

## Impact of modified atmosphere packaging on fruit quality and postharvest life of '0900 Ziraat' cherries

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### Abstract

The sweet cherry is highly perishable with a restricted storage and shelf-life and in some cases unable to reach the final consumer at optimal eating quality after being transported to the market. For this reason, in this research, the effects of different modified atmosphere packaging materials on postharvest life and fruit quality of '0900 Ziraat' cherries (*Prunus avium* L.) were investigated to extend storage and marketing period. For this purpose, cherries were stored for 50 days at 0°C temperature with 90-95% relative humidity in three different types of packaging materials. The first group of cherries was packed in micro-perforated Xtend bags (MAP-1). The second group of cherries was packed in ordinary non-perforated polyethylene bags (MAP-2) and the third group of cherries was packed in ordinary perforated polyethylene bags (MAP-3-Control). Fruit samples were taken from different storage rooms at intervals of 10 days and physical and chemical changes were determined in the fruits. Experiment results showed that the lowest weight losses were obtained on the cherries stored in MAP-1. The cherries stored in MAP-2 had higher soluble solids content. Titratable acidity increased during the first 10 days of storage and then decreased. The fruit stored in MAP-1 had the highest flesh firmness, titratable acidity,  $L^*$ ,  $C^*$  and taste values. The most effective MAP treatment for controlling pitting and stem browning was MAP-1. It can be concluded that '0900 Ziraat' cherry fruits were successfully stored at 0°C temperature and 90-95% RH up to 50 days in MAP-1.

**Keywords:** 0900 Ziraat; Cherry; Modified atmosphere packaging; Postharvest; Quality

### Modifiye atmosferde paketlemenin '0900 Ziraat' kiraz çeşidinin meyve kalitesi ve derim sonrası ömrü üzerine etkileri

#### Öz

Kiraz meyveleri sınırlı muhafaza ve raf ömrü nedeniyle bozulmalara karşı oldukça hassastır ve bazı durumlarda pazarlama sonrası nihai tüketiciye optimum yeme kalitesinde ulaşamamaktadır. Bu nedenle, bu çalışmada, muhafaza ve pazarlama periyodunu uzatmak amacıyla, '0900 Ziraat' kiraz (*Prunus avium* L.) çeşidinin derim sonrası ömrü ve meyve kalitesi üzerine modifiye atmosferde muhafazanın etkileri belirlenmiştir. Bu amaçla kirazlar 3 farklı modifiye atmosfer ortamında 0°C sıcaklık ve %90-95 oransal nemde 50 gün süreyle muhafaza edilmişlerdir. Çalışmada birinci grup kirazlar Xtend® marka torbalar (MAP-1) içerisinde, ikinci grup meyveler deliksiz polietilen torbalarda (MAP-2), üçüncü grup kirazlar ise delikli polietilen torbalar (MAP-3-Kontrol) içerisinde paketlenmiştir. Farklı muhafaza ortamlarından 10 gün aralıklarla meyve örnekleri alınmış ve meyvelerde farklı fiziksel ve kimyasal değişimler belirlenmiştir. Çalışmada en düşük ağırlık kaybı MAP-1 ortamında depolanan kirazlarda tespit edilmiştir. MAP-2 ortamında muhafaza edilmiş kirazlar en yüksek suda çözünebilir kuru madde miktarına sahip olmuşlardır. Titre edilebilir asitlik değerleri muhafazanın ilk 10 gününde artmış, daha sonra ise azalmıştır. En yüksek meyve eti sertliği, titre edilebilir asitlik,  $L^*$ ,  $C^*$  ve tat değerleri MAP-1 ortamında depolanan kirazlarda tespit edilmiştir. Piting ve sap kararmasının kontrol altına alınmasında en etkili MAP uygulaması MAP-1 olarak belirlenmiştir. Sonuç olarak, '0900 Ziraat' kiraz çeşidine ait meyveler 0°C sıcaklık ve %90-95 oransal nemde 50 gün süreyle MAP-1 ortamında başarılı bir şekilde muhafaza edilmişlerdir.

**Anahtar Kelimeler:** 0900 Ziraat; Kiraz; Modifiye atmosfer; Muhafaza; Kalite

### 1. Introduction

Thanks to its early ripening behavior, eye-appealing outward appearance and making high income for the growers, sweet cherry is one of the most popular fruits in Turkey as well

as in other parts of the globe. So, production amount and area of cherries have been constantly increasing in Turkey and in the world during the last decade. The world's sweet cherry production is about 2.2 million tons per year of which Turkey's participation is

approximately 20%. The leading cherry producer countries in the world are Turkey, USA, Iran, Italy and Uzbekistan. The total production of cherries in Turkey is about 445 556 tons and '0900 Ziraat' is the leading cherry variety grown in Turkey (Anonymous, 2014). Turkey is also dominating cherry export in the world.

Fruit quality is very crucial factor for marketing of sweet cherries. The main quality characteristics of this attractive fruit are size, fruit and stem color, sweetness, firmness and phenolic compounds (Esturk et al., 2012). Sweet cherry is one of the most perishable commodities and has very short storage and shelf life. Some of the major quality problems of this delicious fruit are pitting, stem browning, fruit shriveling and darkening, loss of firmness, fruit cracking and decay after harvest (Esti et al., 2002; Alique et al., 2003; Esturk et al., 2012).

Fruits of sweet cherry decay rapidly after harvest with a reduced shelf life and in some cases do not reach the final consumer at optimal quality. The main causes of losses in cherries are weight loss, softening, color changes, stem browning, surface pitting and loss of acidity (Serrano et al., 2005). The harvest period of cherries is relatively short compared to many other horticultural crops. Furthermore, its soft fruit texture limits its availability in the market over longer periods. Thus, extending storage and shelf-life of cherries has vital important for marketing. The harvest time, cultivar, handling, pre-cooling, packaging and storage technology used greatly affect the shelf life and marketing period of cherries.

Improvements in packaging technology e.g. modified atmosphere packaging (MAP) have shown positive results in extending the shelf life of many fresh produce including sweet cherries. Previous studies have shown that modified atmosphere packaging has significant effects on postharvest quality parameters including weight losses (Wargo et al., 2003; Esturk et al., 2012; Tapia García et al., 2017), titratable acidity (Harb et al., 2006; Wang and Long, 2014), skin color (Kucukbasmaci et al., 2008; Tapia García et al., 2017; Wang et al., 2015; Wargo et al., 2003), flesh firmness (Kucukbasmaci et al., 2008; Tapia García et al., 2017; Wang and Long, 2014; Harb et al., 2006;

Wargo et al., 2003), pitting development (Kappel et al., 2002) stem browning (Tapia García et al., 2017; Harb et al., 2006; Wang et al., 2015) and taste (Kucukbasmaci et al., 2008) of different cherry cultivars. Suitably designed MA packs can be utilized to prevent moisture loss, fungal growth, discoloration of pigments and loss of bioactives during post-harvest storage.

Besides temperature management, the use of other technologies including MAP are required to maintain postharvest quality of cherries and to preserve stem color, flavor and decay losses (Yahia, 2009). MAP can help to reach this goal and one of the most practical methods to preserve fruit quality especially during storage and marketing and to decrease postharvest losses in cherry fruit similar to many other perishable produces (Thompson, 2010). MAP stimulates a delay in the physicochemical changes in fruit metabolism with regard to fruit quality loss by increasing the level of CO<sub>2</sub> and decreasing the O<sub>2</sub> content. But, different O<sub>2</sub> (2-10 kPa) and CO<sub>2</sub> (5-20kPa) concentrations have been shown to be optimal for different cherry cultivars (Serrano et al., 2005). Kahlke et al. (2009) pointed out that, during the recent years, the use of MAP has been used to extend shelf life in many types of produce. Also, specially designed MAP for sweet cherries is now available and has gained wide recognition in packaging houses. MAP is the most efficient storage technology especially when used in combination with refrigeration, as lower temperatures help to slow down the respiration and decay development for cherry fruit.

The objective of this study was to examine the effects of different MAPs on postharvest life and quality of '0900 Ziraat' cherries during long term storage.

## 2. Materials and Methods

### 2.1. Fruit material

'0900 Ziraat', which is a superior Turkish cherry variety (*Prunus avium* L.) typically grown on the temperate zone climate regions in whole Turkey, was used as fruit material. Harvest time of this world known variety starts first week of June and extends end of July depending on the regions and altitudes. Cherries were harvested at the optimum harvest maturity (TSS 16.6%,

TA 0.88%), pre-cooled by cold water and transported to the storage unit of Department of Horticulture, Akdeniz University in Turkey. Cherries were carefully selected for uniform size (26-30 mm), free from visual signs of any disease, decay or disorders.

## 2.2. Fruit packaging and storage conditions

The fruits were randomly divided into three groups and each group was given one of the following three treatments: (1) MAP-1, this group of cherries was sealed in packages made of Xtend® film XF.A12 (Cod: 815-PG3, Patent No: 6190710, StePac Co., Antalya, Turkey) containing 5 kg of cherries; (2) MAP-2, this group of fruit was packed in non-perforated polyethylene bags (68.8 x 49.3 cm) containing 5 kg of cherries and (3) MAP-3, this group of cherries was packed in perforated polyethylene bags (with 96 holes of 5.5 mm diameter, and total perforated area of 0.68%) (68.8 x 49.3 cm) containing 5 kg of cherries and considered as control group in the study. Then, cherry fruits were placed in cold storage room, and they were stored for 50 days at 0°C at 90-95% RH. After 10, 20, 30, 40 and 50 days of storage, 100 fruits from each experimental unit were taken to an assessment room; 50 of the cherries were analyzed while the rest were kept for 3 days at 20°C to evaluate shelf-life performance. The same evaluation was made on fruits at the time of commercial harvest (Day 0).

## 2.3. Physiological and chemical analysis

The O<sub>2</sub> and CO<sub>2</sub> concentrations of the headspace inside the packages were measured using CO<sub>2</sub> and O<sub>2</sub> gas analyzer (Servomex, Oxygen Analyzer 570 A Inj. and Bühler, CO<sub>2</sub> Analyzer IR Analysator Typ-3000). Three replicates and two bags for each replication were used to determine O<sub>2</sub> and CO<sub>2</sub> concentrations in the bags. The results were given as kPa O<sub>2</sub> and kPa CO<sub>2</sub> inside the packages. For weight losses, separately numbered fruits were weighed and stored. At the end of selected storage periods and following shelf-life, three replicates of 100 fruits were reweighed and weight loss was calculated and expressed as percent loss from initial weight. Cherries were squeezed with cheesecloth and the juice obtained was evaluated for total soluble solids (TSS) content and titratable acidity (TA). TSS was measured by a digital refractometer (Model Number

REF121, Atago, China) and expressed as % (Erkan, 1997). TA was carried out by titrating 2 mL of fruit juice in 38 mL of distilled water with NaOH 0.1 N to an end point of pH 8.1 and expressed as percent of malic acid equivalents (Karacali, 2006). External skin color was measured on 100 fruits from each replicate using a chromameter (CR 400, Minolta, Ramsey, NJ, USA), which ensured CIE L\*, a\*, and b\* values. These values were then used to calculate hue angle and Chroma, which represent the intensity or color saturation (McGuire, 1992). Flesh firmness was measured by Chatillon Digital Force Gauge equipped with an 8 mm tip. One hundred fruits from each replication were measured at three different sides of their equatorial axes and flesh firmness was expressed as Newton (N). Fruit removal force was measured by Chatillon Digital Force Gauge equipped with notch adapters. One hundred fruits from each replication were picked off from fruit stem and the fruit removal force was recorded and expressed as Newton (N). Stem browning and pitting were physically assessed during the study. Any cherries with visible stem browning and pitting were considered browned and pitted. Stem browning and pitting were calculated as a percentage of fruit expressing the symptoms. Cherries were evaluated by 5 educated panelists at day 10, 20, 30, 40, and 50 of storage. Each treatment group was assessed based on general visual appearance using this scale: 5= excellent; 4= very good; 3= good; 2= poor; 1= very poor (Remon et al., 2003).

## 2.4. Statistical analysis

The experimental design was completely randomized. Replicates of three groups of 100 fruits per treatment for the cold storage were determined. Statistical differences with P-values under 0.05 were considered significant. The Duncan test was used for comparing the means of the sources of variation.

## 3. Results and Discussion

### 3.1. O<sub>2</sub> and CO<sub>2</sub> concentrations in modified atmosphere packages (MAPs)

The variations in O<sub>2</sub> and CO<sub>2</sub> concentrations in different MAPs during storage were shown in Fig. 1. The initial O<sub>2</sub> concentration was approximately 21 kPa for different MAPs. The

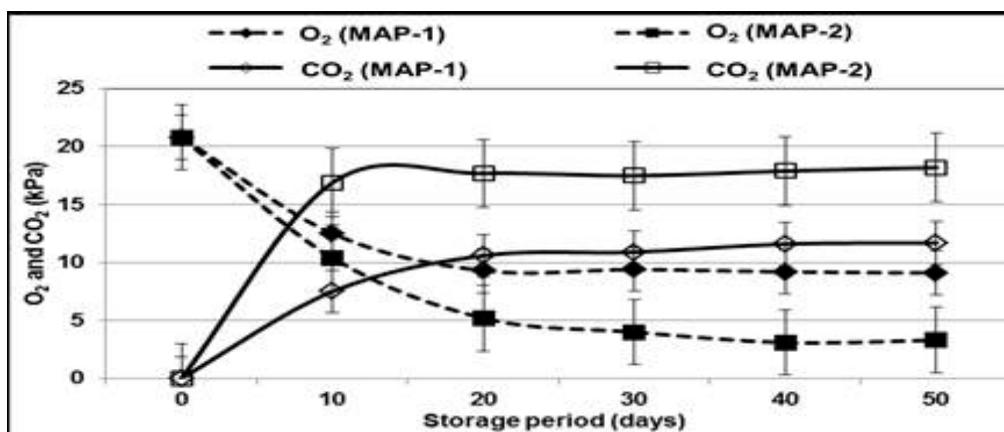


Figure 1. O<sub>2</sub> and CO<sub>2</sub> concentrations in MAPs during storage at 0°C

level of CO<sub>2</sub> increased from 0.03 kPa to 11.7 kPa in MAP-1 and to 18.2 kPa in MAP-2, during the 50 days of storage. The level of O<sub>2</sub> decreased from 20.8 kPa to 9.1 kPa in MAP-1 and to 3.3 kPa in MAP-2 after 50 days of study. Significant differences in O<sub>2</sub> and CO<sub>2</sub> levels were detected between two different types of MAP. A decrease in O<sub>2</sub> and an increase in CO<sub>2</sub> levels occurred inside MAP-1 and MAP-2 throughout the 50 days of storage. Similar trends of decreases in O<sub>2</sub> and increases in CO<sub>2</sub> levels during storage of cherries in MAP were detected by Selcuk and Erkan (2015) on 'Hicaznar' pomegranate, Selcuk and Erkan (2014) on 'Hicrannar' pomegranate fruit, Giacalone and Chiabrando (2013) on 'Sweetheart' cherry fruit. The optimal modified atmospheric conditions for storage and transport of cherries have been widely reported. CO<sub>2</sub> concentrations between 10 and 15 kPa and O<sub>2</sub> concentrations between 3 and 10 kPa have been stated to be adequate for preservation of cherries. Concentrations of O<sub>2</sub> ≤ 1 kPa have been shown as crucial for the onset of pitting and off-flavors in some sweet cherry cultivars. MAP with CO<sub>2</sub>:O<sub>2</sub> concentrations of 8 kPa:5 kPa and 10 kPa:5 kPa have been found to effectively reduce rotting, browning of peduncles, darkening of fruit color and loss of firmness and acidity as compared to fruit packed in macro-perforated box liners in sweet cherries (Wani et al., 2014). In our study the O<sub>2</sub> and CO<sub>2</sub> levels in MAP-1 were in accordance with the findings of these researchers.

### 3.2. Weight loss

Weight losses of cherry fruit are presented in Table 1. As can be seen in this table MAPs significantly decreased weight losses in

cherries. The effects of both storage period and MAPs on weight losses were found statistically significant ( $p < 0.05$ ).

Table 1 clearly showed that the weight loss of cherries increased by prolonged storage time. The weight losses of cherries were 1.08, 2.73 and 3.81% at MAP-1, MAP-2 and MAP-3, respectively. Similar to all perishable produces, appropriate postharvest technology of sweet cherries is required to maintain and develop high fruit quality for consumers. In our study, weight loss of cherries increased in all treatment groups during the storage period. However, results showed that weight loss of control fruit was higher than MA packaged fruit. MAPs significantly reduced weight loss during cold storage. In our study, the lowest weight loss was determined from the cherries stored at MAP-1, the highest weight loss was obtained from the cherries stored at MAP-3 (Control).

Padilla-Zakour et al. (2004) observed that there was about 13% weight loss in the control group in 'Hedelfinger' cherries while MAP treatments showed only 1% weight loss. Serrano et al. (2006) also indicated that wrapped broccoli florets with MAP significantly decreased weight loss compared to the control and the other treatment groups (macro perforated, non-perforated and control). Harb et al. (2006) stated that cold stored 'Regina' cherry fruit without packaging lost more weight compared to MA-packaged fruit. The weight loss reduction resulting from the impact of MAP is owing to the plastic film obstruction of water vapour diffusion, which in turn produces a water vapour pressure within the packages, that was greater as the film porosity or permeability was decreased (Serrano et al., 2006).

Table 1. The effects of different MAPs on weight loss, soluble solids content, titratable acidity and skin color ( $L^*$ ,  $C^*$ ,  $h^\circ$ ) of '0900 Ziraat' cherry fruit during storage at 0°C.

Testing index	Packaging treatments	Storage period (days)						Mean
		0	10	20	30	40	50	
Weight loss (%)	MAP-1	-	0.37	0.57	1.16	1.60	1.71	1.08 c
	MAP-2	-	0.49	1.77	3.07	3.66	4.65	2.73 b
	MAP-3	-	0.74	2.01	3.33	4.30	8.66	3.81 a
	Mean	-	0.53 e	1.45 d	2.52 c	3.19 b	5.01 a	
Soluble solids content (%)	MAP-1	16.60	17.00	16.47	17.63	16.93	17.40	17.01 a
	MAP-2	16.60	16.93	17.67	17.67	15.67	18.00	17.09 a
	MAP-3	16.60	17.67	16.93	16.47	16.80	16.20	16.78 a
	Mean	16.60 ab	17.20 a	17.02 ab	17.26 a	16.47 b	17.20 a	
Titratable acidity (%)	MAP-1	0.88	1.39	0.89	0.95	0.69	0.62	0.90 a
	MAP-2	0.88	1.31	0.98	0.92	0.54	0.57	0.87b
	MAP-3	0.88	1.33	0.82	0.81	0.53	0.49	0.81 c
	Mean	0.88b	1.34a	0.90b	0.89b	0.59c	0.56c	
$L^*$	MAP-1	28.67	29.96	25.67	29.91	27.46	27.51	28.20 a
	MAP-2	28.67	29.29	26.44	30.13	24.70	24.03	27.21 b
	MAP-3	28.67	26.86	27.61	29.37	24.07	24.95	26.92 b
	Mean	28.67b	28.70b	26.57c	29.80 a	25.41 d	25.50 d	
$h^\circ$	MAP-1	7.31	5.44	6.57	4.96	9.16	7.01	6.74 a
	MAP-2	7.31	5.97	7.67	8.20	6.73	6.59	7.08 a
	MAP-3	7.31	5.28	7.15	7.01	7.45	9.44	7.27 a
	Mean	7.31 ab	5.56 b	7.13 ab	6.72 ab	7.78 a	7.68 ab	
$C^*$	MAP-1	15.52	14.10	17.12	12.12	19.06	13.21	15.19 a
	MAP-2	15.52	13.77	15.12	17.44	11.22	12.75	14.30 a
	MAP-3	15.52	12.45	14.04	13.46	12.02	14.65	13.69 a
	Mean	15.52 a	13.44 a	15.43 a	14.34 a	14.10 a	13.54 a	

### 3.3. Total soluble solids content

Total soluble solids (TSS) content of cherries was given in Table 1. The effects of storage period on TSS content were found to be statistically significant ( $p < 0.05$ ). TSS content of the cherries increased by the storage time prolonged. TSS content of cherries at harvest was 16.60% and increased to 17.20% at the end of the 50 days storage period. The mean TSS content of cherries was 17.01, 17.09 and 16.78% at MAP-1, MAP-2 and MAP-3 treatments, respectively. During the entire storage period while the highest TSS content was obtained from the cherries stored at MAP-2 (17.09%), the lowest was obtained from the cherries stored at MAP-3 (16.78%). But in terms of TSS content, there were no statistical differences among MAPs. Soluble solids content of cherries increased by the storage time prolongation. During the all storage period, the highest soluble solids content was obtained from the cherries stored at MAP-2. But, there were no significant differences among MAP-1, MAP-2 and MAP-3 (Control) groups. In terms of TSS content, similar results were also determined by Giacalone and Chiabrande (2013), Alique et al. (2003) and Harb et al. (2003) on sweet cherry fruits.

### 3.4. Titratable acidity

Titratable acidity (TA) of cherries was given in Table 1. The effects of both storage period and MAPs on TA were found to be statistically significant ( $p < 0.05$ ). TA of the fruit increased during the first 10 days of storage in all treatment groups then decreased during the rest of the storage. TA of cherries at harvest was 0.88% and decreased to 0.56% at the end of the study. The highest TA was obtained from the cherries stored at MAP-1 (0.90%) and the lowest TA was obtained from the MAP-3 which was 0.81% (Table 1). In our study, TA first increased and then decreased in all treatment groups and the highest TA was obtained from the cherries stored at MAP-1. Similar results were obtained by Wang and Long (2014). These researches reported that MAP maintained higher TA compared to control fruit.

### 3.5. Skin color

Lightness ( $L^*$ ) values of cherries are given in Table 1. The effects of both storage period and MAPs on  $L^*$  values were found statistically significant ( $p < 0.05$ ).  $L^*$  value of cherries at harvest was 28.67 and it was determined as 25.50 after 50 days of storage. The highest  $L^*$

value was recorded from the cherries stored at MAP-1 (28.20) and the lowest  $L^*$  value was obtained from the fruit stored in MAP-3 conditions (26.92), at the end of the study. The hue angle ( $h^\circ$ ) values of cherries were given in Table 1. The effects of storage period on  $h^\circ$  values were found statistically significant ( $p < 0.05$ ) but the effects of MAPs on  $h^\circ$  values were not found significant. The  $h^\circ$  value of cherries at harvest was  $7.31^\circ$  and it was determined as  $7.68^\circ$  after 50 days of storage. The highest  $h^\circ$  value was determined from the cherries stored at MAP-3 ( $7.27^\circ$ ) and the lowest  $h^\circ$  value was obtained from the control fruit ( $7.08^\circ$ ). The chroma ( $C^*$ ) values of cherries were given in Table 1. The effects of storage period on  $C^*$  values were found statistically significant ( $p < 0.05$ ) but the effects of MAPs on  $C^*$  values weren't found statistically significant. The mean  $C^*$  value of cherries at harvest was 15.52 and decreased to 13.54 at the end of the study (Table 1). While the lowest  $C^*$  value (13.69) was obtained from the cherries stored at MAP-3, the highest (15.19) was obtained from MAP-1. Skin color is a very important quality indicator for cherries. Fruit color is one of the utmost or vital elements which regulate consumer buying choices in cherry fruit (Crisosto et al., 2003). The lightness decreased in all treatment groups but the highest values obtained from MAP-1. These results were similar to the findings of Wang et al. (2015) on cherries. These researchers also reported that MAP maintained  $L^*$  values of cherries during the study. There were no significant differences about  $h^\circ$  values among MAPs and control group but at the end of the study, the highest  $h^\circ$  value was obtained from the cherries stored at MAP-3. Our results showed that the changes of  $C^*$  values in cherry fruits packaged with MAP-1 were lower than other treatments. In terms of  $C^*$  values, similar results were determined by Padilla-Zakour et al. (2004) on 'Lapins' cherries. These researchers indicated that cherries packaged with MA had significantly higher chroma values than the control group.

### 3.6. Flesh firmness

The effects of both storage period and MAPs on flesh firmness were found to be statistically significant ( $p < 0.05$ ). Flesh firmness of cherries at harvest was 17.95 N and decreased to 9.01 N at the end of the study (Table 2). Fruits subjected to MAP-1 treatments displayed better quality, compared to MAP-2 and MAP-3

treatments. At the end of the study, the highest flesh firmness was obtained from the cherries stored at MAP-1 (14.00 N) and the lowest firmness was obtained from the fruit stored in MAP-3 (11.90 N). Flesh firmness was affected by MAPs treatment and it was determined that MAP-1 was more successful than the other treatment groups in maintaining of flesh firmness. Our results were similar to the results of Harb et al. (2006) on 'Regina' cherry fruit. These researchers reported that flesh firmness of MA-packaged cherries was higher than that of control grouped. Wang and Long (2014) also claimed that MAP maintained higher fruit firmness in cherry fruit compared to control fruit after 6 weeks of cold storage.

### 3.7. Fruit removal force

Fruit removal force values of cherries are given in Table 2. The effects of storage period on fruit removal force values were found statistically significant but the effects of MAPs on fruit removal force values weren't found statistically significant ( $p < 0.05$ ). As can be seen from Table 2, the removal force values of cherries decreased by the storage time prolonged. Fruit removal force values of cherries at harvest were 8.30 N and decreased to 4.71 N at the end of the study. The highest fruit removal force value was obtained from the cherries stored at MAP-3 (6.13 N) and the lowest fruit removal force value was obtained from the fruit stored in MAP-1 (5.96 N). However, the effects of MAPs on fruit removal force wasn't found statistically significant. The fruit removal force of cherries decreased by the storage time prolonged. Our results showed that fruit removal force of MAP-3 group cherry fruit were higher than fruit removal force values of MAP-1 and MAP-2 groups.

### 3.8. Pitting and stem browning

The effects of both storage period and MAPs on pitting was found statistically significant ( $p < 0.05$ ). Longer storage periods resulted higher amount of pitting during storage. As can be seen from Table 2, the mean amount of pitting was 0% on the harvest day and increased to 63% on the 50<sup>th</sup> day of storage. The highest pitting was determined from the cherries stored within control group (52%) and the lowest pitting (22%) was obtained from the MAP-1 (Table 2).

Table 2. The effects of different MAPs on flesh firmness, fruit removal force, pitting, stem browning and taste of '0900 Ziraat' cherry fruit during storage at 0°C

Testing index	Packaging treatments	Storage period (days)						Mean
		0	10	20	30	40	50	
Flesh firmness (N)	MAP-1	17.95	23.14	13.8	8.66	7.88	12.55	14.00 a
	MAP-2	17.95	24.65	9.74	8.30	6.96	7.65	12.54 a
	MAP-3	17.95	24.48	9.74	6.57	5.85	6.83	11.90 b
	Mean	17.95b	24.09 a	11.09 c	7.84 de	6.90 e	9.01 d	
Fruit removal force (N)	MAP-1	8.30	5.26	5.82	6.27	4.61	5.49	5.96 a
	MAP-2	8.30	4.22	6.24	5.92	4.61	4.97	5.71 a
	MAP-3	8.30	6.63	6.96	7.45	3.76	3.66	6.13 a
	Mean	8.30 a	5.37 cd	6.34 bc	6.55 b	4.33 d	4.71 d	
Pitting (%)	MAP-1	0	0	34	32	36	28	22 c
	MAP-2	0	0	78	48	94	92	52 a
	MAP-3	0	0	60	64	76	68	45 b
	Mean	0 e	0 e	57 c	48 d	69 a	63 b	
Stem browning (%)	MAP-1	0	0	8	12	20	24	11.00 c
	MAP-2	0	0	52	36	50	66	34.00 a
	MAP-3	0	0	28	26	40	50	24.00 b
	Mean	0 e	0 e	29 c	25 d	37 b	47 a	
Taste* (1-5 score)	MAP-1	5.00	3.80	4.00	4.40	4.40	4.20	4.30 a
	MAP-2	5.00	3.80	3.80	4.00	3.40	3.00	3.83 b
	MAP-3	5.00	3.60	3.20	1.70	2.60	2.60	3.27 c
	Mean	5.00 a	3.73 b	3.67 c	3.37 d	3.47 e	3.27 f	

\* 5 = excellent; 4 = very good; 3 = good; 2 = poor; 1 = very poor.

Stem browning in fruit occurs as a consequence of the compromised cell membrane that accede polyphenol oxidase (PPO) enzyme and other phenolic compounds (Schick and Toivonen, 2002). Stem browning of cherries was given in Table 2. The effects of both storage period and MAPs on stem browning were found statistically significant ( $p < 0.05$ ). Stem browning dramatically increased especially in MAP-2 with prolonging storage duration. The mean amount of stem browning was 0% on the harvest day (day 0) and increased to 34% on the 50<sup>th</sup> day of storage. The highest stem browning (34%) was determined from the cherries stored at MAP-2 group and the lowest stem browning value (11%) was obtained from the MAP-1 (Table 2). Surface pitting in cherries increased by the storage time prolongation but the lowest surface pitting was obtained from the MAP-1. Our results were similar to the findings of Kappel et al. (2002) on cherry fruit. These researchers observed that store of cherry fruit in MAP had lower surface pitting than control group after cold storage. Stem browning dramatically increased especially in control group with extending storage duration. The lowest stem browning was obtained from the MAP-1. Harb et al. (2006) reported that stem of MA-packed fruits remained greener than control fruit. Wang et al. (2015) in their study reported that the fruits stored in MAP were more

marketable and fresher as compared to control cherries.

### 3.9. Taste

The effects of both storage period and MAPs on taste scores were found statistically significant ( $p < 0.05$ ; Table 2). The taste scores were 3.73 on the 10<sup>th</sup> day, 3.67 on the 20<sup>th</sup> day, 3.37 on the 30<sup>th</sup> day, 3.47 on the 40<sup>th</sup> day and 3.27 on the 50<sup>th</sup> day of storages. The highest taste score (4.30) was obtained from the cherries stored at MAP-1 and the lowest (3.27) was obtained from the MAP-3 (Table 2). In terms of taste, the highest taste score was obtained from the cherries stored at MAP-1. Padilla-Zakour et al. (2004) reported that MA packaged 'Hedelfinger' and 'Lapins' cherries had better eating quality and taste compared to control cherries after 4 weeks storage.

### 4. Conclusions

MAPs extended the postharvest life of '0900 Ziraat' cherry fruit by decreasing weight loss, maintaining firmness and visual appearance ( $L^*$ ,  $C^*$ ), reducing the rate of acidity loss and surface pitting, preserving taste and by retaining green stem color. The most effective MAP treatment was MAP-1 for maintaining of postharvest quality of the '0900 Ziraat' cherry

fruit. It can be concluded that '0900 Ziraat' cherry fruit were successfully stored at 0°C temperature and 90-95% RH up to 50 days storage in MAP-1.

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