

Quality Changes of Different Sweet Cherry Cultivars at Various Stages of the Supply Chain

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Abstract

Transportation of sweet cherry fruits to distant markets and further marketing processes often takes approximately 2-3 weeks. The present study investigates the quality changes during this time period at three stages for three sweet cherry cultivars: 'Early Burlat', 'Napoleon', and '0900 Ziraat'. Following pre-cooling, the sweet cherries were placed in modified atmosphere packages and exposed to the following stages for the indicated durations: transportation (T) [8 days at 2 °C and 85% relative humidity (RH)]; distribution center (DC) (4 days at 6.5 °C and 80% RH), and shelf-life (SL) (2 days at 19 °C and 70% RH). Weight losses at the end of the SL stage were 3.11, 3.18, and 2.74%, respectively in 'Early Burlat', 'Napoleon' and '0900 Ziraat'. Fruit firmness decreased after SL as compared to that at other stages and was more remarkable in '0900 Ziraat'. Decreased Chroma values which indicates, the intensity or color saturation were observed in all cultivars, whereas decreased hue angle values colours expressed in degrees were observed in the 'Early Burlat' and '0900 Ziraat'. In addition, a decrease was noted in the titratable acidity of all cultivars at the end of SL. The total soluble solids, total phenolic content, and antioxidant activities were similar for all cultivars at all stages. The visual appearance scores of 'Early Burlat' cherries decreased at the end of SL, because of development of pitting on the fruit surface. The fruit quality changes were limited at T and DC stages; however, these changes became more distinctive during the SL period. It was thus concluded that the SL duration and conditions were of the highest significance with regard to maintenance of the sweet cherry fruit quality.

Keywords: antioxidants, firmness, marketing, pitting, *Prunus avium* L., transportation

Introduction

Sweet cherry is a member of the genus *Prunus* and generally grows in mild climates. It is a fleshy and non-climacteric fruit. The properties of sweet aroma, pleasant color, shape, high antioxidant activity, and nutritional content together enhance the consumer demand for sweet cherries. Accordingly, there is a rapid increase in sweet cherry production and global production sites parallel to the consumer demands. Turkey ranks first in the world's sweet cherry production (Anonymous, 2014). Higher cherry consumption plays a significant role in the prevention of diseases and maintenance of a healthy life. The health benefits of sweet cherry are linked to strong antioxidant activities (Yoo *et al.*, 2010). The antioxidant capacities of sweet cherry fruits depend on the presence of phenolic compounds such as anthocyanins and melatonin (Burkhardt *et al.*, 2001; Vinson *et al.*, 2001). Phenolic antioxidants have several positive effects on human health such as the anticarcinogenic and anti-inflammatory effects (Usenik *et al.*, 2008). The cultivar type and post-harvest conditions have direct impacts on antioxidant activities and phenolic contents of sweet cherries. While the total phenolic content of 'Van' and 'Tragana' cultivars increases, that of 'Burlat' does not significantly change during storage (Esti *et al.*, 2002).

Due to their high respiration rate, minimal reserve carbohydrates, and high susceptibility to mechanical damage, sweet cherries are highly perishable (Kupferman and Sanderson, 2001). Adverse conditions during transportation and marketing of sweet cherries may hinder the supply of high-quality fruits to consumers. Losses in weight, firmness, color, aroma, and acidity as well as desiccation and browning or discoloration of the green stem of the sweet cherry are some of the major quality losses (Alique *et al.*, 2005; Bernalte *et al.*, 2003). Susceptibility to fungal rotting, a high transpiration rate, and vulnerability to physiological disorders such as bruising and pitting aggravate the deterioration of sweet cherry fruits (Alique *et al.*, 2005). Therefore, optimum conditions specific to the cultivar should be provided throughout the entire marketing chain of this fruit to protect its quality. Optimization of harvesting, handling, processing, packaging, storing, transporting, distribution, and marketing conditions play highly significant roles in quality preservation. Modified atmosphere packaging (MAP) technology has been successfully used to maintain the postharvest quality and to prolong the storage period of several fresh fruits and vegetables. MAP technology is more effective in combination with cooling and enables

preservation of the fruit color and brightness and greenness of the stalks as well as reduces weight loss, fruit damage, and spoilage during transport and marketing activities (Kader and Watkins, 2000; Singh *et al.*, 2012; Wani *et al.*, 2014).

As sweet cherries are perishable fruits, relevant attention and great care should be taken while transporting them to distant markets so as to supply quality fruits to the consumers. In some cases, retail chains are not equipped to provide proper conditions to preserve the fruits (Wani *et al.*, 2014). Temperature and relative humidity (RH) are critical factors that influence the quality of sweet cherries during postharvest storage (Yaman and Bayindirli, 2002). Although these two factors are controlled during the storage and transportation processes, it is difficult to adjust them, especially to regulate the RH at the distribution centers and during sales at retailers (Wani *et al.*, 2014). Optimum storage conditions of sweet cherries were reported as 0°C temperature and 90-95% RH (Bernalte *et al.*, 1999). Despite several studies on the storage of sweet cherries, only a few articles simulated the transportation and marketing stages of the supply chain, and additionally the results were controversial perhaps due to the varietal and agro-ecological differences (Wang and Long, 2014). The present study is the first on major cherry cultivars that are exported to distant markets. The cultivar '0900 Ziraat' constitutes a significant proportion cherries traded of the worldwide (Demirtas and Sarisu, 2011).

The present study was conducted to investigate the changes in the physical, chemical, and sensory characteristics of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars during their transportation (T), storage at the distribution centers (DC; wholesalers), and shelf-life (SL; retailers) stages.

Materials and methods

Fruit material and supply chain trial

The experiment was conducted in 2013 on fruits harvested from 13-year-old 'Early Burlat', 'Napoleon', and '0900 Ziraat' sweet cherry trees (*Prunus avium* L.) grafted onto '*Prunus mahaleb*' rootstock in Kemalpaşa, Izmir Province, Turkey. 'Early Burlat', 'Napoleon', and '0900 Ziraat' sweet cherry fruits were harvested at full-ripe stage (08, 22, and 29 May, respectively) and hydro-cooled (fruit pulp temperature at 1-2 °C) the same day. Fruits of uniform size (26-28 mm diameter) that were disease-free and without other defects were selected, put into modified atmosphere packages, and the packages were sealed tightly. MAP were placed into cardboard boxes and subjected to the following stages: a) transportation (T; 8 days at 2 ± 0.5 °C and 85 ± 5% RH) that included the pre-stage at the packing house; b) distribution center (DC; 4 days at 6.5 ± 0.5 °C and 80 ± 5% RH), and c) shelf life (SL; 2 days at 19 ± 0.5 °C and 70 ± 5% RH) to simulate the real conditions faced during marketing.

Considering the actual transportation to distant markets (e.g. from Turkey to the United Kingdom) and distribution centers and the prevailing marketing conditions, the duration of exposure and ambient conditions were defined. Fruit samples were collected at the

end of each stage and subjected to physical, chemical, and sensory analyses. The research was designed as a randomized block design with 5 replications and each MAP package (3 kg of cherry fruits) was considered as a single replication.

Quality attributes

The sweet cherry samples were weighted at the initial phase and at the end of the T, DC and SL stages on an electronic scale (XB 12100, 0.05 g accuracy), and weight loss was determined and expressed as the percent lost from the initial weight.

Fruit firmness was determined on 25 cherry fruit per replicate by using a penetrometer (FT 011) using a 4.0-mm diameter head and conical-shaped spear; the results were expressed in Newtons (N).

The external skin color was measured at the equatorial level on both sides of the 25 sweet cherry fruits by using a colorimeter (CR-300), and the average scores were recorded in terms of CIE- $L^*a^*b^*$ values. These values were then used to calculate

$$\text{Chroma } (C^* = [a^{*2} + b^{*2}]^{1/2}),$$

which indicates the intensity or color saturation and hue angle ($b^\circ = \tan^{-1} [b^*/a^*]$) that is expressed in degrees and represents: 0° (red-purple), 90° (yellow), 180° (bluish-green), and 270° (blue) (McGuire, 1992).

Juice was extracted from 25 cherry fruits per replicate for further analysis. The total soluble solid (TSS) content of the fruit juice was determined by using a digital refractometer (PR-1) and expressed in percent. The titratable acidity (TA) was determined by titrating 10 mL of juice with 0.1 N NaOH up to pH 8.1. The results were expressed as grams malic acid per 100 mL of fruit juice, in accordance with the AOAC standards (1984).

Total phenolic content and antioxidant activity

Fruit extracts were prepared from 10 fruits according to Thaipong *et al.* (2006), with some modifications for total phenolic content and antioxidant activity (in methanol extract) analysis. Total phenolic content was determined by the Folin-Ciocalteu method according to the method of Swain and Hillis (1959), with an incubation time of 120 minutes for color development. The absorbance was measured at 725 nm using a spectrophotometer and the results were expressed as milligram gallic acid equivalent (GAE) per 100 gram of fresh weight (FW) with reference to a gallic acid (0-0.1 mg/mL) standard curve.

The ferric reducing ability of plasma (FRAP) assay was performed as previously described by Benzie and Strain (1996), where reductants ("antioxidants") in the sample reduce Fe (III)/tripyridyltriazine complex to a blue ferrous form, with an increase in the absorbance at 593 nm. The final results are expressed in μmol trolox equivalents (TE)/g FW, with reference to a trolox (25-500 μmol) standard curve.

Decay development

Decay development was examined on 3 kg fruit sample and their rates were expressed in percent.

Sensory evaluation

The sensory quality evaluation of appearance was conducted by an experienced six-member panel on a nine-point hedonic scale: appearance (9: displays the complete characteristics of the sweet cherry appearance at harvest; 7: good appearance; 5: acceptable appearance, slight pitting; 3: poor appearance, moderate pitting; 1: high pitting, decay and/or stem desiccation). The procedures for sensory evaluation of horticultural crops described by Heintz and Kader (1983) were utilized by the panelists.

Statistical analysis

All data were subjected to analyses of variance (ANOVA) by using the IBM SPSS Statistics 19 statistical software. Significant differences between the means for each sweet cherry cultivars were determined by Duncan's multiple range tests at $p < 0.05$. Standard deviation of the mean (SD) was also calculated from the replicates.

Results and discussion

Weight loss and fruit firmness values of cherry cultivars during the transport and marketing stages are presented in Fig. 1. The increases observed in the weight loss of cherry cultivars during T (8 days at 2 °C), DC (4 days at 6.5 °C), and SL (2 days at 19 °C) stages were found to be significant ($p < 0.01$). Such increases became especially distinctive after the SL stage. At the end of all stages, the weight loss in 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars were observed as 3.11, 3.18, and 2.74%, respectively (Fig. 1a). Lower weight loss in the T and DC stages were mainly because of the use of MAP packages (Kucukbasmaci *et al.*, 2008; Singh *et al.*, 2012; Wani *et al.*, 2014) and the limited moisture loss due to ambient conditions (temperature and RH). Weight loss during the SL stage was higher than that at the T+DC stages when the MAP packages were open,

ambient temperature was high (19 °C), and RH was low (70%) during SL for 2 days. Similarly, the weight loss observed in the '0900 Ziraat' cherry cultivar during 6 weeks of storage was lower than that in 2 days of SL at 20 °C (Onursal *et al.*, 2013). Weight loss of the '0900 Ziraat' cherry cultivar at the end of SL stage was 13% lower than that of the other cultivars. Variations in weight loss of the different cherry cultivars in this study comply with those in previous reports (Diaz-Mula *et al.*, 2010), irrespective of the difference in the skin characteristics and composition of the fruits.

Fruit firmness is directly related to storage potential, mechanical resistance, and rot development (Esti *et al.*, 2002). The decreases observed in firmness of all three cherry cultivars during the transport and marketing stages were significant ($p < 0.01$). Fruit firmness of 'Early Burlat', 'Napoleon' and '0900 Ziraat' cultivars were observed to be 9.9, 10.2, and 11.9 N, respectively, at harvest (Fig. 1b). While fruit firmness of 'Early Burlat' and '0900 Ziraat' after DC were similar to that after T, there was a decrease in fruit firmness of 'Napoleon'. Fruit firmness of the cherry cultivars exhibited a decrease after SL as compared to that in the other stages. At the end of SL and compared to the initial firmness values, there were 19.8, 21.2, and 16.5% decreases, respectively, in 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry fruit. Fruits began to soften following rapid loss of moisture from the surface (Wani *et al.*, 2014). The decreases in firmness during the transportation and marketing processes also resulted from moisture loss. Meheriuk *et al.* (1995) reported significant losses in firmness of 'Lapins' cherry cultivar during storage. Similarly, decreasing firmness values were also reported for other cherry cultivars (Kappel *et al.*, 2002; Clayton *et al.*, 2003; Onursal *et al.*, 2013; Wang and Long, 2014). At all stages, fruit firmness of '0900 Ziraat' was about 16.5% higher than that of the other cultivars. Differences in fruit firmness among cultivars indicate the differences in their cell structures, skin characteristics, compositions and/or respiration rates (Karacali, 2012).

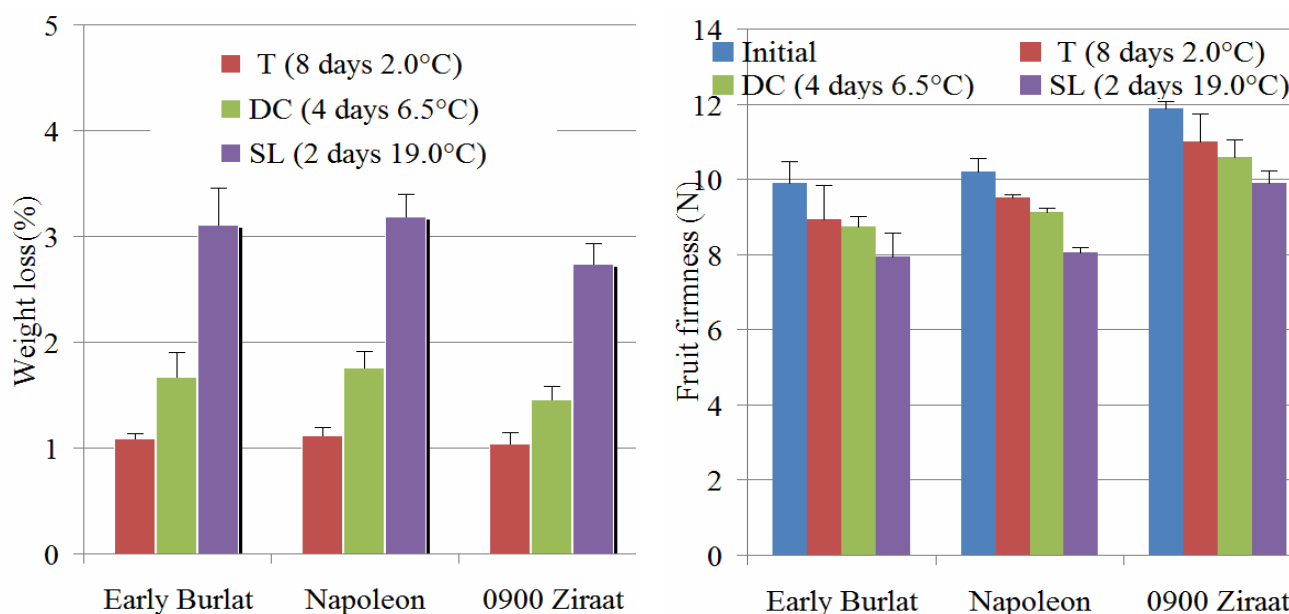


Fig. 1. Postharvest weight loss (a-left) and flesh firmness (b-right) values of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars at three different stages of the supply chain

Tab. 1. Postharvest TSS and TA content of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars at three different stages of the supply chain

Sampling stage	TSS content (%)			TA content (g malic acid/100 mL)		
	'Early Burlat'	'Napoleon'	'0900 Ziraat'	'Early Burlat'	'Napoleon'	'0900 Ziraat'
Initial	14.97 ^{NS}	14.97 ^{NS}	16.50 ^{NS}	0.91 a ^{''}	0.88 a ^{''}	0.99 a ^{''}
T (8 days, 2.0°C)	15.17	15.06	16.69	0.86 ab	0.86 a	0.92 b
DC (4 days, 6.5°C)	15.23	15.23	16.97	0.79 bc	0.86 a	0.93 b
SL (2 days, 19.0°C)	15.17	15.27	17.13	0.72 c	0.79 b	0.88 c

NS, ' ', Nonsignificance or significance at $p < 0.05$ or 0.01 , respectively

'Means for each experiment were separated by different letters within columns by Duncan's multiple-range test, $p < 0.05$

The changes in C^* and b^o values of different cherry cultivars during the transportation and marketing phases are presented in Fig. 2. The decreases in C^* values of the 'Early Burlat' cultivar at T and SL stages and decrease in C^* values of '0900 Ziraat' at the end of SL were statistically significant ($p < 0.01$). The decrease in C^* values of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry fruit during the SL stage were calculated as 15.7, 13.6, and 7.8%, respectively. The changes in b^o values of 'Early Burlat' and '0900 Ziraat' cultivars were similar to the changes observed in C^* values and the decreases at the end of SL were found to be significant ($p < 0.05$). The changes in b^o values of 'Napoleon' cherries were highly limited and varied between 14.53 and 15.75%. The changes in fruit color parameters during the transportation and marketing phases are proportional to the ripening of the fruits. Decreased brightness values were also found in 'Lapins' cherry cultivar during the storage period (Meheriuk *et al.*, 1995). Distinctive changes were not observed in color values of cherries since the fruits were harvested at a fully ripe stage. Color darkening and increased anthocyanin contents were reported for cherries harvested at different ripening stages during storage and shelf life, based on the cultivar and ripening stage (Serrano *et al.*, 2009).

Changes in TSS and TA contents of the cherries during the transportation and marketing stages are given in Tab. 1. It has been reported that TSS and TA contents are related to the intensity of sweet cherry flavor and that consumer

acceptability increases with high TSS and TA levels in the fruit (Crisosto *et al.*, 2003; Kalyoncu *et al.*, 2009). TSS contents of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars during transportation and marketing stages exhibited similar tendencies and they were 15.0-15.2, 15.0-15.3, and 16.5-17.1%, respectively (Tab. 1). Similar to the findings of the present study, significant changes were not observed in the TSS contents of cherries during the MAP storage of fruits (Meheriuk *et al.*, 1995; Meheriuk *et al.*, 1997; Remon *et al.*, 2000; Onursal *et al.*, 2012). The higher TSS contents of '0900 Ziraat' cultivar was mainly due to the cultivar type. Girard and Kopp (1998) reported that the TSS contents of 12 different cherry cultivars ranged between 13.5 and 24.5%. Several other studies also reported significantly different TSS contents for different sweet cherry cultivars (Kappel *et al.*, 2002; Diaz-Mula *et al.*, 2010).

The decreases in TA values of cherries before the SL stage were significant ($p < 0.01$). Such decreases were especially remarkable in the 'Early Burlat' variety (21%). The post-harvest decreases in TA values are proportional to the ripening of the fruits. Similar decreases in TA values were also reported during the storage of '0900 Ziraat' (Kucukbasmaci *et al.*, 2008; Onursal *et al.*, 2013), 'Napoleon' (Esturk *et al.*, 2014), 'Burlat' (Remon *et al.*, 2000), 'Sciazza', 'Ferrovia' (Esti *et al.*, 2002), and 'Lapins' (Meheriuk *et al.*, 1995) cultivars. These decreases are closely related to the ripening level at harvest, storage conditions, and durations (Wani *et al.*, 2014). As sweet cherry fruit is a

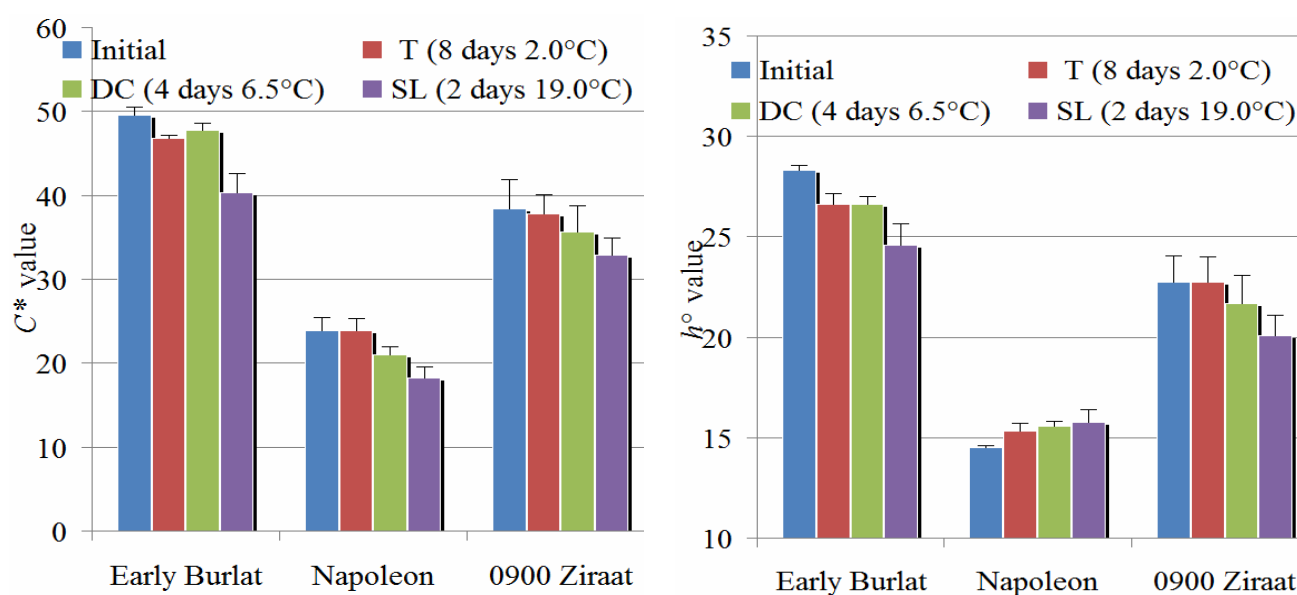


Fig. 2. Postharvest C^* (a-left) and b^o values (b-right) of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars at three different stages of the supply chain

Tab. 2. Post-harvest total phenolic content and antioxidant activity of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars at three different stages of the supply chain

Sampling stage	Total phenolic content (mg GAE/100 g FW)			Antioxidant activity ($\mu\text{mol TE/g FW}$)		
	'Early Burlat'	'Napoleon'	'0900 Ziraat'	'Early Burlat'	'Napoleon'	'0900 Ziraat'
Initial	101.3 ^{NS}	103.5 ^{NS}	94.6 ^{NS}	9.22 ^{NS}	13.32 ^{NS}	7.93 ^{NS}
T (8 days, 2.0°C)	95.7	106.5	95.0	8.38	13.27	7.49
DC (4 days, 6.5°C)	99.5	106.8	94.5	9.42	14.10	7.18
SL (2 days, 19.0°C)	102.2	102.6	88.0	9.21	12.25	6.75

NS, Nonsignificant

non-climacteric fruit, loss in TA tends to occur simultaneously with metabolic activities.

Total phenolic content and antioxidant activity of cherry fruit at harvest and at T, DC, and SL stages are presented in Tab. 2. Significant differences were observed in the total phenolic content and antioxidant activity of the tested cherry cultivars during the transportation and marketing stages. The average total phenolic contents of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cultivars during the transport and marketing processes were 99.7, 104.9, and 93.0 mg GAE/100 g FW, and the antioxidant activities were 9.06, 13.24, and 7.34 $\mu\text{mol TE/g FW}$, respectively. Harvest at fully ripe stage resulted in limited changes in the total phenolic content and antioxidant activity. Serrano *et al.* (2009) reported increased post-harvest total phenolic and antioxidant activity values for cherries based on the ripening levels. Functional parameters reached the maximum levels with 2-day delay in harvest (Diaz-Mula *et al.*, 2010). Total phenolic content and especially the antioxidant activity of 'Napoleon' were significantly higher than those of '0900 Ziraat' cultivar. Previous studies also reported significantly different results for different sweet cherry cultivars (Usenik *et al.*, 2008; Serrano *et al.*, 2009; Diaz-Mula *et al.*, 2010; Kelebek and Selli, 2011).

Decay development was not observed in 'Early Burlat', 'Napoleon' or '0900 Ziraat' cherry fruit during the transportation and marketing stages. However, storage in MAP, climatic conditions during the growth, cultural practices, and disease and pest management practices had significant impacts on rot development.

Visual appearance scores of cherry fruits and stems at the end of T and DC stages were similar to the initial scores. The difference in the decrease in the visual appearance of 'Napoleon' and '0900 Ziraat' cherry fruit at the end of SL stage were not significant. On the other hand, such decreases were found to be significant ($p < 0.01$) in 'Early Burlat' (Tab. 3) mainly because of development of pitting over the fruit skin at the end of SL stage. Stems of all

Tab. 3. Postharvest visual appearance of 'Early Burlat', 'Napoleon', and '0900 Ziraat' cherry cultivars at three different stages of the supply chain

Sampling stage	'Early Burlat'	'Napoleon'	'0900 Ziraat'
Initial	9.0 a ^{2*}	9.0 ^{NS}	9.0 ^{NS}
T (8 days, 2.0°C)	9.0 a	9.0	9.0
DC (4 days, 6.5°C)	8.2 a	8.6	9.0
SL (2 days, 19.0°C)	5.8 b	7.8	8.2

NS, Nonsignificance or significance at $p < 0.01$.*Means for each experiment were separated within columns by Duncan's multiple-range test, $p < 0.05$

cultivars preserved their green color and brightness during the T and DC stages because limited water loss occurred from the fruits and stems during these stages. Storage in MAP was effective in limiting water loss from the stems (Kucukbasmaci *et al.*, 2008; Singh *et al.*, 2012; Wani *et al.*, 2014). Very slight browning or discoloration of the green stem was observed at the end of SL stage.

Conclusion

Changes in the quality parameters of cherry cultivars were more remarkable during the 2-day SL period as compared to the 8-day T period or the 4-day DC period. While '0900 Ziraat' and 'Napoleon' cultivars showed preserved quality at the end of SL stages, some 'Early Burlat' fruits showed visible spoilage. With regard to the investigated quality parameters, '0900 Ziraat' cherry cultivar was found to be superior over the others. The present results clearly indicate the significance of the SL conditions and/or durations for preservation of the sweet cherry quality.

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