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RESEARCH PAPER

The Use of Controlled Atmosphere Box in Sweet Cherry Storage

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Abstract

The aim of the study was to examine the use of controlled atmosphere (CA) box, a new technology, for sweet cherry storage. In addition, this technology was compared to normal (NA) and modified atmosphere (MAP) storages commonly used in sweet cherry preservation. The '0900 Ziraat' sweet cherry variety, the most popular in Türkiye, was used as the material. Fruit harvested at optimum stage were transported to the laboratory immediately, and pre-cooled at 1°C. After pre-cooling, fruit were stored at 0°C and 90±5% relative humidity (RH) for 5 weeks in NA, MAP conditions, and in CA box at 2°C. During the storage period, weight loss, fruit skin color, stem color, respiration rate, soluble solids content (SSC), titratable acidity (TA), gas composition of box and MAP were determined at weekly intervals. Fruit were also evaluated for sensory attributes during cold storage. Samples taken from cold storage in each week were stored for 2 days at 20°C for shelf life and then fruit were re-evaluated. According to evaluation criteria, the CA boxes gave better results than the other storage conditions at the end of the storage period of 35 days. Sweet cherry cv. '0900 Ziraat' could be stored for 5 weeks in CA box and 4 weeks in MAP, with marketable quality.

1. Introduction

Sweet cherry is one of the most important crops of Türkiye, constituting approximately 28% of world production with production capacity of 724 944 tons. According to the Food and Agriculture Organization (FAO) of Statistical Database the world production of sweet cherry is 2 609 550 tons (FAO, 2020). Sweet cherries are excellent source of minerals, vitamins, antioxidant, fiber, carotenoids and bioactive elements (Gimenez et al., 2016). Consumption of sweet cherries plays an important role in preventing diseases and maintaining healthy life. Sweet cherries are usually consumed as fresh fruit (Wani et al., 2014), and a non-climacteric fruit with a high transpiration rate and susceptibility to fungal rots and physiological disorders (Petriccione et al., 2014). Because of high respiration and rapid softening rates, sweet cherries are highly perishable, with a very short shelf life (Lara et al., 2015). The limited harvest season together with its soft texture limits its availability in the market over longer periods; therefore, it needs to be marketed in a short time (Wani et al., 2014). During the marketing period, fruit prices go down with the increase of commodity supply more than demand. Prolonging of storage life of sweet cherries is crucial to balance commodity supply and demand, and create price stability in this period (Koyuncu and Dilmaçünal, 2008).

Cold storage is a common technique for reduce the rate of many metabolic processes in perishable fruits, to maintain quality, and to prolong the storability of cherries considered to be non-chilling sensitive (Petriccione et al., 2014). In order to extend the post-harvest life of the fruit, it is necessary to use new technologies. Among a lot of technologies, the use of MAP has been reported to be effective in sweet cherry storage. MAP is used to supplement low temperature management to delay senescence, reduce physiological disorders, and suppress decay in many fresh fruit and vegetable products loss by increasing the level of CO_2 and decreasing the O_2 content (Serrano et al., 2005).

The CA box (Janny MT) is a newly developed storage technology that uses a special membrane that permits the passage of gases through passive diffusion. There is no need to add gas from external resources. The atmosphere of box is stabilized by the respiration of the crops and by passive diffusion through the membrane. The drop in the level of oxygen and the increase in the level of carbon dioxide in the CA module are regulated by the membrane (Kuentz, 2015).

In this study, it was aimed to compare CA box with plastic box and MAP that are used commercially for sweet cherry storage. In addition, this research was carried out to answer the question: can CA box be a promising storage technology for sweet cherry?

2. Material and Methods

The fruit of sweet cherry cv. '0900 Ziraat' were harvested at optimum stage, and transported to Fruit Research Institute (Eğirdir/Isparta) postharvest laboratory, immediately. Sweet cherry fruit at uniform size, free from visual symptoms of disease or blemishes, were harvested at commercial maturity (harvest parameters; fruit firmness, changes in color, SSC and TA). Fruit were precooled (the internal temperature of fruits reduced to 2-3°C) by forced air at 1°C temperature. After pre-cooling, fruit were divided into three groups. Cherries (first and second groups) packaged in plastic boxes and modified atmosphere bags (MAP/Life Pack®) were stored at 0°C and 90±5% RH in NA. Third group fruit placed in CA modules (Janny MT) were stored at 2°C and same RH. During the storage period of 5 weeks, the following analyses were performed at weekly intervals. Samples taken from cold storage in each week were stored for 2 days at 20°C for shelf life and then fruits were re-evaluated.

2.1. Weight loss

Weight loss of cherries was measured over 5 kg fruit in each replicate and expressed as the percentage of loss of weight with respect to the initial weight. Weight loss was determined by the formula;

$$Weight\ loss = \frac{First\ weight - Last\ weight}{First\ weight} \times 100$$

2.2. Respiration rate

The respiration rate of fruit was measured with a gas chromatography (Agilent 6840) Chemstation A.09.03 [1417]. Measurements were made in split/splitless (S/SL) of inlet in split mode with gas sampling valve with 1 ml gas sample by using fused silica capilar column (GS-GASPRO, 30 m × 0.32 mm I.D., U.S.A), with thermal conductivity detector (TCD) Approximately 200 g from each replicated was enclosed for 1 h in a 0.3 L glass jar. A gas sample was withdrawn from the headspace for determination of respiration rate. The temperature of the oven and TCD detector were 40°C (isothermal), and 250°C respectively. Respiration rate (measured as CO_2 production) was expressed as mL CO_2 $kg^{-1}h^{-1}$.

2.3. Changes in color

Fruit skin and stem color was determined using a colorimeter (CR400, Minolta Co., Japan) over 15 fruit in each replicate. Minolta color measurement apparatus was calibrated according to the standard white calibration plate (Y = 92.3, x = 0.3136 and y = 0.3194). The values were expressed by the CIE L^* (brightness-darkness), a^* (+ a^*: red, − a^*: green) and b^* (+ b^*: yellow, − b^*: blue), C* (color saturation), h° (hue angle).

2.4. Fruit firmness

Fruit firmness was determined using a texture analyzer (Guss FTA Type GS14, Strand, South Africa). It was defined as the maximum load required to penetrate the probe (5 mm diameter) into the fruit flesh (6 mm). The results were expressed in Newton (N).

2.5. Soluble solids content and titratable acidity

Soluble solids content was measured using a digital refractometer (HI 96801, Hanna, UK) and expressed as percentage (%). Titratable acidity was measured via titration of fruit juice with 0.1 N NaOH using automatic titrator (Mettler Toledo, T50 model) and expressed as malic acid content (g 100 ml^{-1}).

2.6. Gas composition

Gas concentration (O_2 and CO_2) in the packages and boxes were measured by Tiempo Test Silver (Janny MT CA, France). The instrument is capable of reading between 0-100% oxygen and carbon dioxide. The carbon dioxide analysis is accomplished by an infrared sensor.

2.7. Sensory analysis

External appearance was rated on a hedonic scale of 0-2 (0: good commercial quality, 1: some damage but still commercially salable, 2: not commercially salable) described by Feng et al. (2004) Pitting was evaluated on scale of 0-4 (0: none, 1: very low, 2: low, 3: medium, 4: high). All analysis were performed at initially and 7+2 days intervals during storage.

2.8. Statistical analysis

Data were subjected to analysis of variance (ANOVA, JMP7), means were separated by means of LSD test ($P<0.05$, 0.01, 0.001).

3. Results and Discussion

Weight loss of fruit increased during cold storage and shelf life trials (Figure1). At the end of cold storage, the weight loss of cherries was between 0.60% (CA) and 6.94% (NA). During five weeks of cold storage, and shelf life the highest average weight loss values were (4.38%, 9.13%) obtained from the NA conditions. MAP and CA box conditions gave statistically similar results in terms of weight loss. The water vapor permeability properties of the MAP and box materials were effective in reducing weight loss compared to NA conditions. Fresh fruit continue respiration activity after harvest and produce excessive water vapor due to respiration. If the products are packaged and stored in the cold, the produced water builds up in the package (Ayhan, 2010). Therefore, storage of the products in suitable water vapor permeability materials is important in preventing weight loss. The results found in this research agree with those of previous studies (Koyuncu et al., 2005a; Goliáš et al., 2007).

Changes in fruit color during cold storage and shelf life are given in Table 1. L* values, which shows fruit brightness-darkness, fluctuated throughout cold storage. While the highest mean L*value was obtained from the CA boxes (25.33), the greatest decrease (24.74) occurred in NA condition. The effect of storage conditions on fruit color during shelf life period was not significant. As the storage time progressed, the fruit skin color C* values (represent saturation) fluctuated according to harvest time. C* values were lower at 3rd and 4th weeks of storage than those of initial values, but increased again at 5th week indicating change of red color of skin. Likewise, a* values (+a* = redness, -a* = greenness) decreased from 12.75 to 10.47, and b* value (+b* = yellowness, -b* = blueness) increased from 4.77 to 5.75 during this period (data not shown). Similar results were found by Koyuncu et al. (2005a) in same cultivar in MAP. However, some researchers (Koyuncu et al., 2005b; Gimenez et al., 2016) stated that C*values of sweet cherry skin increased as storage period progressed. On the other hand, Padilla-Zakour et al. (2004) found that chroma values changed depending on varieties and MAP conditions under cold storage. The average h° values increased regularly during storage period, and reached 23.35 compared with harvest time value of 20.61. The increase of hue angle (h°) in sweet cherries indicates a decrease in red color intensity (Drake and Elfving, 2002). The results found in this research are in accordance with the studies carried out by Drake and Elfving (2002) and Koyuncu et al. (2005a). Other previous researchers who found opposite results (Koyuncu et al., 2005b; Petriccione et al., 2014; Lara et al., 2015). Belović et al. (2014) stated that different trends in color changes refer to different storage periods and different storage conditions and thus cannot be always compared directly.

Storage conditions significantly affected stem color L*, a* and b* values (Table 2). Stem color L* values decreased with increasing storage periods. While the lowest L * values (35.02 in cold storage and 30.44 at shelf condition) were obtained from cherries stored at NA conditions, the highest values were determined as 41.29 and 34.93, respectively, in CA boxes. The value of –a*, which expresses green color of fruit stem, increased due to chlorophyll breakdown as senescence progresses. Chlorophyll is broken down in green part of fruit during storage (Botondi et al., 2003) depending on the surrounding atmosphere of the commodities. Controlled atmosphere box maintained green stem color of cherries better than other conditions since these boxes could regulate low O_2 and high CO_2

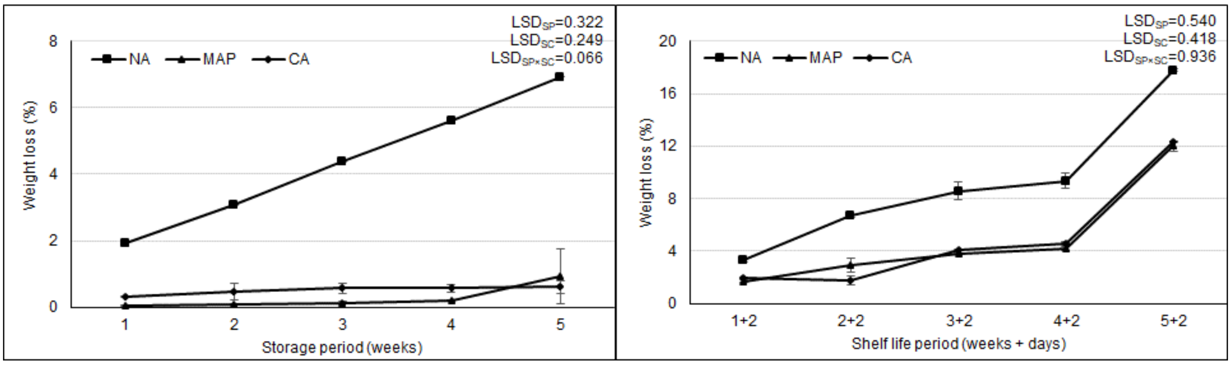

Figure 1. Changes in weight loss of '0900 Ziraat' sweet cherry during cold storage and shelf life in NA, MAP and CA box (SP: Storage period, SC: Storage conditions, CA: Controlled atmosphere, NA: Normal atmosphere, and MAP: Modified atmosphere).

Table 1. Changes in skin color (L*, C*, h°) of '0900 Ziraat' sweet cherry during cold storage and shelf life in NA, MAP and CA box.

Storage conditions		Storage trials							Shelf life trials					
		Storage period (weeks)							Storage period (weeks+days)					
		0	1	2	3	4	5	Means	1+2	2+2	3+2	4+2	5+2	Means
L*	NA	24.85	24.84	25.24	26.03	22.24	25.21	24.74	27.86	27.81	27.02	27.08	27.27	27.41
	MAP	24.85	25.04	25.50	27.21	24.06	23.20	24.98	27.51	27.59	27.57	27.29	27.18	27.43
	CA	24.85	25.43	26.03	27.57	23.25	24.85	25.33	27.11	27.41	27.49	27.56	27.58	27.43
	Means	24.85	25.10	25.59	26.94	23.18	24.42		24.49	27.60	27.36	27.31	27.34	
	SC p<0.01, SP p<0.0001, SC × SP p<0.0001								SC Nonsignificiant, SP p<0.05, SC × SP p<0.0001					
C*	NA	13.61	16.55	14.81	11.03	11.75	16.13	13.98	11.79	12.50	10.19	12.20	12.98	11.93
	MAP	13.61	17.75	14.93	11.72	12.53	13.15	13.95	11.96	10.74	11.55	12.59	12.08	11.79
	CA	13.61	16.49	15.80	13.59	13.61	14.68	14.63	9.61	12.33	12.10	11.16	12.31	11.50
	Means	13.61	16.93	15.18	12.11	12.63	14.65		11.12	11.86	11.28	11.98	12.46	
	SC Nonsignificiant, SP p<0.0001, SC × SP p<0.05								SC Nonsignificiant, SP p<0.01, SC × SP p<0.01					
h⁰	NA	20.61	20.78	22.63	24.95	24.66	23.95	22.93	23.96	23.64	25.88	25.41	25.87	25.22
	MAP	20.61	21.71	22.80	26.48	23.69	23.20	23.08	24.67	25.08	27.68	25.72	27.23	26.11
	CA	20.61	21.95	22.25	23.49	22.82	22.90	22.34	26.14	24.22	24.96	27.29	27.42	25.70
	Means	20.61	21.48	22.56	24.98	23.72	23.35		24.92	24.31	26.17	26.14	26.84	
	SC p<0.05, SP p<0.0001, SC × SP p<0.01								SC Nonsignificiant, SP p<0.01, SC × SP p<0.05					

SP: Storage period, SC: Storage conditions, CA: Controlled atmosphere, NA: Normal atmosphere, and MAP: Modified atmosphere

Table 2. Changes in stem color (L*, C*, h°) of '0900 Ziraat' sweet cherry during cold storage and shelf life in NA, MAP and CA box.

Storage conditions		Storage trials							Shelf life trials					
		Storage period (weeks)							Storage period (weeks+days)					
		0	1	2	3	4	5	Means	1+2	2+2	3+2	4+2	5+2	Means
L*	NA	42.05	31.24	34.29	35.83	34.29	32.43	35.02	27.94	30.91	29.44	30.17	33.72	30.44
	MAP	42.05	34.10	42.92	36.99	41.27	39.25	39.43	33.38	32.76	30.74	33.78	35.18	33.17
	CA	42.05	39.01	42.08	44.03	40.31	40.29	41.30	32.99	39.70	33.51	34.41	34.02	34.93
	Means	42.05	34.78	39.76	38.95	38.62	37.32		31.44	34.46	31.23	32.79	34.31	
	SC p<0.0001 SP p<0.0001 SC × SP p<0.0001								SC p<0.0001SP p<0.001 SC × SP p<0.01					
C*	NA	-15.18	-8.38	-2.76	-2.00	-1.39	-0.32	-5.02	-4.39	-1.42	0.73	0.99	0.85	-0.65
	MAP	-15.18	-12.43	-11.38	-10.05	-7.92	-5.80	-10.46	-7.35	-4.08	-3.84	-1.31	-1.90	-3.70
	CA	-15.18	-14.16	-13.63	-12.20	-11.28	-8.82	-12.55	-9.80	-9.26	-8.01	-8.28	-4.37	-7.94
	Means	-15.18	-11.66	-9.26	-8.08	-6.86	-4.98		-7.18	-4.92	-3.71	-2.87	-1.81	
	SC p<0.0001, SP p<0.0001, SC × SP p<0.0001								SC p<0.0001, SP p<0.0001, SC × SP p<0.0001					
h⁰	NA	28.01	24.46	20.98	19.73	17.33	15.57	21.01	20.05	19.38	18.81	18.94	17.50	18.94
	MAP	28.01	24.38	24.07	23.75	21.39	20.71	23.72	23.39	22.37	22.49	23.05	21.73	22.61
	CA	28.01	27.26	28.38	28.76	25.44	25.89	27.29	25.11	24.52	24.04	23.67	22.78	24.02
	Means	28.01	25.36	24.48	24.08	21.38	20.72		22.85	22.09	21.78	21.89	20.67	
	SC p<0.0001, SP p<0.0001, SC × SP p<0.0001								SC p<0.0001, SP p<0.0001, SC × SP p<0.0001					

SP: Storage period, SC: Storage conditions, CA: Controlled atmosphere, NA: Normal atmosphere, and MAP: Modified atmosphere

inside package. Stem color b* values, represent yellowness, decreased as the storage period progressed in all conditions as expected. The highest average b * values (27.29 and 24.02) were obtained from fruit stems stored in CA box. As can be seen in Table 2, sweet cherries stored in NA had the lowest b * values (15.57 and 17.50) showing darker stem color at the end of storage. Changes in color intensity and quality are important indicators of maturity and quality for fresh cherries (Sharma et al., 2010). Better preservation of fruit skin and stem color in MAP and CA box conditions can be explained by the change of medium gas composition towards oxygen reduction and carbon dioxide increase resulting in slow respiration rate and other metabolic activities. By creating higher CO_2 and lower oxygen O_2 concentrations in the surrounding atmosphere of the commodities, decay, respiration rate, and enzymatic activity can be controlled, resulting in an increase in postharvest quality (Erkan and Eski, 2012).

Changes in fruit firmness during cold storage and shelf life are presented in Figure 2. Throughout the storage period and shelf life a gradual decrease in firmness was observed in all conditions. The fruit firmness values of cherries at harvest time (11.24 N) decreased to 7.43 N (NA) and 9.50 N (CA) at the end of storage period. The effects of storage periods and conditions on fruit firmness were statistically significant (p<0.0001) in all conditions. Fruit firmness is an important quality attribute in sweet cherries that affects consumer acceptance, fruit storage potential and resistance to mechanical damage (Wang and Long, 2014). The results demonstrated that MAP and CA box were more effective than NA to maintain fruit firmness. This can be due to less water loss and low respiration rate of fruit stored under MAP and CA box. It is known that

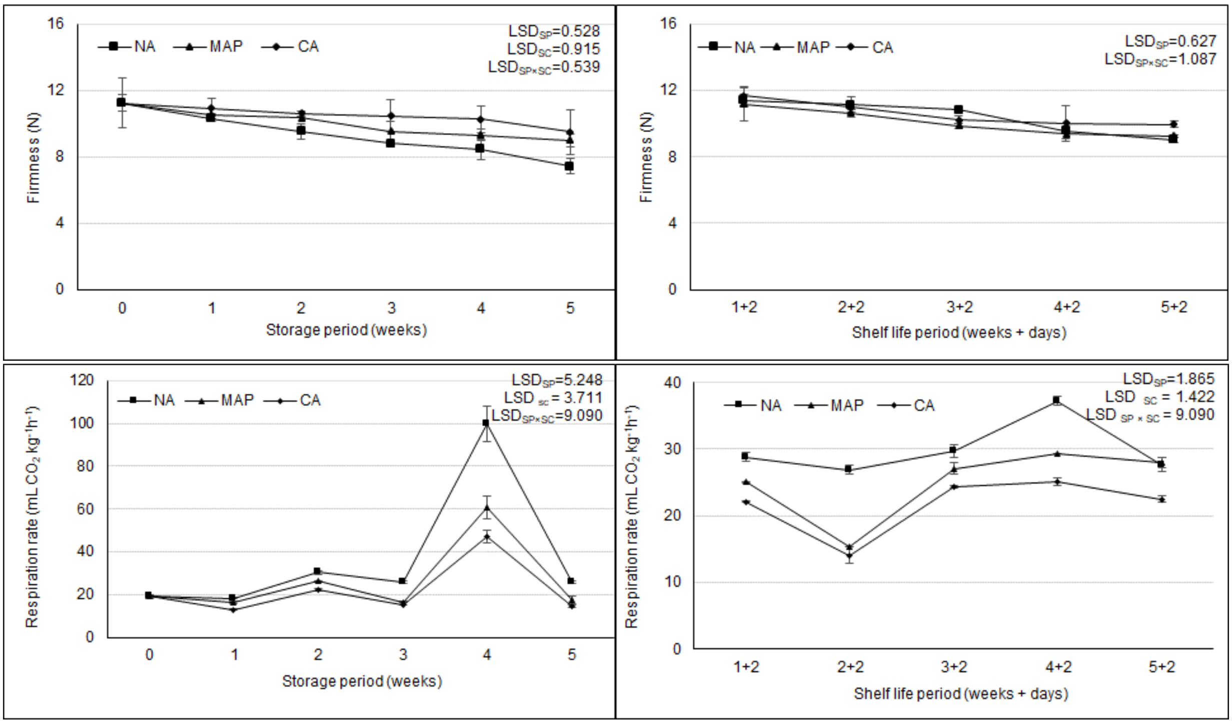

Figure 2. Changes in fruit firmness and respiration rate of ‘0900 Ziraat’ sweet cherry during cold storage and shelf life in NA, MAP and CA box (SP: Storage period, SC: Storage conditions, CA: Controlled atmosphere, NA: Normal atmosphere, and MAP: Modified atmosphere).

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weight loss of sweet cherries might increase with increasing respiration rate during storage. Goliáš et al. (2007) indicated that slow ripening of the sweet cherry in the very low oxygen treatments was reflected by higher firmness after cold storage. Our results are in agreement with Bahar and Dündar (2001) and Goliáš et al. (2007) who found that fruit firmness of sweet cherries stored in MAP decreased during storage. However, in some previous researches, an increase in cherry fruit firmness in cold storage has been reported for different varieties (Remon et al., 2000; Kappel et al., 2002; Koyuncu et al., 2005a; Wang and Long, 2014).

Fluctuations in respiratory rates were observed during storage and shelf life periods (Figure 2). Fluctuation has progressed first, followed by a decreasing curve. The effects of storage condition and periods on respiration rates were significant. The lowest average respiratory rate (21.87 mL CO_2 $kg^{-1}h^{-1}$) was obtained from fruit stored at controlled atmosphere condition. Similarly, suppressing effect of CA boxes on respiration rate (21.59 mL CO_2 $kg^{-1}h^{-1}$) also continued throughout shelf life period. The highest respiration rate values were 36.44 mL CO_2 $kg^{-1}h^{-1}$ and 30.03 mL CO_2 $kg^{-1}h^{-1}$ at cold storage and shelf life conditions, respectively. These lower respiration rate of fruit in CA box compared to other package materials (MAP and plastic box) resulted from lower O_2 and higher CO_2 concentrations in CA boxes. As can be seen in Figure 2, the lowest O_2 was measured in CA box with an equilibrium O_2 concentration of 1.42- 3.20% after one week. The next lowest respiration rate was in MAP, since it had lower O_2 concentration (between 5.12- 9.01%) than NA (21.0%). Wang and Long (2014) reported that the lowest respiration rate of sweet cherries was in MAP with an equilibrium O_2 concentration of~2.0%, followed by other MAP with ~7.7%. The concentration of O_2 to preserve the quality of sweet cherries under CA was between 3-10% (Mitcham et al., 2003). Similarly, Wang and Long (2014) found that respiration rates of sweet cherries were affected very little by O_2 concentration from 21% to ~10%, but declined in a logarithmic manner from ~10% to ~1%.

Changes of TA during cold storage and shelf life are given in Table 3. One of the main factors of taste formation in fruit is TA (Karaçalı, 2009). Storage condition and periods significantly affected TA contents of cherries. TA of fruit decreased with increasing storage time in both cold room and shelf life. During the 5-week cold storage, the lowest average TA value was obtained from NA as 0.430 g 100 ml^{-1}, and the highest in CA box (0.494 g 100 ml^{-1}). This trend continued in shelf- life studies, and the fruit packaged in CA box gave slightly higher TA (0.445 g 100 ml^{-1}) content than those of others. It was reported that lower O_2 and elevated CO_2 inhibited the respiration rate of cherries during low temperature storage, and the inhibition persisted even after 36 h at room temperature (Wang and Long, 2014). Sweet cherries, a non–climacteric fruit, do not have starch or other carbohydrates to provide the energy for respiration; they use sugars and acids (Khorshidi et al., 2014). The fact that the fruit stored in NA (21.0% O_2) have a higher TA value than those of lower O_2 conditions, is the faster metabolic activity of the fruit in NA (Erbaş and

Table 3. Changes in SSC and TA of '0900 Ziraat' sweet cherry during cold storage and shelf life in NA, MAP and CA box.

Storage conditions		Storage trials							Shelf life trials					
		Storage period (weeks)							Storage period (weeks+days)					
		0	1	2	3	4	5	Means	1+2	2+2	3+2	4+2	5+2	Means
SSC	NA	15.4	16.1	15.5	17.0	14.9	14.7	15.6	15.5	16.2	14.4	14.7	16.4	15.4
	MAP	15.4	15.2	15.4	15.2	14.7	14.5	15.1	15.3	16.5	15.3	14.7	15.8	15.5
	CA	15.4	14.7	15.1	16.3	14.6	14.5	15.1	15.4	15.6	13.7	16.1	15.1	15.2
	Means	15.4	15.3	15.3	16.2	14.8	14.6		15.4	16.1	14.5	15.1	15.8	
	SC Nonsignificiant, SP p<0.01, SC × SP Nonsignificiant								SC Nonsignificiant, SP p<0.0001, SC × SP p<0.001					
TA	NA	0.592	0.548	0.428	0.407	0.301	0.304	0.430	0.549	0.516	0.425	0.389	0.305	0.437
	MAP	0.592	0.515	0.488	0.440	0.378	0.380	0.466	0.519	0.498	0.451	0.358	0.338	0.433
	CA	0.592	0.532	0.497	0.464	0.440	0.438	0.494	0.559	0.486	0.444	0.384	0.355	0.445
	Means	0.592	0.532	0.471	0.437	0.373	0.374		0.542	0.500	0.440	0.377	0.333	
	SC p<0.05, SP p<0.0001, SC × SP p<0.05								SC p<0.01, SP p<0.0001, SC × SP Nonsignificiant					

SP: Storage period, SC: Storage conditions, CA: Controlled atmosphere, NA: Normal atmosphere, MAP: Modified atmosphere, SSC: Soluble solids content (%), and TA: Titratable acidity (g 100 ml^{-1}).

Koyuncu, 2016). Wang and Long (2014), reported that the decreased respiration rate in response to lower O_2 concentration implies that the gas permeability of the commercial MAP should ideally equilibrate at an O_2 concentration lower than ~10% to efficiently reduce sweet cherry catabolic activity during storage. Similar observations were recorded by Padilla-Zakour et al. (2004), where MA stored sweet cherries had lower TA levels than air- stored fruit.

The average SSC of fruit (14.6%) decreased at the end of 35 days compared to initial value (15.4%), with fluctuation during cold storage. By contrast, there was minor increase in SSC during shelf life, which can be attributed to higher weight loss by evaporation compared to cold storage. Generally, SSC tended to increase until 21 day of storage and then decreased. However, SSC at harvest time (15.4%) remained almost constant (with mean values of 15.6, 15.1, 15.1%) during cold storage. No significant differences existed among the three conditions during storage, but differences between storage periods for SSC values were significant (Table 3). Previous researchers reported constant soluble solid levels throughout storage time when sweet cherries stored in MAP conditions (Meheriuk et al., 1997; Remon et al., 2000).

The O_2 and CO_2 gases in the MAP and CA box during storage are given in Figure 3. The oxygen concentrations in the first week were 9.01% in MAP and 3.12% in controlled atmosphere box, while these values found as 5.12% and 1.43%, respectively, at the end of storage period.CO_2 values increased in both MAP and CA box during storage. The O_2 gas in the CA box went down to 3.12 % within one week and remained fairly constant (1.42-3.12 %) in the rest of storage period. However, the O_2 concentration of MAP did not go down at these levels, and fluctuated between 3.83 % and 9.01%. Another difference between MAP and CA box was the final concentration of O_2. As cited above, O_2 concentration of MAP dramatically higher than that of CA box in final week. It was thought that the well regulation of gases in Janny MT box lead to preserve fruit quality better than other conditions. Similarly, Padilla-Zakour et al. (2004), reported that sweet cherries stored in MAP with lower O_2 had higher fruit quality according to bags with higher O_2. CA box had higher CO_2 concentration than MAP during 5 weeks, with similar curve.

The results of the sensory tests are presented in Figure 3. The overall acceptability of cherries decreased during storage and shelf life trials. The good commercial quality was obtained from the CA box during 5 weeks, while sweet cherries stored in NA had non-marketable quality after third week of storage. Fruit in MAP maintained their quality until fifth week of cold storage, but overall acceptability scores of these fruit reached to non-marketable limit with plus 2 days shelf life. With respect to pitting, cherries stored in all three conditions had no physiological disorders for the first 2 week in storage (data not shown). While cherries in NA had low level pitting at the 3th week of storage, fruits stored in MAP and CA box showed pitting (very low) in the 4th and 5th week, respectively. But overall acceptability scores of fruit were still well within the range of acceptability (value< 2.0) in these periods. Drake and Elfving (2002) indicated that longer storage time was associated with increased pitting, showing little relationship to the year of harvest. They also found that the poorest appearance score after 21 days of storage (1.58) was still less than 2.0 (limit value), similarly to our results.

4. Conclusion

MAP and CA box had different atmospheric compositions during 5 weeks storage period. CA box had lower O_2 (1.42-3.12%) and higher CO_2 (5.10-7.27%) than MAP, resulting in better quality after 5 weeks. Sweet cherries stored in CA box had more vivid green stem than those of MAP and NA at the end of storage. Cherries packaged in plastic boxes and stored in NA lost their commercial properties after three weeks. At the end of 35 days of cold storage and shelf life, CA module was more effective in maintaining fruit quality compared with other conditions. Sweet cherry cv. '0900 Ziraat'

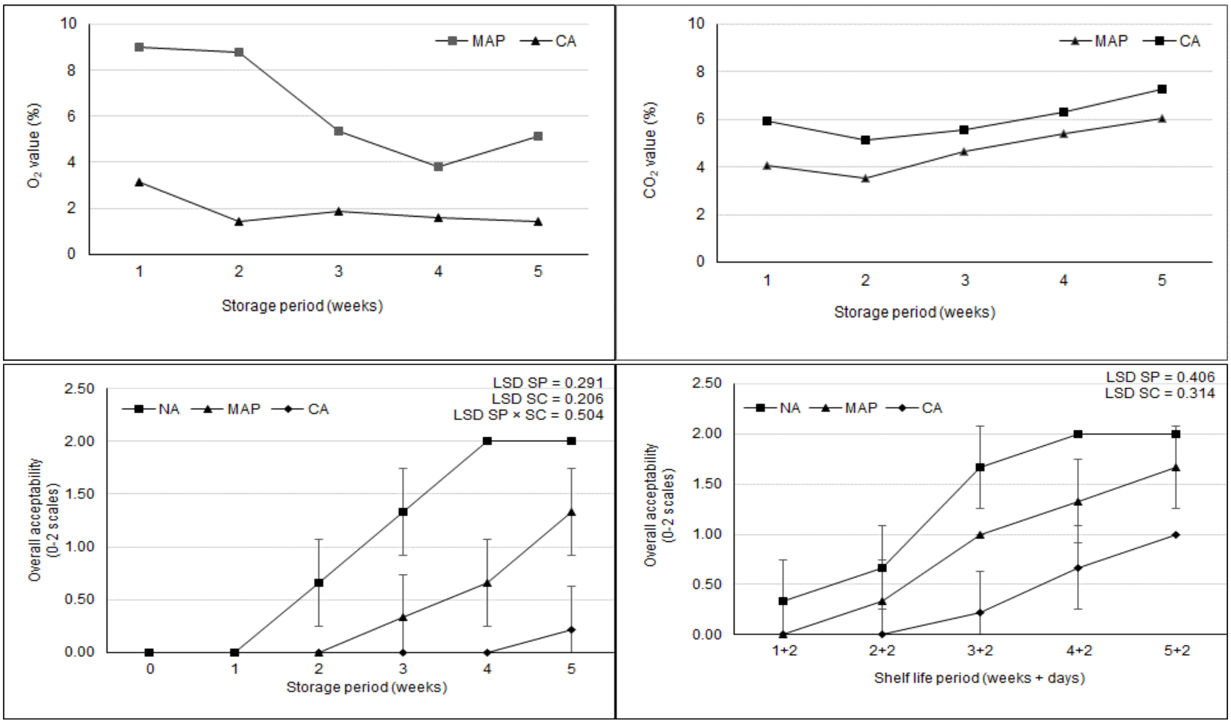

Figure 3. Changes in O_2 and CO_2 composition within MAP and CA box, and fruit overall acceptability of '0900 Ziraat' sweet cherry during cold storage and shelf life in NA, MAP and CA box (SP: Storage period, SC: Storage conditions, CA: Controlled atmosphere, NA: Normal atmosphere, and MAP: Modified atmosphere).

could be stored for 5 weeks in CA box and 4 weeks in MAP, with marketable quality. The module (Janny MT) can be used as an alternative to MAP, which is commonly used in storage in cherry. However, further detailed research on this subject is needed to investigate.

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