HortiS (2025) 42(3):126-135
http://doi.org/10.16882/HortiS.1845203

HORTICULTURAL STUDIES

RESEARCH PAPER

Extension of Storage Life and Delay of Quality Losses in Capia Pepper by Modified Atmosphere Packaging Impregnated with Thyme Oil

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Article History
Received 10 December 2025
Accepted 25 December 2025
First Online 29 December 2025

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Keywords
Bioactive compounds
MAP
Package
Shelf-life
Weight loss

Abstract

The effect of Modified Atmosphere Packaging (MAP) impregnated with thyme oil (TO) on the quality and bioactive compounds of capia pepper cv. AG48 F1 during storage was investigated. For this purpose, harvested peppers were divided into 3 groups. The first group (MAP+TO) samples were placed in MAP impregnated with TO, the second group (MAP) was placed only in MAP and the last group (Control-C) peppers were packaged in plastic boxes. All peppers were stored at 8±1°C and 90±5% relative humidity for 40 days. For shelf-life studies, peppers were stored at 20°C and 60±5% relative humidity for 2 days after cold storage. Modified Atmosphere Packaging treatments showed significantly better results than the C group for the quality parameters. The MAP+TO was the most effective treatment, especially in reducing the weight loss, preserving the firmness and acidity loss, and slowing down the respiration rate. These positive effects were maintained under shelf life conditions. As a result, it is thought that the MAP+TO treatment could be an alternative tool for delaying quality loss and extending storage life of peppers.

1. Introduction

Peppers are grown in almost every region of Türkiye (3.318.000 tonnes), and 54.79% of total pepper production consists of capia type peppers (TÜİK, 2025). The wide variety of consumption patterns has led to an increase in the production capacity of capia peppers. Despite the increase in the production and consumption of pepper, the number of studies on postharvest physiology is quite low. In Türkiye, there are still serious quality losses in capia pepper during all stages of the chain from harvest to consumption. Today, a healthy life and nutrition are among the most important problems of humanity. Therefore, consumers' demand for high quality and nutritional value products is increasing day by day. Naturally, these products are becoming the focus of new studies. In line with consumer demands, reducing the use of chemicals during storage and extending the storage life of products with natural ingredients are becoming increasingly important. For this reason, the number of studies on the postharvest use of essential oils is increasing. Essential oils have both antioxidative and antimicrobial effects because they contain various bioactive components such as terpenes, flavonoids and carotenes (Burt, 2004). However, direct contact of these essential oils with fresh products may cause deterioration in taste, aroma, odor, and color. Therefore, it is important to use essential oils by absorbing them into packaging materials without direct contact with the product. Thyme oil is one of the most effective essential oils with antimicrobial properties (Söğüt and Seydim, 2018). Thyme, which has a distinctive pungent odor, contains two active ingredients, thymol and carvacrol. The carvacrol content of thyme oil varies between 50-80% and its antimicrobial effect is very high (Kulisic et al., 2004). It is known that thyme oil effectively inhibits many microorganisms and has positive effects on cold storage and shelf life of horticultural products (Zhou et al., 2019; Babalık et al., 2020; Sapper et al., 2020).

The weight loss (water loss), chilling injury, tissue softening, decay development and physiological disorders observed in peppers during storage and transportation processes cause significant quality losses (Sakaldaş, 2012). In addition, *Botrytis cinerea* and *Alternaria alternata* are the most common decay agents observed during storage of peppers and cause significant economic losses (Rodov et al., 1995). It has been reported that modified atmosphere packaging (MAP) reduces weight loss and delays softening during storage and transportation of peppers (Aharoni et al., 2007). It has also been stated that chilling injury and decay rates are reduced in peppers stored in MAP (Rodov et al., 1995; Ulukapı et al., 2008).

In the light of all this information, it is thought that modified atmosphere bags impregnated with thyme oil can be effective in reducing postharvest quality losses of capia pepper cv. AG48 F1. No study has been found in Turkiye or in the world investigating the effects of thyme oil and MAP treatments on storage life of capia type peppers. Therefore, in the present study, the effect of MAP impregnated with thyme oil on the quality and bioactive compounds of capia pepper variety AG48 F1 during storage was investigated.

2. Material and Methods

2.1. Fruit material

The fruits of capia pepper cv. AG48 F1, widely grown in Antalya/Türkiye, were used as plant material in the current research. Pepper fruits were obtained from a commercial orchard located at Antalya.

2.2. Harvest, package and storage

Fruits harvested by hand using a clipper at the optimum harvest stage (the fruit color is fully red) were immediately transported to the laboratory with a refrigerated vehicle. Peppers were pre-cooled with forced air (3-4°C) to reach fruit internal temperature of 7-8°C. The peppers were divided into 3 groups after discarding bruised and damaged fruits. The first group (MAP+TO) peppers were placed in thyme oil impregnated MAP (LPDE, 5 kg, Aypek, Bursa, Türkiye). The second group (MAP) fruits were placed only in MAP (LPDE, 5 kg). The last group (control-C) peppers were packaged in plastic boxes. All packaged peppers were stored at 8±1°C and 90±5% relative humidity for 40 days. Pepper samples were subjected to the following physical and biochemical analyses at the beginning and 10-20 day intervals during storage. For shelf-life studies, peppers were stored at 20°C and 60±5% relative humidity for 2 days after cold storage, and all analyses were repeated except for total phenolic, carotenoid and antioxidant contents.

2.3. Physical and biochemical analyses

All physical and biochemical analyses were performed in three replicates, and 3 kg of fruit was used for each replicate.

2.3.1. Weight losses

The pepper samples, with known initial weight, were weighed using a digital balance (Scaltec SBA51, Germany) with an accuracy of 0.01 g in each analysis period, and the weight losses were determined as a percentage (%).

2.3.2. Fruit firmness

Fruit firmness was measured in 10 peppers (for each replication) by a texture analyzer (Lloyd LF Plus, Ametek, UK) with a 50 N Load cell and 5.1 mm probe.

2.3.3. Fruit skin color

Pepper’s skin color was determined in 10 peppers using a Minolta colorimeter (Minolta: CR 300, Japan). The hue angle (h°) and chroma (C*) values were calculated using the following formulas; $h° = (180/\pi) *(\arctan (b^* / a^*)$, $C^* = [(a^*)^2 + (b^*)^2]^{½}$

2.3.4. Soluble solids content (SSC)

The juice of peppers was obtained from the different parts of 10 fruits and SSC (%) was measured using a digital refractometer (Pocket PAL-1, Atago, Japon).

2.3.5. Titratable acidity (TA)

The TA of fruit juice, which was obtained for SSC analysis, was measured using a pH meter (Hanna Instruments, Italy). The pepper juice (10 mL) was titrated using NaOH solution (0.1 N) until reaching to a pH value of 8.1. The results were calculated based on the consumed volume of NaOH, and given as g citric acid 100 mL^{-1}.

2.3.6. Respiration rate

Peppers, were weighed 300±50 g into glass jars (gas-tight, 3 L) and tightly closed. After 1.5-2.0 h at room condition (20°C), the 15-20 mL gas sample, taken from the jars using a gastight syringe, was injected into the gas chromatography with a thermal conductivity detector (Agilent Technologies, Palo Alto, CA, USA). The results were given as mL CO_2 kg^{-1} h^{-1}.

2.3.7. The gas composition of MAP

The gas concentration of MAP was measured using a gas analyzer (Gaspace 2, Systech Instruments, UK).

2.3.8. Electrolyte leakage

Electrolyte leakage was determined according to Fan and Sokorai (2005). Electrolyte leakage was calculated as a percentage.

2.3.9. Total phenolic, carotenoid and antioxidant contents

Extraction of samples; 25 mL of methanol was added to 5 g of fresh pepper sample and homogenized with a homogenizer (JSHR-270A) for 2 min and then kept at 4°C in dark conditions for 14-16 h. Then, the samples were centrifuged at 8000 rpm for 30 min and the supernatants were transferred to tubes with a Pasteur pipette and stored at -20°C until analyzed (Thaipong et al., 2006).

Total phenolic, carotenoid and antioxidant contents of peppers were determined according to Hillis and Swain (1959), Kirk and Allen (1965) and Benzie and Strain (1996), respectively.

2.3.10. Sensory evaluations

Chilling injury index; chilling injury was determined as a percentage of total fruit surface area containing sunken lesions or surface pitting. For this purpose, a 0-3 scale (0: no signs of chilling injury, 1: <10% of the surface area shows signs of chilling injury, 2: 10-30% of the surface area shows signs of chilling injury; 3: >30% of the surface area shows signs of chilling injury) was used. External appearance and taste; for external appearance, a 1-9 scale (1-4: unmarketable, 5: marketable, 7: good, 9: very good), and for taste, a 1-5 scale (1: very poor, 2: poor, 3: medium, 4: good, 5: excellent) was used (Erbaş ve Koyuncu, 2016). Decay rate;as the percentage of decayed pepper fruit was determined according to Koyuncu et al. (2023).

2.4. Statistical analysis

The experiment was set up with 3 replications (consisting of 3 kg) according to the completely factorial randomized design. The data obtained from the experiment were subjected to the variance analysis using the JMP7 package program, and the differences between the averages of each analysis period and each storage treatment were grouped according to the Tukey's multiple comparison test (P< 0.05).

3. Results and Discussions

3.1. Weight loss

It is known that weight loss increases in peppers during storage due to the acceleration of metabolic processes such as respiration and transpiration. Similarly, in the current study, the weight loss of peppers increased (P<0.01) regularly during storage (Table 1). Weight losses ranging from 1.95% (MAP+TO) to 2.89% (C) on the 10th day of storage were between 5.80% (MAP+TO) and

Table 1. *P* values for storage periods, storage techniques and their interactions.

Quality parameters	Cold storage			Shelf-life		
	SP	ST	SP × ST	SP	ST	SP × ST
Weight loss	**	**	**	**	**	**
Fruit firmness	**	**	ns	**	**	ns
Respiration rate	**	**	**	**	*	ns
Gas composition in MAP – O_2	**	**	**	-	-	-
Gas composition in MAP – CO_2	**	**	**	-	-	-
SSC	*	ns	ns	*	*	*
TA	**	**	**	**	**	*
Electrolyte leakage	**	**	**	**	**	*
External appearance	**	*	ns	**	**	**
Taste	**	*	ns	**	**	**
Fruit skin color - L*	**	ns	ns	*	**	*
Fruit skin color - C*	**	*	ns	**	*	ns
Fruit skin color - h°	ns	*	*	ns	ns	ns
Total phenolic content	**	ns	ns	-	-	-
Total carotenoid content	**	**	ns	-	-	-
Antioxidant activity	**	**	**	-	-	-

SP: Storage periods, ST: Storage techniques, SSC: Soluble solids contents, TA: Titratable acidity, ns: non-significant, **: P<0.01, *: P<0.05.

13.95% (C) at the end of storage. In the control group, weight losses increased significantly after the 20th day of storage, but these values were lower in the MAP-treated peppers (Figure 1). MAP aims to slow down the metabolic processes of the products by using the gas composition that changes as a result of their respiration (Ben-Yehoshua et al., 1998; Tiribolulu, 2019). It is also expected that weight loss, respiration rate or softening of products will be delayed due to the slowing down of the metabolic rate. Indeed, in the current study, MAP treatment combined with cold storage significantly prevented weight loss in peppers (Figure 1). Similarly, Sudhakar et al. (2021) reported that storage under MAP conditions had positive effects on reducing weight loss in peppers. In the present study, weight loss of peppers during shelf life was measured higher than those of stored in cold storage. While the weight loss on the 40+2nd day was measured as 17.20% in the control group, it was determined as 8.99% and 8.98% in the MAP and MAP+TO treatments, respectively (Figure 1). In parallel with our findings, Ahmad et al. (2021) stated that storage temperature is the most important factor affecting the weight loss of fresh products.

3.2. Fruit firmness

Firmness in fresh fruits and vegetables is an important quality criterion for marketing, and products that maintain their firmness during storage creates a fresher perception in the eyes of the consumer (Althaus and Blanke, 2022). In the present study, fruit firmness decreased as the storage period extended in all treatments. The fruit firmness, which was 14.01 N at the beginning, was

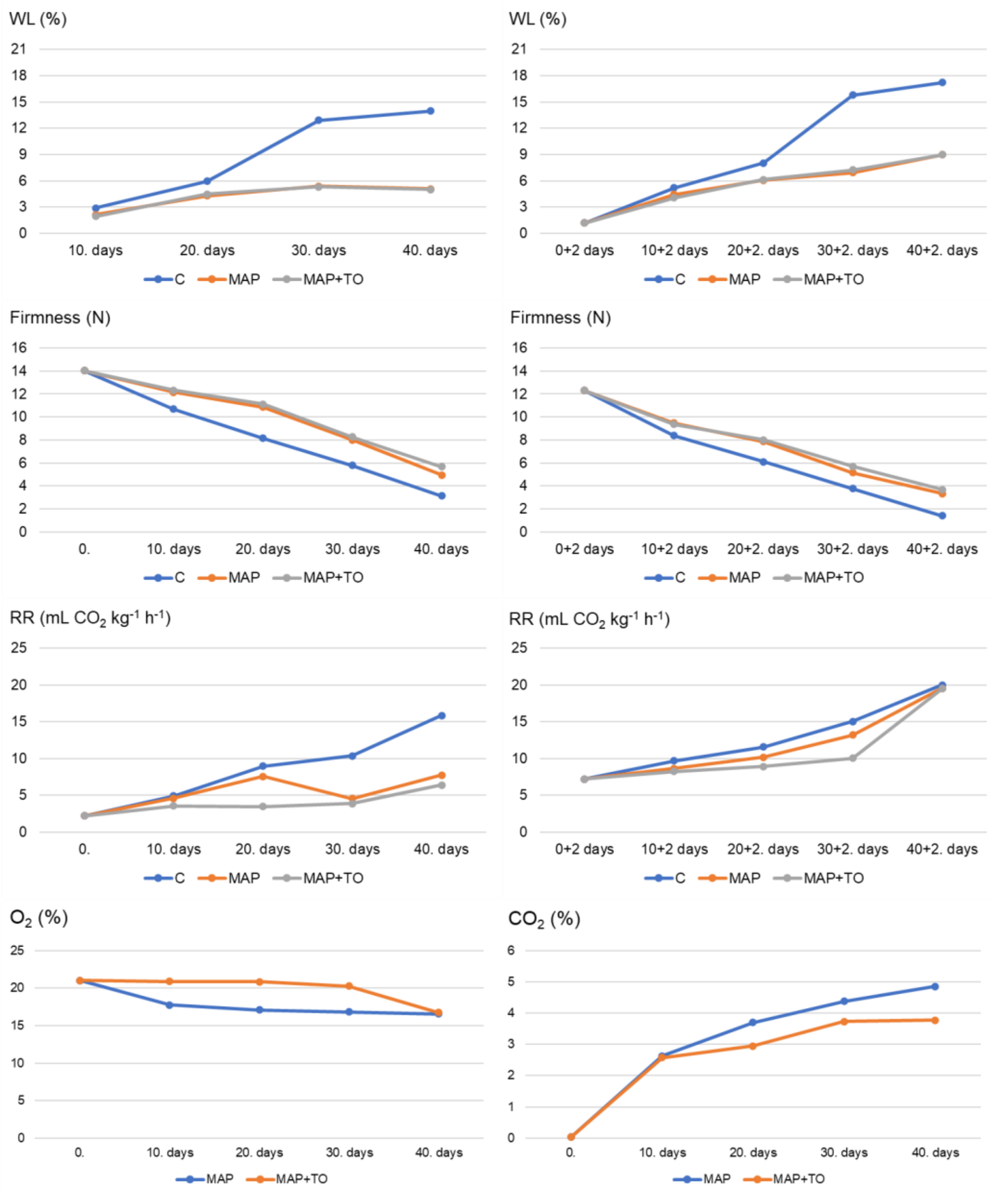

Figure 1. The effects of different storage techniques on weight loss (WL), fruit firmness, respiration rate (RR), and the composition of oxygen (O_2) and carbon dioxide (CO_2) inside the packaging of peppers during storage and shelf life (C: Control, MAP: Modified atmospheric package, TO: Thyme oil).

measured as 3.14 N, 4.96 N and 5.67 N at the end of cold storage in C, MAP and MAP+TO treatments (*P*<0.01), respectively (Table 1, Figure 1). Similar results were obtained in room conditions, but firmness losses were higher than those in cold storage. The increased softening of peppers due to high storage temperatures under shelf-life conditions was also reported by Sharma et al. (2018). The firmness value, initially determined as 12.29 N in room temperature, changed between 1.40 N (C) and 3.69 N (MAP+TO) on the 40+2nd day (Figure 1). Similarly, Cheema et al. (2018) stated that the fruit firmness of peppers decreased as the storage period increased, and these decreases were associated with high respiration rate and weight loss. In this study, the peppers stored under MAP conditions had higher firmness values (Figure 1). Different researchers reported that MAPs can delay softening by limiting water loss in peppers (Sharma et al., 2018; Erbaş and Koyuncu, 2024).

3.3. Respiration rate

Respiration rate of peppers increased during storage compared to initial value in both cold storage and shelf life. The respiration rate, which was 2.23 mL CO_2 kg^{-1} h^{-1} at the beginning, changed between 6.39 mL CO_2 kg^{-1} h^{-1} (MAP+TO) and 15.84 mL CO_2 kg^{-1} h^{-1} (C) at the end of cold storage (*P*<0.01). While the respiration rates of peppers were similar in all three treatments during the first 10 days of storage, differences began to be observed among treatments after the 20th day. The respiration rate of peppers stored in MAP was measured lower than that of control group, and this effect partially continued until day 30+2 under shelf conditions. However, at the end of the shelf life (40+2nd day), the respiration rates of the peppers varied between 19.99 (C) and 19.51 mL CO_2 kg^{-1} h^{-1} (MAP+TO), and no significant differences were detected among treatments (Figure 1). In parallel with our findings, Ahamad et al. (2024) reported that respiration rates of peppers increased with ripening as the storage period was extended. It was reported that the respiration rate of peppers stored in MAP was suppressed (Barbosa et al., 2020), while this value of peppers increased with increasing storage temperature (Erbaş and Koyuncu, 2024).

3.4. Gas composition in MAP

While the oxygen concentration in MAP decreased, the carbon dioxide concentration increased during storage. The oxygen concentration, which was 21.00% at the beginning of cold storage, decreased to 16.58% in MAP and 16.75% in MAP+TO treatments at the end of storage. Carbon dioxide concentration, which was 0.03% at the beginning, increased to 4.85% in MAP and to 3.78% in MAP+TO treatments (*P*<0.01) on the 40th day (Figure 1, Table 1). Gas concentrations in MAPs are parallel to the respiration rate findings (Figure 1). Similar results regarding changes in gas concentrations in MAP during storage were also reported in the studies conducted on peppers by Devgan et al. (2019) and Malakar et al. (2020).

3.5. SSC and TA

As seen in Figure 2, the SSC contents of peppers increased in all treatments compared to the initial value (7.13%) at the end of storage. On day 40, SSC contents decreased in C and MAK+TO treatments compared to the 30th day. Çavuşoğlu (2018) explained this situation as sugars can also be used in respiration as maturity progresses, and thus decreases in SSC values may occur towards the end of the storage period. Under shelf life conditions, the SSC values of peppers showed fluctuations similar to those in cold storage. The value measured as 7.80% at the beginning changed between 7.13% (MAP) and 7.60% (C) on the 40+2nd day. Findings of an increase and then a decrease in the SSC values of peppers both during shelf life and cold storage were also reported in the study of Nasef (2020).

Decreases were detected in the TA values of peppers during cold storage and shelf life. The value, which was 0.24 g 100 mL^{-1} at the beginning, was measured as 0.23 g 100 mL^{-1}, 0.18 g 100 mL^{-1} and 0.13 g 100 mL^{-1} at the end of the 40th day in MAP+TO, MAP and C treatments (*P*<0.01), respectively (Table 1, Figure 2). It can be stated that MAP treatments delay the acidity loss of peppers. Similar results were also determined under shelf life conditions. The value measured as 0.24 g 100 mL^{-1} at the beginning, changed between 0.15 g 100 mL^{-1} (C) and 0.21 g 100 mL^{-1} (MAP+TO) at the end of 40+2nd days (Figure 2). Sabır et al. (2011) reported that acidity loss was delayed along with ripening in products stored under MAP conditions, while Frans et al. (2021) reported that acidity loss slowed down due to the slowing of respiration rate in peppers stored under the same conditions.

3.6. Electrolyte leakage

Electrolyte leakage, an important parameter for assessing cell membrane integrity, increased steadily in all treatments during storage. The value, which was 6.87% at the beginning, changed between 25.89% (MAP+TO) and 33.94% (C) at the end of storage. These values were measured as 31.55%, 33.51% and 41.58% in MAP+TO, MAP and C group (*P*<0.01), respectively, at the end of the shelf life (40+2nd). The values were measured higher under shelf life conditions (Figure 2) and indeed, it was reported that ion leakage in peppers increased in parallel with the increase in storage temperature (Cheng et al., 2023). The electrolyte leakage values of peppers stored under MAP conditions were lower than those of control group. This effect partially continued under shelf life conditions (Figure 2). It is reported that as storage

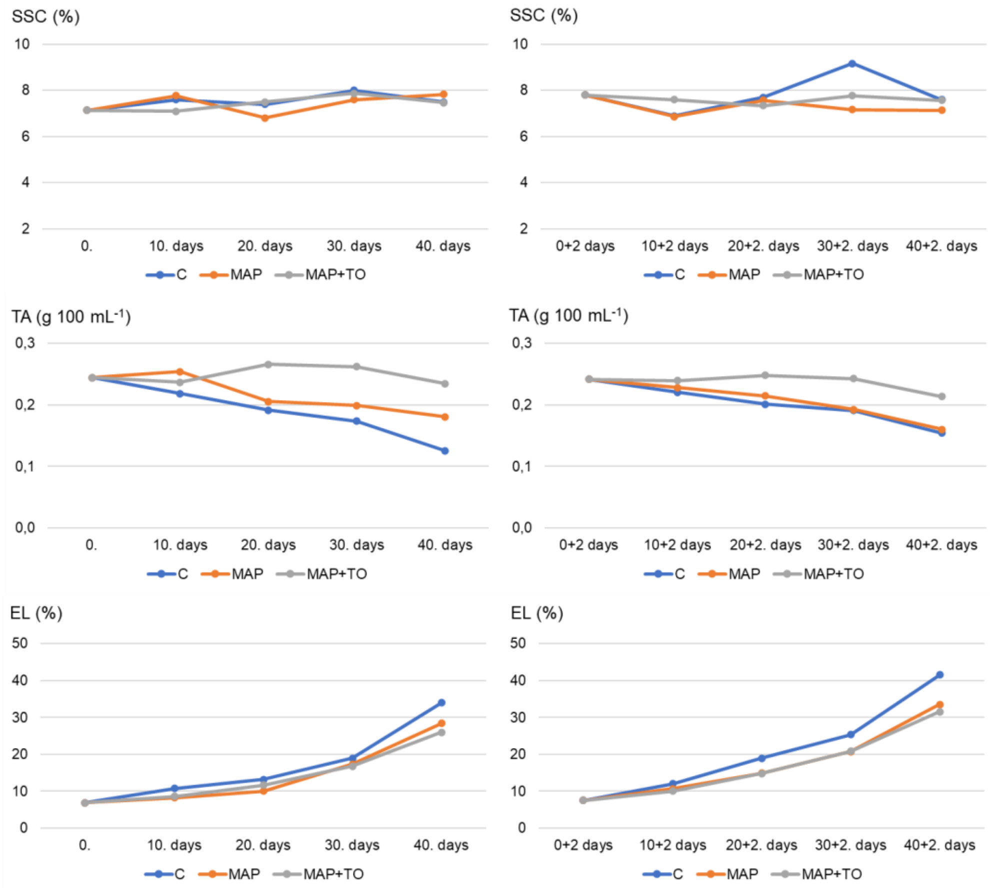

Figure 2. The effects of different storage techniques on soluble solids content (SSC), titratable acidity (TA) and electrolyte leakage (EL) of peppers during storage and shelf life (C: Control, MAP: Modified atmospheric package, TO: Thyme oil).

time extends, membrane integrity in peppers deteriorates and ion leakage rates increase (Erbaş and Koyuncu, 2021). However, it has been reported that MAP treatment reduces membrane ion leakage and weight loss by preserving membrane integrity (Li et al., 2011; Afolabi et al., 2023). Similar findings were also obtained in the current study.

3.7. Sensory evaluation

The external appearance and flavor scores of the peppers decreased steadily throughout storage. Significant decreases in appearance scores did not occur until day 30, but the decreases became more pronounced on day 40. At the end of storage, the control group received the lowest appearance score (4.67 points), while MAP and MAP+TO gave the highest score (5.83 points). Under shelf life conditions, external appearance scores decreased with increasing storage time. These decreases were more obvious after day 30+2. On day 30+2, control samples received 5.50 points, while MAP and MAP+TO treatments gave 7.17 points. At the end of shelf life, control group received a score of 3.50 (below marketable value), while the other two treatments received 5.17 points (MAP) and 5.33 points (MAP+TO). Both at the end of cold storage and shelf life, control treatment received unmarketable scores (Figure 3). The visual quality loss of peppers varies depending on parameters such as water loss, color change and softening during storage and negatively affects consumer preferences (Arimboor et al., 2015). Storage factors such as temperature and relative humidity also accelerate or slow down these processes (Kader, 2002). Therefore, it is reported that MAPs, which are known to slow down the metabolic activity and moisture/water loss of products, also preserve the visual quality in peppers (González-Aguilar et al., 2004). In parallel with the above information, in the present study, it was determined that the external appearance scores of the peppers stored under MAP conditions were higher (Figure 3). There was no change in taste scores on day 20 in cold storage and 10+2 in shelf life conditions. After the 20th day of cold storage, the taste scores began to differ in the control group and decreased significantly towards the end of storage. Peppers stored in MAP received a good score (5 points) for taste even on day 20+2. At the end of cold storage, the control group received 3 points, while MAP and MAP+TO gave 3.61 and 3.67 points. At the end of the shelf life, control samples received 2 points and were described as poor for taste. MAP (3.11 points) and MAP+TO (3.33 points) treatments were evaluated as medium in terms of taste (Figure 3). Similar to the current study, MAPs have been reported to slow down the respiratory rate and metabolic processes by controlling the concentration of oxygen and carbon dioxide in them and delay the degradation of

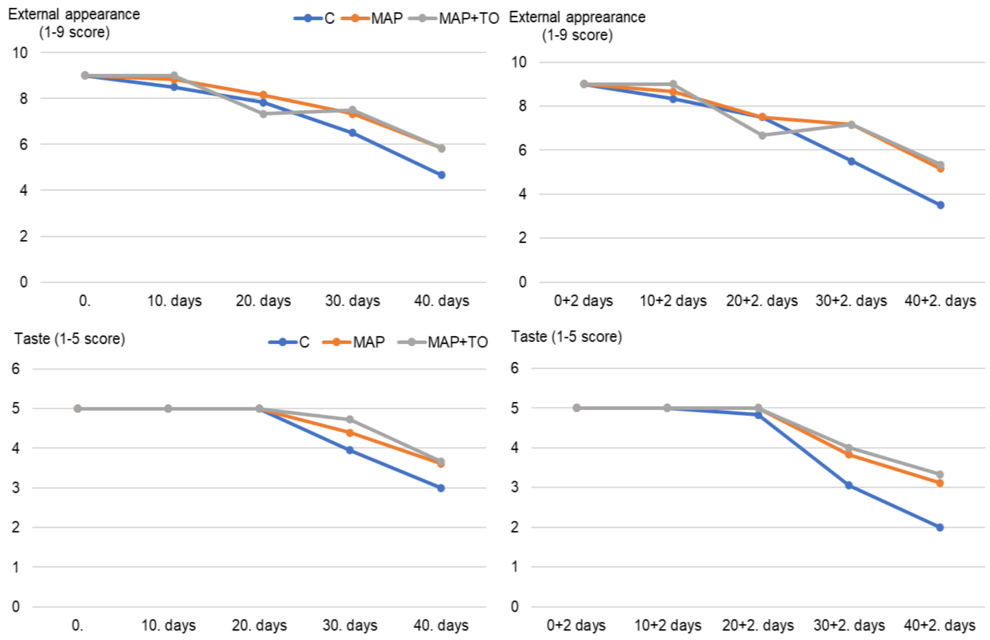

Figure 3. The effects of different storage techniques on external appearance and taste of peppers during storage and shelf life (C: Control, MAP: Modified atmospheric package, TO: Thyme oil).

taste compounds (Zhou et al., 2018). During the storage period, chilling injury symptoms were not observed in peppers.

3.8. Fruit skin color

Changes in the color values of peppers during storage are presented in Figure 4. The fruit color L* value was measured as 34.70 at the beginning of storage and the values decreased with the increasing storage time. At the end of storage, L* values were measured as 31.59 in C, 33.18 in MAP and 33.35 in MAP+TO. It was determined that MAP treatments were more effective in preserving the L* value, which represents brightness. Under shelf life conditions, L* values did not show as significant decreases as those found in cold storage, but more fluctuations were observed. However, at the end of shelf life, the highest L* value (33.99) was measured in the MAP+TO treatment, while the lowest value (31.58) was determined in C group. The C* value, which expresses the vividness of the color, was measured as 25.88 at the beginning, and varied between 29.86 (C) and 32.60 (MAP+TO) at the end of storage. The C* values were generally higher in MAP treatments. Similar findings were obtained under shelf life conditions, and the highest C* values at the end of shelf life were obtained from peppers stored in MAP. The h° value of peppers generally decreased during cold storage compared to the initial value (31.34°). These decreases were more obvious in C group and less in MAP conditions. This positive effect of MAP treatments on h° values partially disappeared under shelf life conditions, and fluctuations occurred in h° values. However, the highest h° value (30.07°) at the end of shelf life was obtained from MAP+TO. Similar to our findings, it has been reported that MAP has positive effects on color change in fruits and vegetables, and these effects are even more pronounced when used together with MAP and thymol, eugenol or menthol (Çiftci et al., 2022). It has also been reported that color changes in products may slow down as a result of high carbon dioxide and/or low oxygen concentrations inside the packaging (Barbosa et al., 2020).

3.9. Total phenolic and carotenoid content and antioxidant activity

There were fluctuations in the total phenolic content of peppers during cold storage. The phenolic content, which was 90.42 mg 100g^{-1} at the beginning, was measured highest (115.48 mg 100g^{-1}) in MAP+TO at the end of storage, while C group gave the lowest value (90.34 mg 100g^{-1}) (Figure 5). Phenolic compounds in products during storage are affected by many factors such as maturity stage, storage condition and duration (Zhuang et al., 2012). Pepper is a very rich food source for phenolic compounds, which affect not only the antioxidant capacity of peppers but also their aroma, color and taste profile (Sora et al., 2015). In the current study, phenolic content generally decreased and then partially increased as storage time extended. Similarly, Barbosa et al. (2020) reported that total phenolic content in red peppers stored in MAP initially decreased and then partially increased during storage.

Total carotenoid contents, generally, increased during storage. At the end of storage, the highest total carotenoid content (3.91 mg 100g^{-1}) was measured in the control group, followed by MAP (3.24 mg 100g^{-1}) and MAP+TO (3.00 mg 100g^{-1})

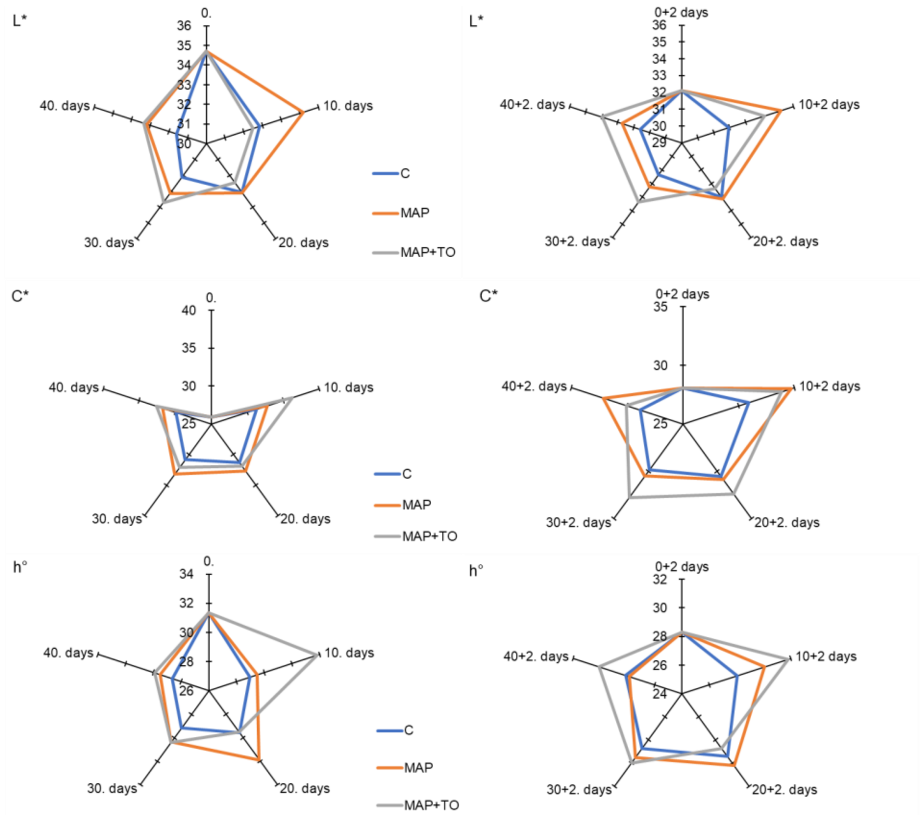

Figure 4. The effects of different storage techniques on fruit skin colour (L*, C* and h°) of peppers during storage and shelf life (C: Control, MAP: Modified atmospheric package, TO: Thyme oil).

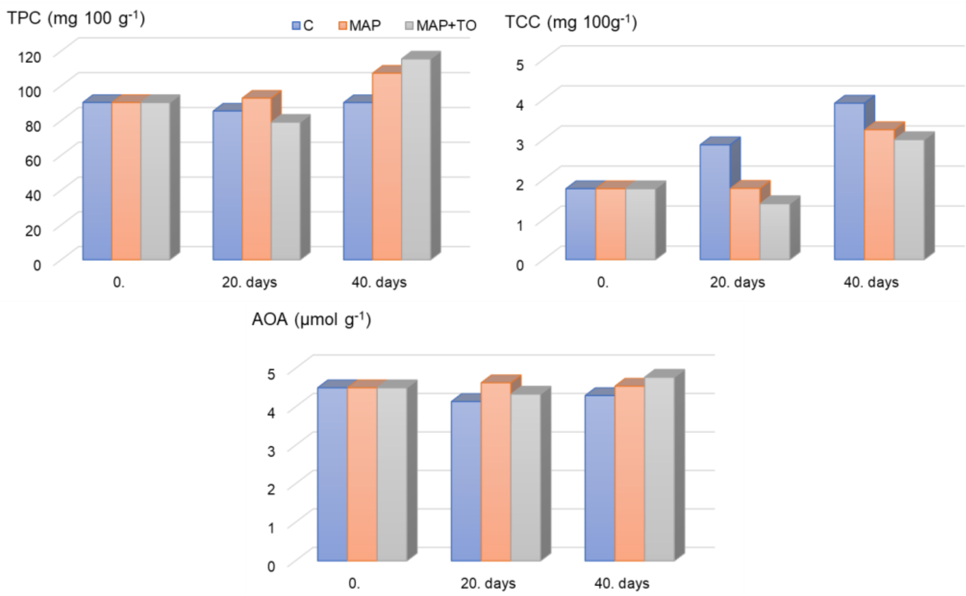

Figure 5. The effects of different storage techniques on total phenolic content (TPC), total carotenoid content (TCC) and antioxidant activity of peppers during storage (C: Control, MAP: Modified atmospheric package, TO: Thyme oil).

treatments (*P*<0.01), respectively. Total carotenoid contents of peppers stored in MAPs were slightly lower than those in the control group (Figure 5). Carotenoids are pigments generally responsible for the yellow, orange or red colors of products. Total carotenoid expression indicates the sum of all carotenoid compounds (β-carotene, xanthophylls, lycopene, etc.) in the products, which is an important parameter for both visual quality and nutritional/antioxidant potential (Atçeken, 2023). In this study, total carotenoid content increased in all treatments at the end of storage. These increases were lower in those stored under MAP conditions (Figure 5). Carotenoid synthesis in products increases with chlorophyll degradation as ripening progresses. It has been reported that under MAP conditions, low O_2 and high CO_2 concentrations slow down respiration in peppers, delaying pigment oxidation and thus limiting the increase in carotenoids (Muftuoğlu et al., 2012).

Antioxidant activity of peppers, measured as 4.50 µmol g^{-1} at the beginning of storage, varied between 4.14 µmol g^{-1} (C) and 4.63 µmol g^{-1} (MAP) on the 20th day of storage. At the end of storage, antioxidant activity values were measured between 4.30 µmol g^{-1} (C) and 4.77 µmol g^{-1} (MAP+TO) (Figure 5). As with the total phenolic and carotenoid contents, antioxidant activity of peppers stored under MAP conditions was also measured as higher compared to control samples. Similar to the study findings, Barbosa et al. (2020) reported increases in antioxidant activity values of peppers during storage. Cerit (2015) reported that peppers stored under MAP conditions had higher antioxidant capacity than the control group.

4. Conclusions

In the study, MAP treatments were more effective than C group in terms of maintaining quality of peppers during storage. MAP treatments were remarkably effective, especially, maintaining fruit firmness, reducing weight loss and respiration rate. These positive effects were more obvious in MAP+TO. As a result, it is thought that the MAP+TO could be an alternative tool for delaying quality loss and extending storage life of peppers.

Acknowledgements

The authors gratefully acknowledge the financial support of the Scientific and Technical Research Council of Türkiye (TÜBİTAK, Project number: 1919B012337079).

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