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Delaying Ripening and Maintaining Cherry Tomato Fruits Quality by Some Postharvest Applications

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ABSTRACT

This research was conducted through the 2024 and 2025 seasons on cherry tomatoes cv. Katalina-522. Cherry tomatoes were harvested when they reached the pink stage to study the effect of various postharvest applications (1-methylcyclopropene (1-MCP) at 5%, activated carbon at 5g, active modified atmosphere packaging (MAP) at 3% O_2 + 5% CO_2 and 5% O_2 + 5% CO_2 and passive MAP) in addition to untreated fruits (control) on delaying ripening and preserving the quality characteristics of cherry tomatoes through cold storage at 10ºC with relative humidity 90-95% for 30 days. The findings showed that all postharvest applications outperformed the untreated fruits in preserving fruit quality and prolonging the storage period. However, 1-MCP and activated carbon treatments were successful in slowing down ripening and preserving quality attributes through all storage periods. Furthermore, 1-MCP proved to be the most efficient treatment in decreasing weight loss, lycopene accumulation, changes of color, and ethylene production and modifying the atmosphere inside the package, in addition to maintaining firmness, titratable acidity and total soluble solids, and the appearance of fruits was excellent after 30 days of storage with no signs of decay.

KEYWORDS: cherry tomato, 1-methylcyclopropene, activated carbon, modified atmosphere packaging, delaying ripening, storability.

1. INTRODUCTION

Cherry tomatoes are extremely perishable and have a short shelf life after harvest due to their elevated water content and rapid production of ethylene and rates of respiration (Taye et al., 2017), leading to faster ripening and quality deterioration (Alexander & Grierson, 2002; Bailén et al., 2006). As climacteric fruits, they follow a ripening pattern that continues after harvest and is largely driven by ethylene production (Carrari & Fernie, 2006). This process involves a peak in rate of respiration and a significant rise in ethylene levels (Akbudak et al., 2007), which negatively impacts key quality characteristics including firmness, color, total soluble solids and acidity. These changes accelerate ripening and senescence, ultimately affecting the fruit's overall sensory quality (Martínez-Romero et al., 2007). Tomato fruits face several postharvest challenges, including high metabolic and physiological activity, quality deterioration, shriveling, rapid decay, and senescence (El-Ramady et al., 2015). In order to mitigate these issues, most postharvest storage methods focus on regulating respiration and ethylene activity to slow down these changes (Martínez-Romero et al., 2007). Consequently, it is essential to develop cost-effective and efficient techniques to control microbial contamination, delay ripening, prolong storage duration, and preserve fruit quality, as well as extend the postharvest life of cherry tomato fruits, especially during combination with storage in low temperatures.

1-Methylcyclopropene (1-MCP) is a widely used postharvest technology that helps minimize the effects of ethylene and prolong the storage life of climacteric fruits (Satekge & Magwaza, 2022). 1-MCP inhibits ethylene action and prolongs the postharvest life of tomatoes (Sabir & Agar, 2011) by blocking ethylene receptors. This reduces respiration rates and ethylene production, thereby slowing ripening, maintaining firmness, preserving titratable acidity, chlorophyll degradation, and delaying lycopene accumulation (Guillén et al., 2007).

Activated carbon (AC) is well known for its excellent adsorption properties. It is produced from renewable sources, making it a natural, eco-friendly, non-toxic, edible, odorless, reusable, and cost-effective material. Additionally, it can be locally manufactured using organic waste and serves multiple purposes. AC has the ability to release adsorbed antimicrobial agents, helping to prevent pathogenic growth or bacteria. At the same time, free carbon atoms on its surface can absorb gaseous molecules such as oxygen, water vapor, ethylene, and odor, which are key factors that contribute to the causes of food deterioration and senescence, thereby impacting the quality and the safety of food (Chaemsanit et al., 2018). Activated carbon has proven to be effectively used with the aim of lowering ethylene levels, slowing ripening, and enhancing fruit firmness and preserving quality, in addition to extending the postharvest life of tomato fruits (Bailén et al., 2007).

Modified atmosphere packaging (MAP) is a commonly employed method to slow the ripening of fruits after harvest and delay related changes of biochemical and physiological through optimizing the levels of O_2 and CO_2 surrounding the produce (Akbudak et al., 2007). Furthermore, Fagundes et al. (2015) noted that storing cherry tomatoes in an active MAP environment containing 5% oxygen and 5% carbon dioxide reduced the production of ethylene and respiration rates, minimized the loss of weight, lycopene biosynthesis, red color development and firmness loss, inhibited the growth of decay-causing pathogens, effectively delayed ripening, maintained quality, and prolonged postharvest life. Similarly, Akbudak et al. (2012) demonstrated that passive MAP was also beneficial in maintaining the cherry tomatoes quality throughout the storage.

This research aimed to assess the impact of 1-methylcyclopropene, activated carbon, and modified atmosphere packaging on delaying ripening, maintaining the quality of fruits, and extending the storability of cherry tomato fruits throughout the storage until 30 days at 10°C.

2. MATERIALS AND METHODS

Cherry tomato fruits (*Solanum lycopersicum* var. cerasiforme), cultivar Katalina-522, were harvested when they reached the pink stage, with approximately 50-60% of the fruit surface showing red coloration, from a private farm in Wadi El-Natrun, El-Behira Governorate. The fruits were harvested on January 3rd and 5th during the 2024 and 2025 seasons, respectively, and then transported to the laboratory of Vegetable Handling Research Department, Horticultural Research Institute, Agricultural Research Center, Giza, Egypt. For the storage experiment, only fruits with uniform color, size (20-25 mm in diameter), and appearance, free from fungal infection or any physical defects, were carefully selected.

Cherry tomatoes were packed in transparent plastic punnets; each punnet contains about 250 g of fruit. Three punnets were packed in a carton box (30 cm × 22 cm × 7.5 cm) and enclosed with a polypropylene bag (30 µm thickness), constituting an experimental unit. Experimental units were divided into six different treatments: exposure to 1-methylcyclopropene (1-MCP) sheets containing 5%, activated carbon micro-perforated sachets (3.5 × 4 cm) containing 5 g, active modified atmosphere packaging (MAP) flushed with various gas mixtures of 3% O_2 + 5% CO_2, and 5% O_2 + 5% CO_2, passive MAP treatment (without gas flushing), as well as untreated fruits as a control treatment.

Each treatment consists of eighteen experimental units, and all treatments were stored at 10ºC with 90-95% relative humidity. All samples were organized according to a complete randomized design. From each treatment, three experimental units were randomly selected and immediately assessed after harvest, as well as after 5, 10, 15, 20, 25, and 30 days of storage, to assess the following characteristics:

1. **Weight loss (%):** This was measured using the following equation: $[(W_a-W_b)/W_a] \times 100$.

Where: W_a= Initial fruit weight, W_b = fruit weight at the sampling period

2. **General appearance:** This was assessed using a 9-point score**,** where 9 is excellent, 7 is good, 5 is fair, 3 is poor, and 1 is unsalable. Fruits with a rating of 5 or lower were considered unmarketable, following the criteria established by Kader (2002).
3. **Decay:** The severity of fruit decay and disorders was assessed using a subjective scoring system based on a 1 to 5 scale, where 1: no decay, 2: slight decay, 3: moderate decay, 4: severe decay, and 5: extreme decay, as described by Wang and Qi (1997).
4. **Fruit firmness:** This was evaluated with a hand pressure tester (Italian model) featuring an 8 mm plunger, and the results were recorded in kg/cm^2 (Abbott, 1999).
5. **External surface color:** The fruit color was evaluated with a Minolta CR-400 Chroma Meter. The a* value was recorded to describe red-green intensity, where a*>0 indicates red intensity and a*<0 indicates green intensity.
6. **Total soluble solids (%):** This was assessed using the digital refractometer (model 3-34), following the method described by AOAC (1990)**.**
7. **Titratable acidity (%):** This was measured through titration with 0.1 N NaOH using indicator phenolphthalein, as outlined by AOAC (1990).
8. **Lycopene content (mg/g fresh weight):** Lycopene concentration was assessed according to the method outlined by Anthon and Barrett (2006).
9. **Gas composition in packages:** This was measured using the F-950 handheld ethylene analyzer, which measures oxygen, carbon dioxide and ethylene to ensure optimal produce quality throughout the storage period.

2.1. Statistical analysis:

Data analysis was carried out using MSTATC software to determine the means, variance, and standard error. The Least Significant Difference (LSD) at a 5% significance level was calculated to assess mean differences, following the method outlined by Snedecor and Cochran (1980).

3. RESULTS AND DISCUSSION

3.1. Weight loss

Water loss is a major factor in deterioration, leading to a reduction in marketable weight, which results in quantitative crop losses. Additionally, it negatively impacts quality by causing wilting, shriveling, and tissue softening (Irtwange, 2006). The findings show that postharvest treatments, storage periods, and their interactions significantly influenced the percentage of weight loss in fruits during two seasons, as illustrated in Table (1). The data indicate a gradual increase in weight loss percentage with prolonged storage periods due to the ripening process, consistent with the results of Gharezi et al. (2012), due to nutrient consumption during respiration and the exchange of water caused by differences in the pressure of the water vapor gradient between the tissue and the ambient air during the entire storage period (Won et al., 2018). However, cherry tomatoes treated with all postharvest applications exhibited significantly

Table 1. The impact of various postharvest applications on the percentage of weight loss in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
First season (2024)								
1-MCP	0.00 t	0.10 st	0.12 st	0.19 r-t	0.25 q-s	0.32 p-s	0.50 l-p	0.21 E
AC	0.00 t	0.12 st	0.21 q-t	0.32 p-s	0.41 n-r	0.62 j-n	0.82 i-k	0.36 D
Active MAP ($3\%O_2+5\%CO_2$)	0.00 t	0.18 r-t	0.31 p-s	0.57 k-o	0.70 j-l	0.96 hi	1.32 g	0.58 C
Active MAP ($5\%O_2+5\%CO_2$)	0.00 t	0.13 st	0.25 q-s	0.33 o-s	0.45 m-q	0.70 j-l	0.96 hi	0.40 D
Passive MAP	0.00 t	0.27 p-s	0.40 n-r	0.66 j-m	0.84 ij	1.26 g	1.58 f	0.72 B
Control	0.00 t	1.15 gh	2.06 e	2.95 d	3.81 c	4.52 b	5.30 a	2.83 A
Mean	0.00 G	0.33 F	0.56 E	0.84 D	1.08 C	1.40 B	1.75 A	
Second season (2025)								
1-MCP	0.00 x	0.07 w	0.09 uv	0.16 tu	0.21 st	0.27 p-r	0.42 n	0.17 F
AC	0.00 x	0.09 vw	0.11u-w	0.23 rs	0.35 o	0.56 l	0.71 j	0.29 E
Active MAP ($3\%O_2+5\%CO_2$)	0.00 x	0.14 uv	0.25 q-s	0.50 m	0.63 k	0.88 h	1.11 g	0.50 C
Active MAP ($5\%O_2+5\%CO_2$)	0.00 x	0.11 u-w	0.21 st	0.30 o-q	0.41 n	0.65 k	0.83 hi	0.36 D
Passive MAP	0.00 x	0.20 st	0.32 op	0.60 kl	0.78 i	1.14 g	1.51 f	0.65 B
Control	0.00 x	1.13 g	2.04 e	2.83 d	3.69 c	4.45 b	5.15 a	2.76 A
Mean	0.00 G	0.29 F	0.50 E	0.77 D	1.01 C	1.33 B	1.62 A	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

minimized loss of weight as compared with untreated fruits. After 30 days of storage, the findings reveal that the treatment by 1-methylcyclopropene (1-MCP) resulted in the lowest weight loss percentage, followed by activated carbon (AC) and active modified atmosphere packaging (MAP) at 5% O_2 + 5% CO_2, with a significant variation between them. Meanwhile, the untreated fruits exhibited the highest weight loss percentage. These results were consistent with Bailén et al. (2006), Taye et al. (2017), Gaikwad et al. (2020) and Bahar et al. (2022), and this was attributed to these treatments (1-MCP, AC, or active MAP at 5% O_2 + 5% CO_2) removing, absorbing or inhibiting the production of ethylene and decreasing the rate of respiration, thus reducing the loss of weight loss of tomatoes (Bailén et al., 2007, Wrzodak and Gajewski, 2015 and Taye et al., 2017). Furthermore, the active modification of the atmosphere inside the packaging, along with the high humidity maintained by reducing the transpiration rate and balancing the moisture between the fruits and the package, significantly delayed water loss in cherry tomatoes, thereby delaying the ripening process (Manasa et al., 2018).

3.2. General appearance

The general appearance score of cherry tomatoes was significantly influenced by postharvest treatments, storage durations, and their interactions in the two seasons, as illustrated in Table (2). The data show a significant decline in general appearance with prolonged storage periods; these are confirmed by Mohammed et al. (2021). This decline may be attributed to wilting, shriveling, decay, color changes, and overall deterioration (Zeng et al., 2020). Shrinkage is a key indicator of deterioration, resulting in a deterioration of quality and a reduction in quantity (Gharezi et al., 2012). However, all postharvest applications resulted in significantly higher

Table 2. The impact of various postharvest applications on the general appearance (score) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	8.91 A
AC	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	7.00 cd	8.43 B
Active MAP ($3\%O_2$+$5\%CO_2$)	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	6.33 d	5.00 e	7.76 C
Active MAP ($5\%O_2$+$5\%CO_2$)	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	6.33 d	8.33 B
Passive MAP	9.00 a	9.00 a	8.33 ab	7.00 cd	6.33 d	5.00 e	3.00 f	6.81 D
Control	9.00 a	8.33 ab	7.00 cd	6.33 d	5.00 e	3.00 f	1.00 g	5.67 E
Mean	9.00 A	8.89AB	8.56 B	8.11 C	7.44 D	6.44 E	5.11 F	
				Second season (2025)				
1-MCP	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	8.91 A
AC	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	7.00 cd	8.43 B
Active MAP ($3\%O_2$+$5\%CO_2$)	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	6.33 d	5.00 e	7.76 C
Active MAP ($5\%O_2$+$5\%CO_2$)	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	6.33 d	8.33 B
Passive MAP	9.00 a	9.00 a	8.33 ab	7.67 bc	6.33 d	5.00 e	3.00 f	6.91 D
Control	9.00 a	8.33 ab	7.00 cd	6.33 d	5.00 e	3.67 f	1.00 g	5.76 E
Mean	9.00 A	8.89 A	8.56AB	8.22 B	7.44 C	6.56 D	5.11 E	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.
*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

general appearance scores of cherry tomatoes compared to the control treatment. Furthermore, 1-MCP maintained the excellent appearance of the fruits with no noticeable changes until 30 days of storage. Activated carbon showed the good appearance of fruits after 30 days, while active MAP (5% O_2 + 5% CO_2) showed the good appearance of fruits after 25 days of storage. In contrast, untreated fruits recorded the lowest appearance score, making them unsalable until 30 days of the storage period. These findings are in line with Domínguez et al. (2016), Ibrahim and Abdullah (2018) and Atala and El-Gendy (2020).

1-MCP suppressed enzyme activities associated with cell wall breakdown and ethylene production (Zhang et al., 2020). Moreover, it regulated both ethylene biosynthesis and respiration, thereby delaying ripening in cherry tomato fruits (Taye et al., 2017). Additionally, 1-MCP treatment decreased the production of ethylene, delayed the climacteric peak and ripening, and extended the fruits' shelf life (Opiyo and Ying, 2005).

Activated carbon can adsorb gases like oxygen, water vapor, and ethylene, thereby decreasing deterioration and senescence, preserving fruit quality characteristics, and extending postharvest life (Chaemsanit et al., 2018). Furthermore, ripening characteristics such as color change, weight loss, and firmness progressed at a slower rate in tomatoes treated by activated carbon acting as an ethylene scavenger, an effect attributable to the role of ethylene in triggering these parameters (Alexander and Grierson, 2002). Consequently, adding activated carbon inside the packages to remove ethylene from the environment can delay ripening, maintain quality, and extend the storability of tomatoes (Bailén et al., 2006).

In MAP treatment, a reduction in oxygen concentration slows down respiration and metabolic activities, while an increase in CO_2

concentration decreases ethylene sensitivity, delays chlorophyll degradation, and inhibits fungi. These benefits of modified atmosphere packaging enable producers and wholesalers to extend the storability of fresh products (Abou-Zaid et al., 2020). Furthermore, Manasa et al. (2018) reported that cherry tomatoes stored in MAP maintained their storability over 33 days, whereas those in the control treatment lasted only 15 days.

3.3. Decay

As presented in Table (3), the data reveal that postharvest applications, storage durations, and their interaction significantly impact decay (score) in both seasons. The decay score of cherry tomatoes increased significantly with prolonged storage period, which aligns with Abdullah and Ibrahim (2018). This was attributed to the physiological changes that occurred in the fruits through storage, including increased respiration rates, enhanced enzyme activity, and cell wall degradation. These factors led to fruit softening and ripening, resulting in greater moisture condensation on the fruit's surface, reduced firmness, and increased susceptibility to fungal infections (Juan et al., 1999). Furthermore, all postharvest applications had a significantly greater effect in minimizing the decay score compared to untreated fruits. Additionally, the 1-MCP, AC, and active MAP (5% O_2 + 5% CO_2) treatments showed no signs of decay throughout the storage period, while passive MAP treatment was less effective in preventing decay. In contrast, the untreated fruits recorded the highest decay score. These findings are consistent with Bailén et al. (2006), Ibrahim and Abdullah (2018) and Abou-Zaid et al. (2020).

Table 3. The impact of various postharvest applications on the decay (score) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 D
AC	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 D
Active MAP ($3\%O_2+5\%CO_2$)	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	2.00 f	1.14 C
Active MAP ($5\%O_2+5\%CO_2$)	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 D
Passive MAP	1.00 h	1.00 h	1.00 h	1.00 h	1.67 g	3.00 d	4.00 b	1.81 B
Control	1.00 h	1.00 h	1.00 h	1.67 g	2.33 e	3.67 c	5.00 a	2.24 A
Mean	1.00 D	1.00 D	1.00 D	1.11 D	1.33 C	1.78 B	2.33 A	
				Second season (2025)				
1-MCP	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 D
AC	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 D
Active MAP ($3\%O_2+5\%CO_2$)	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	2.33 d	1.19 C
Active MAP ($5\%O_2+5\%CO_2$)	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 D
Passive MAP	1.00 f	1.00 f	1.00 f	1.00 f	1.67 e	3.33 c	4.33 b	1.91 B
Control	1.00 f	1.00 f	1.00 f	1.67 e	2.33 d	3.00 c	5.00 a	2.14 A
Mean	1.00 D	1.00 D	1.00 D	1.11 D	1.33 C	1.72 B	2.44 A	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

The beneficial impact of 1-MCP in reducing decay may be due to its ability to inhibit enzyme activity involved in cell wall breakdown, inhibit the growth and development of undesirable microbes, reduce rot rate, and also maintain the postharvest quality of fruits (Blankenship and Dole, 2003 and Sabir et al., 2012). Also, activated carbon can release antimicrobial compounds like ethanol and sulfur dioxide, which help inhibit the growth of microorganisms responsible for food spoilage and foodborne illnesses (Chaemsanit et al., 2018). Additionally, modifying the storage atmosphere by lowering the levels of O_2 and increasing CO_2 concentrations in MAP treatment effectively reduces decay in horticultural crops. Reduced oxygen levels can significantly slow the proliferation of spoilage microorganisms (Soliva-Fortuny and Martín-Belloso, 2003). Furthermore, postharvest that rely on reduced oxygen levels and increased carbon dioxide concentrations are regarded as a promising method for controlling fungal decay in cherry tomatoes and preventing spoilage-related diseases (Abou-Zaid et al., 2020).

3.4. Firmness

The firmness of fruit is a crucial determinant of the postharvest quality and shelf life of tomato fruits (Kibar and Sabir, 2018). As present in Table (4), fruit firmness had significantly declined as the storage period extended; this is aligning with Gharezi et al. (2012). Fruit softening occurs as a result of the breakdown of cell wall components, deterioration of the structure of the cell, and changes in the materials inside the cells (Mwaurah et al., 2020).

Table 4. The impact of various postharvest applications on the firmness (kg/cm^2) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	2.14 a	2.10 ab	2.04 c	1.93 d	1.84 g-i	1.73 lm	1.51 p	1.90 A
AC	2.14 a	2.05 bc	1.91 de	1.87 e-g	1.79 i-k	1.84 g-i	1.10 u	1.81 B
Active MAP ($3\%O_2+5\%CO_2$)	2.14 a	2.00 c	1.85 f-h	1.68 mn	1.45 q	1.05 uv	0.60 x	1.54 D
Active MAP ($5\%O_2+5\%CO_2$)	2.14 a	2.04 c	1.89 d-g	1.74 kl	1.67 n	1.33 r	1.04 v	1.69 C
Passive MAP	2.14 a	1.90 d-f	1.78 j-l	1.52 p	1.26 s	0.92 w	0.51 y	1.43 E
Control	2.14 a	1.80 h-j	1.58 o	1.20 t	0.87 w	0.56 xy	0.32 z	1.21 F
Mean	2.14 A	1.98 B	1.84 C	1.66 D	1.48 E	1.24 F	0.85 G	
				Second season (2025)				
1-MCP	2.30 a	2.26 ab	2.21 bc	2.10 d	1.99 fg	1.89 ij	1.66 mn	2.06 A
AC	2.30 a	2.20 c	2.09 d	2.05 de	1.96 gh	1.90 i	1.20 r	1.96 B
Active MAP ($3\%O_2+5\%CO_2$)	2.30 a	2.16 c	2.02 ef	1.84 jk	1.62 n	1.22 r	0.76 t	1.70 D
Active MAP ($5\%O_2+5\%CO_2$)	2.30 a	2.21 bc	2.06 de	1.91 hi	1.81 k	1.50 o	1.19 r	1.85 C
Passive MAP	2.30 a	2.06 de	1.94 g-i	1.68 m	1.42 p	1.08 s	0.66 u	1.59 E
Control	2.30 a	1.97 fg	1.74 l	1.36 q	1.03 s	0.73 t	0.49 v	1.37 F
Mean	2.30 A	2.14 B	2.01 C	1.82 D	1.64 E	1.39 F	0.99 G	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

This is primarily driven by the enzymatic actions of polygalacturonase (PG) and pectin methyl esterase (PME), along with hydrolysis of starch into glucose, which is closely related to ethylene production, ultimately leading to fruit softening (Vicente et al., 2007). However, all postharvest applications played a significant role in preserving fruit firmness compared to untreated fruits. After 30 days of storage, 1-MCP exhibited the highest firmness retention, making it the most efficient treatment in preserving firmness, followed by AC and active MAP (5% O_2 + 5% CO_2) treatments, with significant differences observed between them in the first season. Active MAP (3% O_2 + 5% CO_2) and passive MAP treatments were comparatively less efficient in maintaining firmness, with significant differences observed between them. Meanwhile, untreated fruits recorded the lowest firmness levels after 30 days of storage in both seasons. These findings are aligned with Bailén et al. (2006), Ibrahim and Abdullah (2018) and Abou-Zaid et al. (2020).

The beneficial impact of 1-MCP and MAP in preserving the firmness of fruits may be attributed to their ability to suppress the activity of enzymes that degrade the cell wall, such as PG, PME, and cellulase, by inhibiting ethylene biosynthesis. This process reduces the degradation of the cell wall and the hydrolysis of water-soluble pectin, thereby maintaining cell wall integrity, delaying fruit softening during ripening, and helping to preserve the firmness of cherry tomato fruits (Opiyo and Ying, 2010 and Akbudak et al., 2012). Furthermore, the application of activated carbon to absorb ethylene from the environment of storage can effectively slow down the ripening process, significantly reduce firmness loss, and extend the period during which tomatoes remain marketable (Bailén et al., 2007).

3.5. Color (a* value)

The surface color of tomatoes is a key visual characteristic that serves as an indicator of ripeness and significantly influences their marketability and consumer preference (Park et al., 2018). The color parameter a* value was significantly impacted by postharvest applications, storage periods, and their interaction in the two seasons, as presented in Table (5). The findings show that a* values significantly increased with prolonged storage periods, indicating more red and ripe fruits. These findings are consistent with those of Abdullah and Ibrahim (2018), and this may be due to the transformation of chloroplasts into chromoplasts, which is associated with tomato ripening. This process leads to chlorophyll degradation and lycopene accumulation (Tadesse et al., 2015). Tomatoes naturally exhibit an increase in the production of ethylene, reaching a climacteric peak that accelerates ripening and enhances color change (Tadesse et al., 2012). However, the data reveal that tomatoes treated with 1-MCP exhibited lower a* values (less skin redness), followed by those treated with AC and active MAP (5% O_2 + 5% CO_2), with significant differences observed between those treatments. In contrast, untreated tomatoes had higher a* values (greater skin redness) throughout storage. These findings are in line with Bailén et al. (2006), Ibrahim and Abdullah (2018) and Abou-Zaid et al. (2020).

Unpackaged fruits may have greater exposure to oxygen, which is essential for ethylene production and oxidation, sugar metabolism, and respiration; this process ultimately accelerates color changes in the fruits (Atoo et al., 2022), as ethylene stimulates chlorophyll losses, leading to enhanced lycopene biosynthesis in fruits (Gaikwad et al., 2020). Therefore, removing inhibiting ethylene can slow down color changes during storage and prolong the shelf life of fruits (Salviet, 1999). The use of 1-MCP delays the development of color in cherry tomatoes by reducing the production of ethylene and slowing down senescence, which slows chlorophyll breakdown and lycopene accumulation (Opiyo and Ying, 2005). Also, the reduction of color development by activated carbon can be attributed to its ability to lower ethylene levels and respiration rates, thereby slowing the deterioration process, delaying ripening and color development, and maintaining the quality of fruit (El-Anany and Hassan, 2013).

Table 5. The impact of various postharvest applications on the color (a* value) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	11.84 g´	12.02 f´	13.11 b´	14.29 x	15.26 v	16.31 r	17.82 n	14.38 F
AC	11.84 g´	12.19 é	13.96 z	15.22 v	16.38 q	17.71 o	18.65 l	15.14 E
Active MAP ($3\%O_2+5\%CO_2$)	11.84 g´	12.89 ć	14.90 w	16.01 t	18.34 m	21.51 g	24.41 d	17.13 C
Active MAP ($5\%O_2+5\%CO_2$)	11.84 g´	12.32 d´	14.21 y	15.57 u	16.43 q	18.83 k	19.92 i	15.59 D
Passive MAP	11.84 g´	13.54 á	14.89 w	17.32 p	20.89 h	23.89 e	30.43 b	18.97 B
Control	11.84 g´	13.98 z	16.21 s	19.24 j	23.64 f	29.63 c	35.31 a	21.41 A
Mean	11.84 G	12.82 F	14.55 E	16.27 D	18.49 C	21.31 B	24.42A	
				Second season (2025)				
1-MCP	11.18 g´	11.36 f´	12.45 ć	13.62 y	14.60 v	15.65 r	17.61 n	13.78 F
AC	11.18 g´	11.35 f´	13.30 á	14.47 w	15.62 r	16.96 o	17.87 l	14.39 E
Active MAP ($3\%O_2+5\%CO_2$)	11.18 g´	12.23 d´	14.24 x	15.34 t	17.67 m	20.85 g	23.74 d	16.46 C
Active MAP ($5\%O_2+5\%CO_2$)	11.18 g´	11.66 é	13.55 z	14.91 u	15.75 q	18.15 k	19.24 i	14.92 D
Passive MAP	11.18 g´	12.88 b´	14.23 x	16.68 p	20.22 h	23.24 e	29.73 b	18.31 B
Control	11.18 g´	13.32 á	15.55 s	18.58 j	22.98 f	28.99 c	34.66 a	20.75 A
Mean	11.18 G	12.13 F	13.89 E	15.60 D	17.81 C	20.64 B	23.81A	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

In addition, MAP slowed down the production of ethylene and the respiration rates by creating a modified atmosphere inside the packaging with low O_2 and high CO_2 levels; this atmospheric change reduced metabolic activities (Atoo et al., 2022). These findings are in line with Taye et al. (2017), who reported that elevated CO_2 levels inhibited ethylene production, thus causing a slower red color development of cherry tomatoes during ripening.

3.6. Total soluble solids

Total soluble solids (TSS) serve as a general indicator of sugar content in fruits, representing the combined amount of sugars and soluble minerals (Manasa et al., 2018). There are significant effects on TSS % by postharvest treatments, storage periods, and their interaction in both seasons. As illustrated in Table (6), TSS % in cherry tomatoes initially increased until the 15th day of storage, then gradually declined until the end of the storage period. These findings are in line with those reported by Taye et al. (2017). The initial rise in TSS % can be explained by moisture loss during storage and the breakdown of polysaccharides (starch) to simple sugars, which lead to a higher TSS value (Gharezi et al., 2012). However, the subsequent decline in TSS % is likely attributed to the oxidative degradation of sugars caused by respiration and overripening (Antala et al., 2014).

All postharvest treatments effectively preserved TSS % during the storage duration in comparison to the control treatment. Among the treatments, fruits treated with 1-MCP exhibited the highest TSS %, followed by AC and active MAP (5% O_2 + 5% CO_2), with significant differences observed between them. Conversely, the control treatment recorded the lowest TSS %. In other words, the 1-MCP, AC, and active MAP (5% O_2 + 5% CO_2) treatments recorded a relatively slow increase in TSS % and reached

Table 6. The impact of various postharvest applications on the percentage of total soluble solids in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	5.71 q	5.84 op	6.00 k	6.13 ij	6.27 g	6.68 b	6.52 d	6.16 A
AC	5.71 q	5.83 op	5.97 kl	6.18 hi	6.40 f	6.30 g	6.10 j	6.07 B
Active MAP ($3\%O_2+5\%CO_2$)	5.71 q	5.90mn	6.26 g	6.59 c	7.00 a	5.24 r	3.31 u	5.72 D
Active MAP ($5\%O_2+5\%CO_2$)	5.71 q	5.85n-p	6.01 k	6.20 h	6.47 de	6.20 h	5.80 p	6.04 C
Passive MAP	5.71 q	5.93 lm	6.43 ef	6.68 b	5.87 no	4.20 t	2.09 w	5.27 E
Control	5.71 q	6.00 k	6.62 c	6.95 a	5.00 s	3.10 v	1.91 x	5.04 F
Mean	5.71 E	5.89 D	6.22 B	6.45 A	6.17 C	5.29 F	4.29 G	
				Second season (2025)				
1-MCP	6.11 r	6.24 q	6.39 m	6.53 l	6.65 i	7.08 c	6.96 f	6.57 A
AC	6.11 r	6.23 q	6.37mn	6.57 j-l	6.71 h	6.60 ij	6.31 op	6.42 B
Active MAP ($3\%O_2+5\%CO_2$)	6.11 r	6.31 op	6.65 i	6.99 ef	7.41 a	5.68 t	3.74 w	6.13 D
Active MAP ($5\%O_2+5\%CO_2$)	6.11 r	6.27 pq	6.39 m	6.59 jk	6.84 g	6.54 kl	5.95 s	6.38 C
Passive MAP	6.11 r	6.33 no	6.84 g	7.06 cd	6.27 pq	4.59 v	2.46 y	5.67 E
Control	6.11 r	6.40 m	7.02 de	7.34 b	5.40 u	3.50 x	2.30 z	5.44 F
Mean	6.11 E	6.30 D	6.61 B	6.85 A	6.55 C	5.67 F	4.62 G	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.
*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

peak values on days 25, 20, and 20, respectively, and declined at the end of storage. In contrast, untreated fruits reached their peak of TSS % on day 15 and then gradually declined until the 30th day of storage. These findings align with the results of Taye et al. (2017) and Atoo et al. (2022).

The preservation of TSS content in cherry tomatoes treated with 1-MCP, AC, and active MAP (5% O_2 + 5% CO_2) can be attributed to these treatments, which remove or absorb exogenous ethylene from the surrounding atmosphere, thereby reducing the respiration rate, metabolic activity and physiological changes of fruits during storage, hence retarding the ripening process (Bailén et al., 2006, Wrzodak and Gajewski., 2015 and Atoo et al., 2022).

3.7. Titratable acidity

The data shown in Table (7) indicate that the content of titratable acidity (TA) was significantly affected by postharvest applications, storage duration, and their interaction in both seasons. As storage time increased, TA levels declined significantly, aligning with the findings of Mohammed et al. (2021). The reduction in TA through storage duration is likely due to the decrease of organic acid concentrations as the fruit ripens (Atoo et al., 2022). This decline occurs because organic acids serve as substrates in respiratory processes throughout the ripening (Tilahun et al., 2017).

However, all postharvest applications significantly slowed the degradation of titratable acidity (TA) throughout storage in comparison to the control. Among the treatments, cherry tomatoes treated by 1-MCP showed the highest TA levels, followed by AC and active MAP (5% O_2 + 5% CO_2), with no significant differences observed between those treatments. Meanwhile, fruits treated with active MAP (3% O_2 + 5% CO_2) and passive were less effective, with significant differences observed between those treatments. In

Table 7. The impact of various postharvest applications on the percentage of titratable acidity in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
First season (2024)								
1-MCP	0.58 a	0.57 ab	0.56 a-c	0.54 a-d	0.51 c-g	0.48 e-j	0.46g-k	0.53 A
AC	0.58 a	0.56 a-c	0.54a-d	0.52 b-f	0.47 f-j	0.44i-m	0.40 l-n	0.50 B
Active MAP ($3\%O_2$+$5\%CO_2$)	0.58 a	0.54a-d	0.50d-h	0.47 f-j	0.43 j-m	0.37 no	0.29 q	0.45 C
Active MAP ($5\%O_2$+$5\%CO_2$)	0.58 a	0.56 a-c	0.53 a-e	0.50 d-h	0.45 h-l	0.41k-n	0.36n-p	0.48 B
Passive MAP	0.58 a	0.52 b-f	0.47 f-j	0.43 j-m	0.36 n-p	0.31 pq	0.27 q	0.42 D
Control	0.58 a	0.49 d-i	0.44i-m	0.39 mn	0.32 o-q	0.29 q	0.20 r	0.39 E
Mean	0.58 A	0.54 B	0.51 C	0.48 D	0.42 E	0.38 F	0.33 G	
Second season (2025)								
1-MCP	0.52 a	0.51 a	0.50 ab	0.48 a-c	0.45 b-f	0.42 d-i	0.40 f-j	0.47 A
AC	0.52 a	0.50 ab	0.48 a-c	0.46 b-e	0.41 e-i	0.38 h-l	0.34k-m	0.44 B
Active MAP ($3\%O_2$+$5\%CO_2$)	0.52 a	0.48 a-c	0.44c-g	0.41 e-i	0.37 i-l	0.31mn	0.23 p	0.39 C
Active MAP ($5\%O_2$+$5\%CO_2$)	0.52 a	0.50 ab	0.47a-d	0.44 c-g	0.39 g-k	0.35j-m	0.30m-o	0.42 B
Passive MAP	0.52 a	0.46b-e	0.41 e-i	0.37 i-l	0.30 n-o	0.25 op	0.21 p	0.36 D
Control	0.52 a	0.43c-h	0.38 h-l	0.33 lm	0.26 n-p	0.21 p	0.14 q	0.32 E
Mean	0.52 A	0.48 B	0.45 C	0.42 D	0.36 E	0.32 F	0.27 G	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

contrast, the control treatment recorded the lowest TA levels at the end of the storage duration. These results align with the findings of Sabir and Agar (2011), El-Anany and Hassan (2013) and Park et al. (2018). The efficiency of 1-MCP, AC, and MAP treatments in maintaining TA levels can be attributed to their role in slowing down respiration, reducing the production of ethylene, and delaying the ripening, which slows the decrease of TA (El-Anany and Hassan, 2013, Park et al., 2018 and Atoo et al., 2022).

3.8. Lycopene content

Lycopene is the main pigment that gives ripe tomatoes their red color (Gharezi et al., 2012). The findings shown in Table (8) reveal that postharvest treatments, storage duration, and their interactions exhibited a significant effect on lycopene content. The data show a considerable rise in lycopene levels as the storage duration extended; this is consistent with observations of Gharezi et al. (2012). Tomato color is strongly associated with lycopene concentration, and as the fruit matures, chloroplasts transform into chromoplasts, resulting in a significant rise in lycopene concentration during storage (Tadesse et al., 2015). This increase could be due to the ripening process and the rate of respiration (Workneh et al., 2011). Moreover, significant differences in lycopene synthesis and accumulation were observed among the various treatments. All postharvest treatments effectively slowed down lycopene accumulation compared to the untreated control. Furthermore, 1-MCP was the superior treatment in reducing lycopene accumulation, resulting in the lowest lycopene content, followed by AC and active MAP (5% O_2 + 5% CO_2), with significant differences observed between those treatments. In contrast, the highest lycopene content was observed in untreated fruits. These findings align with the results of Taye et al. (2017) and Sabir and Agar (2011).

Table 8. The impact of various postharvest applications on the content of lycopene (mg/g F.W.) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	0.68 á	0.75 z	0.93 w	1.36 u	1.58 t	1.75 s	2.53 o	1.37 F
AC	0.68 á	0.81 y	1.18 v	2.00 q	2.74 n	3.38 j	4.69 g	2.21 E
Active MAP ($3\%O_2$+$5\%CO_2$)	0.68 á	0.90 wx	1.73 s	2.84 m	3.37 j	4.71 g	5.57 e	2.83 C
Active MAP ($5\%O_2$+$5\%CO_2$)	0.68 á	0.86 xy	1.22 v	2.27 p	2.89 m	3.67 i	4.82 f	2.34 D
Passive MAP	0.68 á	0.95 w	1.85 r	3.14 k	4.02 h	6.61 c	7.86 b	3.59 B
Control	0.68 á	1.53 t	2.97 l	3.97 h	5.93 d	7.87 b	9.94 a	4.70 A
Mean	0.68 G	0.97 F	1.65 E	2.60 D	3.42 C	4.67 B	5.90 A	
				Second season (2025)				
1-MCP	0.53 á	0.60 z	0.78 w	1.21 u	1.43 t	1.60 s	2.38 o	1.22 F
AC	0.53 á	0.66 y	1.02 v	1.85 q	2.59 n	3.23 j	4.54 g	2.06 E
Active MAP ($3\%O_2$+$5\%CO_2$)	0.53 á	0.75 wx	1.58 s	2.69 m	3.22 j	4.56 g	5.42 e	2.68 C
Active MAP ($5\%O_2$+$5\%CO_2$)	0.53 á	0.71 xy	1.07 v	2.12 p	2.74 m	3.52 i	4.67 f	2.19 D
Passive MAP	0.53 á	0.80 w	1.69 r	3.02 k	3.87 h	6.45 c	7.69 b	3.44 B
Control	0.53 á	1.38 t	2.83 l	3.82 h	5.79 d	7.72 b	9.78 a	4.55 A
Mean	0.53 G	0.82 F	1.50 E	2.45 D	3.27 C	4.51 B	5.75 A	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.
*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

The delayed color development observed with 1-MCP treatment is due to its ability to lower respiration rates and reduce the production of ethylene, thereby slowing the ripening process, minimizing chlorophyll degradation, and delaying lycopene biosynthesis (Sabir and Agar, 2011). 1-MCP inhibits the accumulation of mRNA responsible for the expression of 1-aminocyclopropane-1-carboxylic acid (ACC) synthase, ACC oxidase, and the ethylene receptor in tomatoes. As a result, the inhibition of ACC synthase and ACC oxidase temporarily delays the development of red coloration of the fruits (Guillén et al., 2007).

Moreover, incorporating activated carbon as an ethylene adsorbent within the packaging contributed to delaying ripening and color development, which ultimately prolonged the storage life of tomatoes (Bailén et al., 2006). Additionally, Taye et al. (2017) observed that an environment with increased CO_2 and decreased O_2 levels slowed down further ripening by suppressing lycopene production within packaged cherry tomatoes.

3.9. Gas composition in packages

As shown in Tables (9, 10 and 11), the data reveal a significant reduction in O_2 percentages, along with an increase in CO_2 percentages and ethylene concentrations (ppm) inside the packaging over the storage duration in both seasons. These results align with the findings of Bailén et al. (2006) and Taye et al. (2017) and can be attributed to the climacteric nature of tomatoes. As climacteric fruits, tomatoes undergo a ripening process characterized by a peak in respiration and a significant increase in ethylene production (Akbudak et al., 2007). Consequently, this process leads to increased oxygen consumption and the production of CO_2 and ethylene as the fruits continue to ripen (Albornoz et al., 2019).

Table 9. The impact of various postharvest applications on O_2 (%) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	20.80 a	20.65 b	20.57 c	20.43 e	19.81 g	19.67 i	18.54 m	20.07 B
AC	20.80 a	20.63 b	20.50 d	20.26 f	19.74 h	18.69 l	18.15 n	19.82 C
Active MAP ($3\%O_2+5\%CO_2$)	3.00 y	2.80 z	2.62 á	2.27 b´	1.95 ć	1.52 d´	1.20 é	2.19 F
Active MAP ($5\%O_2+5\%CO_2$)	5.00 r	4.86 s	4.67 t	4.42 u	4.05 v	3.68 w	3.29 x	4.28 E
Passive MAP	20.80 a	20.31 f	19.53 j	19.32 k	16.36 o	15.03 p	13.70 q	17.86 D
Control	20.80 a	20.80 a	20.80 a	20.80 a	20.80 a	20.80 a	20.80 a	20.80 A
Mean	15.20 A	15.01 B	14.78 C	14.58 D	13.78 E	13.23 F	12.61G	
				Second season (2025)				
1-MCP	20.80 a	20.71 b	20.62 cd	20.48 e	19.98 g	19.84 h	18.60 k	20.15 B
AC	20.80 a	20.67bc	20.59 d	20.35 f	19.83 h	18.80 j	18.29 m	19.90 C
Active MAP ($3\%O_2+5\%CO_2$)	3.00 x	2.81 y	2.64 z	2.31 á	2.00 b´	1.61 ć	1.30 é	2.24 F
Active MAP ($5\%O_2+5\%CO_2$)	5.00 q	4.89 r	4.71 s	4.50 t	4.10 u	3.75 v	3.31 w	4.32 E
Passive MAP	20.80 a	20.31 f	19.58 i	18.35 l	16.40 n	15.11 o	13.88 p	17.78 D
Control	20.80 a	20.80 a	20.80 a	20.80 a	20.80 a	20.80 a	20.80 a	20.80 A
Mean	15.20 A	15.03 B	14.82 C	14.47 D	13.85 E	13.32 F	12.70 G	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.
*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

However, 1-MCP and AC treatments exhibited higher O_2 and lower CO_2 concentrations, with significant differences observed between them. Additionally, the ethylene levels in the packages containing cherry tomatoes treated with 1-MCP and AC were low, with no significant differences observed between those treatments, followed by the active MAP (5% O_2 + 5% CO_2) treatment. This trend was further supported by the changes in O_2, CO_2, and ethylene concentrations throughout the storage period in comparison to the initial levels. In contrast, unpackaged fruits showed no significant changes in oxygen and carbon dioxide concentrations throughout the storage periods. Overall, the interaction between postharvest applications and storage durations significantly impacted gas concentrations after 30 days of storage. These results may be due to the ability of 1-MCP, AC, and MAP treatments to suppress ethylene production and action, subsequently lowering respiration rates, reducing O_2 consumption, and limiting CO_2 and ethylene accumulation inside the packages. These findings align with previous research conducted by Bailén et al. (2006), Wrzodak and Gajewski (2015), Taye et al. (2017), Park et al. (2018) and Bahar et al. (2022).

Furthermore, 1-MCP reduces the biosynthesis of ethylene through inhibiting the enzymes activities responsible for its production, specifically 1-aminocyclopropane-1-carboxylic acid oxidase (ACO) and 1-aminocyclopropane-1-carboxylic acid synthase (ACS) (Zhang et al., 2020). When ACO and ACS activities are decreased, the synthesis and oxidation of ACC decline, leading to a decrease in the synthesis of ethylene and a subsequent reduction in ethylene-induced respiration. Also, 1-MCP blocks ethylene production by binding to its receptors (Mata et al.,

Table 10. The impact of various postharvest applications on CO_2 (%) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	0.03 á	0.08 á	0.21 y	0.36 x	0.67 u	0.88 s	1.24 r	0.50 E
AC	0.03 á	0.13 z	0.24 y	0.47 w	0.74 t	1.98 p	1.35 q	0.71 D
Active MAP ($3\%O_2+5\%CO_2$)	5.00 L	5.43 j	5.95 h	6.61 f	7.89 c	8.20 b	8.53 a	6.80 A
Active MAP ($5\%O_2+5\%CO_2$)	5.00 L	5.34 k	5.66 i	6.17 g	6.63 f	6.89 e	7.15 d	6.12 B
Passive MAP	0.03 á	0.54 v	0.58 v	1.29 r	3.10 o	4.18 n	4.94 m	2.09 C
Control	0.03 á	0.03 á	0.03 á	0.03 á	0.03 á	0.03 á	0.03 á	0.03 F
Mean	1.69 G	1.93 F	2.11 E	2.49 D	3.18 C	3.69 B	3.87 A	
				Second season (2025)				
1-MCP	0.03 b´	0.06áb´	0.18 z	0.33 y	0.60 v	0.81 t	1.10 s	0.44 E
AC	0.03 b´	0.10 á	0.21 z	0.42 x	0.66 u	1.90 q	1.20 r	0.65 D
Active MAP ($3\%O_2+5\%CO_2$)	5.00 m	5.35 k	5.64 i	6.36 g	7.46 c	7.90 b	8.34 a	6.58 A
Active MAP ($5\%O_2+5\%CO_2$)	5.00 m	5.28 l	5.52 j	5.91 h	6.50 f	6.74 e	7.00 d	5.99 B
Passive MAP	0.03 b´	0.43 wx	0.47 w	1.17 r	2.86 p	3.94 o	4.86 n	1.97 C
Control	0.03 b´	0.03 b´	0.03 b´	0.03 b´	0.03 b´	0.03 b´	0.03 b´	0.03 F
Mean	1.69 G	1.88 F	2.01 E	2.37 D	3.02 C	3.55 B	3.76 A	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

2021). This interaction creates a double bond with the metal in the receptor, thereby blocking ethylene signal transmission. Consequently, 1-MCP disrupts the ethylene signaling pathway and effectively inhibits the production of ethylene (Atoo et al., 2022).

Activated carbon possesses both mesopores and macropores, which facilitate the diffusion of ethylene-containing air through the particles to the internal surface, where ethylene is adsorbed. Additionally, activated carbon shows strong potential for use in oxygen removal in agricultural crop packaging, helping to reduce the respiration rate. This is because activated carbon can quickly form stable covalent bonds with oxygen, interacting with carbon-oxygen functional groups such as carbonyl and hydroxyl groups (Chaemsanit et al., 2018).

In MAP treatment, reducing oxygen levels while increasing carbon dioxide concentrations helps limit the production of ethylene in tomato fruits, as oxygen plays a key role in converting ACC to ethylene (Vunnam et al., 2014). Moreover, MAP treatment not only inhibits ethylene synthesis but also decreases oxygen consumption, thereby enhancing the storability of fruits. Cherry tomatoes treated with 5% CO_2 had a longer storage duration than untreated ones, likely because elevated CO_2 competitively inhibits ethylene production, effectively regulating ethylene biosynthesis during storage (Taye et al., 2017).

Table 11. The impact of various postharvest applications on the concentration of ethylene (ppm) in cherry tomato fruits during storage in the 2024 and 2025 seasons.

Treatments *	Storage periods (days)							Mean
	0	5	10	15	20	25	30	
				First season (2024)				
1-MCP	0.00 o	0.00 o	0.00 o	0.01 no	0.03m-o	0.05k-o	0.06 j-n	0.02 D
AC	0.00 o	0.00 o	0.01 no	0.02 no	0.05 k-o	0.06 j-n	0.08 i-m	0.03 D
Active MAP ($3\%O_2+5\%CO_2$)	0.00 o	0.09 i-l	0.13 g-i	0.16 g	0.28 f	0.32 ef	0.40 d	0.20 B
Active MAP ($5\%O_2+5\%CO_2$)	0.00 o	0.00 o	0.02 no	0.04 l-o	0.10 h-k	0.11 g-j	0.15 gh	0.06 C
Passive MAP	0.00 o	0.15 gh	0.36 de	0.48 c	0.55 b	0.60 b	0.68 a	0.40 A
Control	0.00 o	0.00 o	0.00 o	0.00 o	0.00 o	0.00 o	0.00 o	0.00 E
Mean	0.00 G	0.04 F	0.09 E	0.12 D	0.17 C	0.19 B	0.23 A	
				Second season (2025)				
1-MCP	0.00 m	0.00 m	0.00 m	0.01 m	0.03k-m	0.04j-m	0.07 i-l	0.02 D
AC	0.00 m	0.00 m	0.01 m	0.01 m	0.04 j-m	0.05j-m	0.07 i-l	0.03 D
Active MAP ($3\%O_2+5\%CO_2$)	0.00 m	0.08h-k	0.11 g-i	0.14 g	0.24 f	0.30 e	0.37 d	0.18 B
Active MAP ($5\%O_2+5\%CO_2$)	0.00 m	0.00 m	0.02 lm	0.03 km	0.08 h-k	0.09 g-j	0.14 g	0.05 C
Passive MAP	0.00 m	0.13 gh	0.34 de	0.45 c	0.51 b	0.56 b	0.64 a	0.38 A
Control	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 E
Mean	0.00 G	0.04 F	0.08 E	0.11 D	0.15 C	0.17 B	0.22 A	

The similar capital or lowercase letters in the columns and rows indicate that no significant differences were found between the treatments, storage durations, and their interactions at the 0.05 significance level.

*1-MCP: 1-Methylcyclopropene, AC: Activated Carbon, MAP: Modified Atmosphere Packaging

4. CONCLUSION

The use of 1-MCP effectively reduced ethylene production, slowed the ripening process, and helped maintain the quality attributes of the fruits during storage. After 30 days of storage at 10°C, the fruits retained their excellent appearance with no signs of decay.

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الملخص العربي

تأخير النضج و المحافظة على جودة ثمار الطماطم الشيرى ببعض تطبيقات ما بعد الحصاد

نوره على جاد الرب أحمد، نعمه محمد حسين و محسن السيد محمد سعد

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أُجري هذ البحث خلال موسمي 2024 و 2025 على الطماطم الشيرى صنف كتالينا 522. تم حصاد ثمار الطماطم الشيرى عند وصولها الى مرحلة اللون الوردى لدراسة تأثير تطبيقات ما بعد الحصاد المختلفة (١- ميثيل سيكلوبروبان بتركيز ٥٪، الفحم النشط بتركيز ٥ جرام، التعبئة فى الجو الهوائى المعدل الموجب بتركيز ٣ % اكسجين + ٥ % ثانى اكسيد الكربون و بتركيز ٥ % اكسجين +٥ % ثانى اكسيد الكربون ، والتعبئة فى الجو الهوائى المعدل السالب) بالاضافة الى الثمار غير المعاملة (الكنترول) على تأخيرالنضج والمحافظة على خصائص الجودة لثمارالطماطم الشيرى خلال التخزين المبرد على درجة حرارة ١٠°م ورطوبة نسبية ٩٠ – ٩٥ % لمدة 30يوم. أظهرت النتائج أن جميع تطبيقات مابعد الحصاد تفوقت على الثمار غير المعاملة فى المحافظة على جودة الثمار وأطالة فترة التخزين. ومع ذلك، نجحت المعاملة بـ١- ميثيل سيكلوبروبان والفحم النشط فى تأخير النضج والمحافظة على صفات الجودة خلال جميع فترات التخزين. علاوة على ذلك، المعاملة بالـ١- ميثيل سيكوبروبان كانت الاكثر فعالية فى تقليل الفقد فى الوزن وتراكم الليكوبين والتغير فى اللون و إنتاج الإثيلين، وتعديل الجو الهوائى داخل العبوة بالاضافة الى المحافظة على صلابة الثمار والمواد الصلبة الذائبة الكلية والحموضة وكان مظهر الثمار ممتازاً بعد ٣٠ يوم من التخزين بدون ظهور اى علامات تالف.

الكلمات المفتاحية: الطماطم الشيرى – ١- ميثيل سيكلوبروبان – الفحم النشط – التعبئة فى جو هوائى معدل – تأخير النضج – القدرة التخزينية.