days

Table 9. Effect of 1-methylcyclopropane, potassium permanganate and silica gel treatments and storage period on O₂ (%) 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 CO₂ (%) 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

of storage, KMnO₄ + silica gel treatment recorded the high levels of O₂ and the low levels of CO₂ and ethylene inside the package, while, the low level of O₂ and the high levels of CO₂ and ethylene recorded in control. This was also confirmed by the variations in O₂, CO₂, 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 O₂ and decreased accumulation of CO₂ and ethylene concentrations inside the packages (Taye *et al.*, 2019; Enriquez, 2020; Chanka *et al.*, 2024).

Furthermore, 1-MCP and KMnO₄ 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 (Atoot *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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