

Storage type and 1-methylcyclopropene can alter keeping of color, vitamin C and antioxidant capacity in 'Ankara' pear (*Pyrus communis* L.)

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Abstract

In this study, combined effects 1-methylcyclopropene (1-MCP) treatment and storage technology was investigated with respect to skin and flesh color and selected health benefit properties such as vitamin C content and antioxidant capacity in 'Ankara' winter pear. Fruit were stored directly in CA (3 kPa O₂ + 1.5 kPa CO₂) cabinets or air at 0±1°C and 85-90% RH for 210 days after 1-MCP treatment (300 ppb). During cold storage period, fruit were transferred to 20±1°C for 14 days at certain intervals to follow changes in aforementioned properties during shelf life in two consecutive years. Cold storage and shelf life periods were the main factors affecting investigated fruit properties. The combined effects of 1-MCP treatment and CA storage on the variables were not stable in both years. During shelf life period, lightness and hue values decreased but chroma values increased in skin and flesh. However, 1-MCP did not significantly affect color parameters in both cold storage technology. The effect of 1-MCP on investigated color parameters and health benefits is more clear during shelf life period after air storage than CA-storage. Significant difference between 1-MCP treated or non-treated fruit after CA storage conditions did not observe in terms of investigated parameters. For this reason, 1-MCP treatment can be suggested for air storage conditions. Additionally, 'Ankara' pear cultivars seem to be resistant to flesh browning related physiological conditions.

Keywords: chroma, controlled atmosphere, hue, DPPH

INTRODUCTION

1-methylcyclopropene (1-MCP) (Dias et al., 2021) and controlled atmosphere (CA) storage (Thompson et al., 2019) technologies can be used to keep quality during long storage periods in pear fruit. In many studies, 1-MCP provided keeping fruit quality by preventing skin, flesh browning, and decrease in antioxidative characteristics (Dong et al., 2018; Łysiak et al., 2021). Appropriate CA storage conditions retarded scald, internal browning and loss of antioxidant compounds (Gago et al., 2015; Guerra et al., 2012).

'Ankara' pear is one of the winter type national pear cultivars of Turkey. Because of its very sweet, juicy, buttery taste, this fruit is desired in local markets during winter season. Pekmezci (1975) who defined optimum cold storage temperature as 0°C for six months began postharvest studies on this cultivar. For keeping quality in this cultivar during regular air (RA) storage at 0°C, different 1-MCP doses between 150 and 500 ppb were suggested by Kurubaş and Erkan (2018) and Bakoğlu and Tuna Gunes (2020). Demirci (2003) revealed that 3 kPa O₂ + 1.5 kPa CO₂ can be used for CA storage conditions for a storage period longer than 7 months. There is no knowledge available about combined effect of 1-MCP treatment and CA storage conditions on keeping skin and flesh color, health benefits in 'Ankara' pear fruit. That is why our question is what the combined effect is of 1-MCP and CA conditions on aforementioned properties in 'Ankara' pear during shelf life period of 14 days after long-term cold storage duration at 0°C.

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MATERIALS AND METHODS

The fruit of 'Ankara' were harvested at commercial maturity (Ankara, Turkey) in two sequential years and treated with 300 ppb 1-MCP at $20\pm1^{\circ}\text{C}$ for 24 h. Treated and non-treated fruit were then stored in RA and/or CA conditions (3 kPa O_2 + 1.5 kPa CO_2) (Fruit Control Equipments S.R.L.) at $0\pm1^{\circ}\text{C}$ and 85-90% relative humidity for 210 d. In order to observe changes during shelf life, fruit were kept at $20\pm1^{\circ}\text{C}$ for 7 to 14 d after removal from cold storage at certain intervals. Skin and flesh color were determined with a colorimeter (CR-200 Minolta, Japan) in CIE $L^*a^*b^*$ color system and were presented as L^* , chroma (C^*), hue (h°) and delta E (ΔE) (McGuire, 1992). Antioxidant capacity (AOC) was analyzed as in Brand-Williams et al. (1995). Vitamin C was analyzed by HPLC (Shimadzu DAD, SPD-M 10 AVP) in 10 g flesh sample homogenized in metaphosphoric acid (6%). This study was set based on completely randomized experimental design with three replications and ten fruit were used in each replication. Analysis of variance (ANOVA) was performed at $P\leq0.05$ error level by MINITAB software (MINITAB 17 Inc., trial version) and significant means were grouped by Tukey's test by MSTAT-C (Michigan State University, MI, USA). The factors were storage period (SP), shelf life period (SL), storage type (ST) and treatments (T).

RESULTS AND DISCUSSION

Fruit skin lightness changed based on SP between 63.72 and 65.34. Neither 1-MCP treatment nor storage types significantly affected this parameter in both years, that is why data were not covered in this paper ($P\leq0.05$) (Table 1).

Higher skin C^* values were obtained toward the end of cold storage period and on the 14th day of shelf life period after removal cold room in both years (Table 2). Eventually, fruit color became more saturated. This phenomena occurred in 1-MCP treated fruit, as well. In the 1st year, CA-stored fruit showed higher C^* values after a cold storage period of 210 days. The effect of 1-MCP was significant for 90th and 150th days of storage period with lower C^* values. The combined effect of storage type and 1-MCP treatment was significant in the 2nd year, however, Tukey's tests showed that there was not a meaningful difference between 1-MCP-treated and non-treated fruit during the shelf life after CA storage. In contrast, the difference in 1-MCP-treated fruit was more attractive during shelf life periods after removal from air storage of 210 days ($P\leq0.05$) (Tables 1 and 2).

Impact of SP, ST and T on fruit skin h° values was not stable for both years (Table 1). Generally, skin h° values decreased by progressing the cold storage and shelf life periods after removal from both storage conditions (Table 2). In the 1st year, 1-MCP-treated fruit had higher h° values and it can be an evidence on obstructive effect of 1-MCP treatment on chlorophyll degradation after removing the fruit from air and CA storage. A similar effect was observed in fruit stored in CA conditions without 1-MCP treatment. In the 2nd year, in CA storage conditions, meaningful differences between 1-MCP-treated and non-treated fruits in terms of h° values were not observed during shelf life periods. But higher h° values were determined in air-stored fruit with 1-MCP treatment. SP $\times$ ST interactions showed that CA conditions alone were more effective on preventing decrease of h° values. For both years, general skin color difference (ΔE values) increased by cold storage and shelf life periods after removal from air and CA storage. Even if ST $\times$ T interactions were significant for only the 2nd year ($P\leq0.05$), Tukey's tests presented no meaningful difference between 1-MCP-treated and non-treated fruit during shelf life after removal from CA conditions (Figure 1).

Table 1. The effect of storage period, shelf life, storage type and treatment on color characteristics of 'Ankara' pear fruit.

Variation sources ^a	Skin				Flesh				Vitamin C (mg 100 g ⁻¹)	DPPH scavenging capacity (%)
	L*	C*	Hue (°)	ΔE	L*	C*	Hue (°)	ΔE		
1 st year										
SP	**	***	***	***	***	***	***	***	***	***
SL	ns	**	***	ns	ns	ns	*	ns	**	***
ST	ns	ns	***	*	ns	***	***	***	ns	***
T	ns	***	***	ns	ns	***	***	***	***	***
SP×SL	ns	*	ns	ns	ns	***	ns	ns	ns	ns
SP×ST	ns	**	ns	ns	ns	***	***	***	**	***
SP×T	ns	*	*	ns	*	***	***	***	**	***
SL×ST	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SL×T	ns	ns	ns	ns	ns	***	*	ns	ns	*
ST×T	ns	ns	***	ns	*	***	ns	**	**	***
SP×SL×ST	ns	ns	ns	ns	ns	**	**	ns	ns	ns
SP×SL×T	ns	ns	ns	ns	ns	***	ns	ns	ns	*
SP×ST×T	ns	ns	***	ns	ns	***	**	***	ns	***
SL×ST×T	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
SP×SL×ST×T	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
2 nd year										
SP	**	***	***	***	**	***	***	***	***	***
SL	ns	ns	***	ns	ns	***	***	ns	*	***
ST	ns	ns	***	***	ns	***	***	***	*	***
T	ns	***	***	**	*	***	***	***	***	***
SP×SL	ns	ns	ns	ns	ns	ns	ns	ns	*	*
SP×ST	ns	ns	***	**	ns	***	***	***	***	***
SP×T	ns	ns	***	ns	ns	***	***	***	ns	***
SL×ST	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
SL×T	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
ST×T	ns	***	***	***	*	***	***	***	**	***
SP×SL×ST	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SP×SL×T	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SP×ST×T	ns	ns	***	**	ns	***	***	***	**	***
SL×ST×T	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SP×SL×ST×T	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

^aSP – storage period, SL – shelf life, ST – storage type, T – 1-methylcyclopropene (1-MCP) treatment.

ns – not significant at p>0.05; *, **, and ***, significant at p≤0.05, 0.01, and 0.001 significance levels, respectively.

Fruit flesh L* values decreased during cold storage and shelf life periods in both storage type and both years. 1-MCP treatment caused higher flesh L* values in air-stored fruit during shelf life while the effect of 1-MCP was non-significant in fruit stored in CA conditions in both years (Table 3). Prolonging of the shelf life period caused increase in flesh C* values. Higher C* values were recorded during shelf life in fruit stored under air conditions. 1-MCP-treated fruit had lower flesh C* values during shelf life period after removal from air and CA storage. In the 1st year, 1-MCP treatment seems to prevent increase in flesh C* values. In the 2nd year, although variance analysis pointed out a significant effect of 1-MCP treatment in CA-stored fruit for keeping chroma values during shelf life period, Tukey's tests showed flesh chroma values in the same statistical group. For both years, fruit flesh h° values decreased by storage and shelf life periods. Additionally, in both years, fruit stored in regular air storage conditions, showed lower h° values during shelf life period. Based on the average values, in the first year, 1-MCP treated fruit had higher h° values. It means that 1-MCP treatment helped for keeping h° values in flesh. But combined effect of storage type and 1-MCP treatment was not significant (Table 3).

Table 2. Significant variations in fruit skin chroma and hue values of 'Ankara' pear fruit stored in air or CA with or without 1-MCP.

Variation sources ^a		Chroma, 1 st year					
SP×SL*	SP	0 d ^a	90 d	150 d	210 d		
SL	7	35.93±0.16 ^b C.a ^c	37.07±0.36 BC	37.49±0.45 B.b	40.41±0.64 A.a		
	14	36.15±0.23 C.a	37.07±0.39 C.a	39.45±0.42 B.s	41.28±0.40 A.a		
SP×ST**	Air	36.21±0.18 B.a	36.67±0.34 B.a	38.74±0.51 A.a	39.80±0.43 A.b		
	CA	35.87±0.21 C.a	37.47±0.37 B.a	38.21±0.53 B.a	41.88±0.47 A.a		
SP×T*	+1-MCP	35.69±0.14 C.a	36.19±0.33 C.b	37.74±0.43 B.b	40.98±0.46 A.a		
	-1-MCP	36.40±0.20 C.a	37.96±0.18 B.a	39.21±0.51 B.a	40.70±0.62 A.a		
		Chroma, 2 nd year					
SP***	SP	0 d	90 d	120 d	150 d	180 d	210 d
ST×T***	C*	36.75±0.11 C	36.83±0.19 BC	37.09±0.25 BC	37.77±0.29 AB	37.76±0.33 AB	38.09±0.32 A
	ST	Air	CA				
T	+1-MCP	36.38±0.16 B.b	37.20±0.18 A.a				
	-1-MCP	38.35±0.22 A.a	37.60±0.20 B.a				
		Hue, 1 st year					
SL***	SL	7 d	14 d				
h°		114.20±0.45 A	113.37±0.46 B				
	SP	0 d	90 d	150 d	210 d		
T	+1-MCP	118.04±0.21 A.a	116.25±0.23 B.a	113.93±0.34 C.a	112.40±0.63 D.b		
	-1-MCP	115.52±0.34 A.b	113.40±0.42 B.b	112.16±0.50 C.b	108.57±0.90 D.a		
ST×T***	ST	Air	CA				
	+1-MCP	115.75±0.39 A.a	114.56±0.60 A.a				
	-1-MCP	111.03±0.71 B.b	113.79±0.45 B.b				
		Hue, 2 nd year					
SP×ST***	SP	0 d	90 d	120 d	150 d	180 d	210 d
ST	Air	117.78±0.23 A.a	114.47±0.71 B.b	113.93±0.65 B.b	112.87±0.58 C.b	111.71±0.84 D.b	109.61±1.15 E.b
	CA	117.90±0.12 A.a	116.34±0.20 B.a	115.32±0.31 BC.a	114.52±0.18 CD.a	113.93±0.24 DE.a	112.91±0.29 E.a
T	+1-MCP	117.99±0.16 A.a	116.56±0.21 B.a	115.68±0.26 Bc.a	114.67±0.30 CD.a	114.19±0.23 DE.a	113.24±0.20 E.a
	-1-MCP	117.69±0.20 A.a ^c	114.25±0.65 B.b	113.56±0.58 BC.b	112.72±0.49 C. b	111.45±0.77 D.b	109.27±1.07 E.b
ST×T***	ST	Air	CA				
	+1-MCP	115.46±0.30 A.a	115.32±0.28 A.a				
	-1-MCP	111.33±0.61 B.b	114.99±0.32 A.a				

^aSP – storage period, SL – shelf life, ST – storage type, T – 1-methylcyclopropane (1-MCP) treatment; d – day; *, **, and ***, significant at p≤0.05, 0.01, and 0.001 significance levels, respectively.

^bData were presented as mean ± standard error of mean.

^cCapital letters show horizontal comparisons, small letters show vertical comparisons.

Table 3. Significant variations in fruit flesh, L, chroma and hue values of 'Ankara' pear fruit stored in air or CA with or without 1-MCP.

Variation sources ^a	L*, 1 st year					
	SP	0 d ^a	90 d	150 d	210 d	
T	+1-MCP	78.89±0.26 ^b AB,a ^c	77.67±0.30 B,a	79.11±0.31 A,a	65.19±0.42 C,a	
	-1-MCP	78.75±0.26 A,a	77.60±0.25 A,a	77.36±0.47 A,b	65.37±0.40 B,a	
ST×T**	L*, 1 st year					
	ST	Air	CA	ST	Air	CA
T	+1-MCP	75.56±1.21 A,a	74.88±1.25 A,a	T	+1-MCP	78.22±0.15 A,a
	-1-MCP	74.54±1.14 B,a	75.01±1.19, A,a		-1-MCP	77.38±0.18 B,b
SP×T*	Chroma, 1 st year					
	ST	Air	CA	ST	Air	CA
T	+1-MCP	15.54±0.22 B,b	16.40±0.28 B,a	T	+1-MCP	16.19±0.16 A,a
	-1-MCP	19.64±0.62 A,a	17.79±0.26 A,b		-1-MCP	17.81±0.34 A,a
SP×T***	Hue, 1 st year					
	SP	0 d	90 d	150 d	210 d	
T	+1-MCP	105.28±0.31 A,a	102.31±0.36 C,a	103.38±0.17 B,a	101.53±0.55 D,a	
	-1-MCP	104.21±0.19 A,b	100.11±0.15 B,b	99.90±0.27 B,b	98.83±0.37 C,b	
ST	Air	104.89±0.38 A,a	100.71±0.29 B,b	101.09±0.61 B,b	98.75±0.40 C,b	
	CA	104.60±0.18 A,a	101.71±0.49 B,b	102.20±0.46 B,b	101.60±0.49 C,b	
SL×T***	Hue, 2 nd year					
	SL	7 d	14 d			
T	+1-MCP	103.44±0.38 A,a	102.81±0.38 B,a			
	-1-MCP	100.80±0.45 A,b	100.72±0.47 A,b			
SP×ST***	Hue, 2 nd year					
	SP	0 d	90 d	120 d	150 d	210 d
ST	Air	104.18±0.08 A,a	102.73±0.10 B,b	102.60±0.10 B,b	102.10±0.08 C,b	100.91±0.27 D,b
	CA	103.63±0.10 A,b	103.16±0.08 B,a	102.93±0.09 B,a	102.40±0.06 C,a	101.83±0.08 D,a
T	+1-MCP	104.09±0.10 A,a	103.05±0.09 B,a	102.79±0.08 B,a	102.29±0.06 C,a	101.79±0.09 D,a
	-1-MCP	103.72±0.12 A,b	102.84±0.12 B,b	102.75±0.13 B,a	102.20±0.10 C,a	100.95±0.28 D,b
ST×T***	Chroma, 2 nd year					
	ST	Air	CA	ST	Air	CA
T	+1-MCP	102.71±0.14 A,a	102.73±0.12 A,a			
	-1-MCP	102.09±0.20 B,b	102.76±0.09 A,a			

^aSP – storage period, SL – shelf life, ST – storage type, T – 1-methylcyclopropene (1-MCP) treatment, d – day, *, **, and ***, significant at p≤0.05, 0.01, and 0.001 significance levels, respectively.

^bData were presented as mean ± standard error of mean.

^cCapital letters show horizontal comparisons, small letters show vertical comparisons.

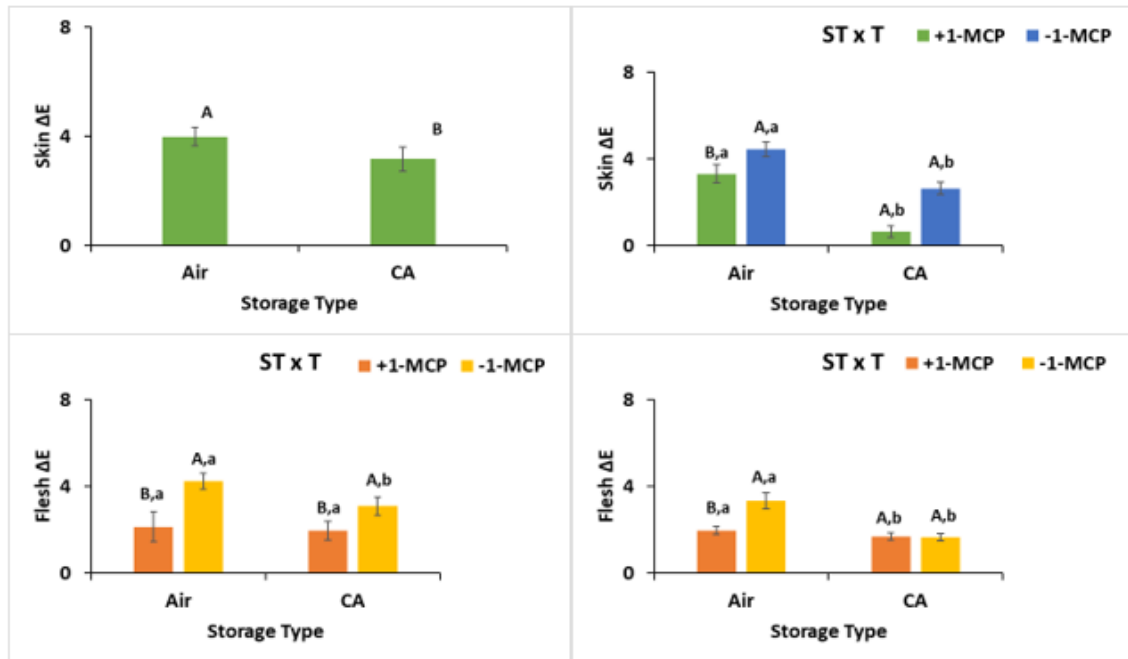


Figure 1. Effect of storage type (ST) and 1-MCP treatment (T) on color differences (ΔE values) in 'Ankara' pear fruit in the 1st (left) and 2nd (right) year. Capital letters show differences among 1-MCP treatments, small letters show differences between storage types.

However, storage type and 1-MCP treatment interactions were significant for the 2nd year. While significant differences were observed for 1-MCP treated fruit stored in air storage, similar trend was not observed in 1-MCP-treated and non-treated fruit after removal from CA storage. Color difference (ΔE values) increased with progressing in storage period and shelf life after removal from cold storage. ΔE values in flesh of air-stored fruit was higher than CA-stored one during shelf life period in both years (Table 1; Figures 1 and 2). According to the average values, 1-MCP treated fruit had lower difference values during shelf life periods in both years. If we check the data from storage type side, in the 1st year, 1-MCP treated fruit showed lower color difference during shelf life after RA and CA storage period of 210 days. But in the 2nd year, for CA storage conditions, Tukey's test classified these values in the same group. These results show that for 'Ankara' pear cultivar, the effect of 1-MCP during shelf life of CA-stored fruit can change based on the years.

General trends observed in color parameters of skin and flesh of fruit stored in air and treated with or without 1-MCP were observed in the same cultivar by Kurubaş and Erkan (2018), as well. Demirci (2003) reported similar color changes in fruit stored in the same CA conditions. So, during shelf life of 'Ankara' pear fruit after a cold storage period of 210 days either under CA or under air conditions, it is very difficult to visually follow color changes neither in 1-MCP-treated nor in CA-stored fruit. It cannot be concluded that 1-MCP strengthens the effect of long-term CA storage during a shelf life period of 14 days. In 'Ankara' pear fruit, we did not observe any browning disorders both after cold storage and during shelf life periods (Figure 2). This can be resulted from low polyphenol oxidase activity which mentioned by Bakoğlu and Tuna Gunes (2020).

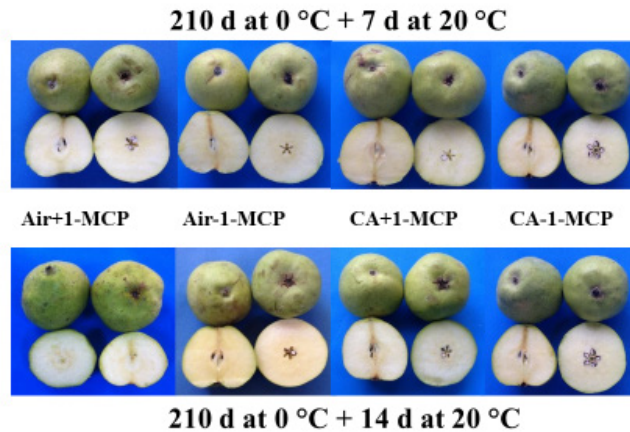


Figure 2. Appearance of 'Ankara' pear fruit during shelf life periods after removal from air and CA storage for 210 days.

In the current study, health benefits, e.g., vitamin C and antioxidant scavenging capacity, decreased during cold storage and shelf life periods in both years. Rapid decreases were also found by Silva et al. (2010). The preservative effect of 1-MCP on vitamin C was more clear in air-stored fruit in both years. However, this effect depended on the seasons in CA-stored fruit (Figure 3). The results we obtained in our study are in agree with some studies (Chiriboga et al., 2013) but in conflict with others (Larrigaudière et al., 2004). Similar trends were observed for antioxidant capacity of the fruit. It is difficult to say that 1-MCP helps for keeping antioxidant capacity during shelf life after long-term CA-storage.

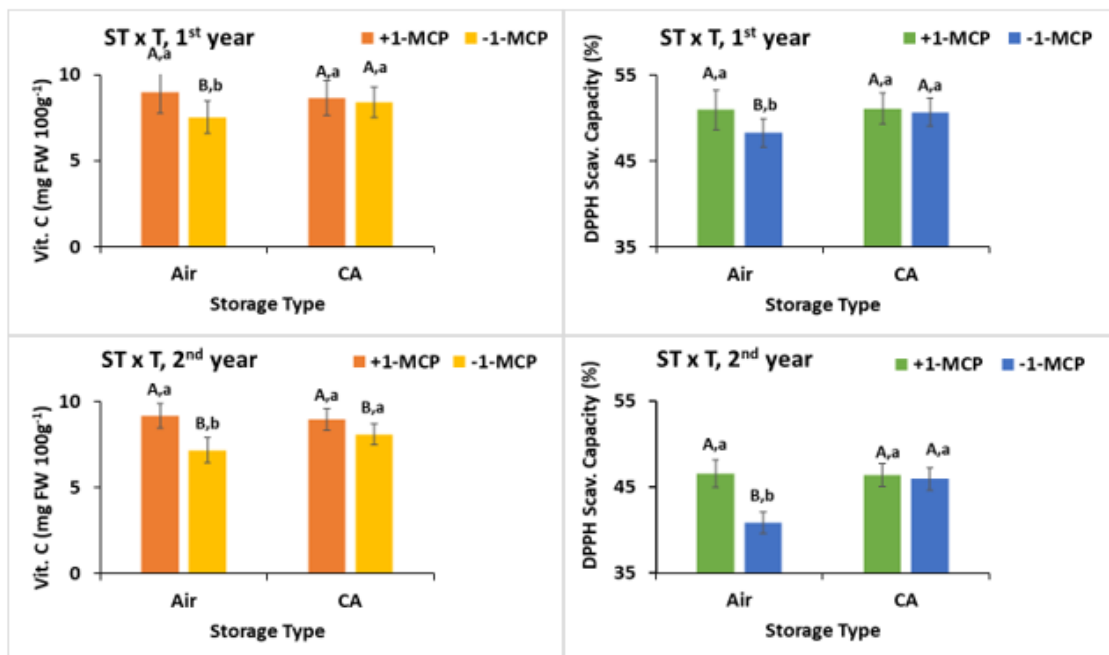


Figure 3. Interactive effects of storage type (ST) and 1-MCP treatment (T) on vitamin C and DPPH scavenging capacity in 'Ankara' pear fruit. Capital letters show differences among 1-MCP treatments, small letters show differences between storage types.

CONCLUSIONS

During shelf life period after a cold storage of 210 days, lightness and hue values decreased but C* values increased in skin and flesh of 'Ankara' pear cultivar. These changes were observed after air and CA storage conditions. But it was difficult to follow them visually. No flesh browning symptoms were observed in fruit during cold storage and also shelf life periods after removal from cold storage conditions. It seems that 'Ankara' pear fruit is resistant to flesh browning related physiological disorders.

That is why for today, this cultivar could not take the place it deserved in the European market. The effect of 1-MCP on keeping color parameters and health benefits in 'Ankara' pear fruit is more clear during shelf life of air-stored fruit than CA-stored one. It means that the preservative effect of 1-MCP is variable depending on fruit growth and development seasons. This points out once more the importance of ecological factors during fruit growth and development in postharvest physiology. Since there is no significant difference between 1-MCP-treated or non-treated fruit for after storage under CA conditions, 1-MCP could be a treatment causing extra expenses for producers using CA storage technology for 'Ankara' pear cultivar.

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