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Research Article

Effects of Post-Harvest UV-C and Hot Water Treatments on Quality Attributes of '0900 Ziraat' Cherries throughout the Cold Storage in Modified Atmosphere Packages

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Abstract

In this study, effects of post-harvest UV-C, Hot Water and UV-C + Hot Water treatments on quality attributes and especially on phenolics of '0900 Ziraat' cherries grown under Mersin Taurus Mountains conditions throughout the cold storage were investigated. For this purpose, before to store, cherry fruits were subjected to UV-C treatments for 5 minutes and Hot Water treatments at 50 °C for 1 minute. The fruits harvested at full-ripe period were then stored in modified atmosphere packages (MAP) (Xtend®) for 20 days at 0 °C temperature and 90±5% relative humidity. Throughout the storage period, weight loss, skin color, suspended solids content, titratable acidity, total phenolics and antioxidant analyses were performed in every 4th day of storage (0, 4, 8, 12, 16 and 20th days). Effects of experimental treatments on phenolics were investigated in detail. Present findings revealed that UV-C + Hot Water treatments without any chemicals better preserved the quality attributes and significantly restricted the losses in protocatechic acid, chlorogenic acid and q-coumaric acid contents.

Key words: Hot water, MAP, storage, sweet cherry, UV-C.

0900 Ziraat' Kiraz Çeşidinde UV-C ve Sıcak Su Uygulamalarının Modifiye Atmosfer Koşullarında Muhafazaya Etkileri

Özet

Bu çalışmada hasat öncesi UV-C, Sıcak Su ve UV-C + Sıcak Su uygulamalarının Mersin Toroslar koşullarında yetiştirilen '0900 Ziraat' kiraz çeşidinin soğukta muhafazası süresince kalite ve özellikle fenolik bileşiklerin değişimleri incelenmiştir. Bu amaçla depolama öncesi kiraz meyvelerine 5 dakika süreyle UV-C ve 1 dakika süreyle 50 °C'de sıcak uygulaması yapılmıştır. Tam olum döneminde hasat edilen meyveler 20 gün süre ile modifiye atmosfer paketleri (Xtend®) içerisinde 0 ˚C sıcaklık ve %90±5 oransal nem koşullarında depolanmıştır. Depolama periyodu süresince her 4. gün meyve örneklerinde; ağırlık kaybı, meyve kabuk rengi, suda çözünebilir kuru madde, titre edilebilir asit miktarı, toplam fenolik ve antioksidan analizleri yapılmıştır. Ayrıca uygulamaların fenolik maddelere etkileri detaylı olarak incelenmiştir. Çalışma sonucunda ele alınmış olan bütün kalite değerlerinde hasat sonrası kimyasal içermeyen ve alternatif bir uygulama olan UV-C uygulamasının depolama süresince meyve kalitesini daha iyi koruduğu, aynı zamanda fenolik maddelerden protokateşuik, klorojenik asit ve Q-kumarik asit miktarında azalmayı sınırlandırdığı tespit edilmiştir.

Anahtar kelimeler: Sıcak su, MAP, depolama, kiraz, UV-C.

Introduction

Appearance of cherries significantly attracts consumers. Rich vitamins, minerals and antioxidants increase the interest of consumers in this dietary fruit. Cherries generally ripen at certain periods and them a delicate nature. Therefore, they should be marketed in a short period of time. Markets are served with large quantities of fruit at harvest season of cherries. To prevent such pile-ups in markets and to have a price equilibrium, fruits should be cold-stored for couple of days or for a week (Gündüz, 1993). Cherries can be stored at -1 and 0°C temperatures and 80-95% relative humidity. Storage durations may vary from one cultivar to another, but can be prolonged up to 1-4 weeks (Karaçalı, 1993).

Increasing productions and resultant exports have increased the significance of post-harvest technologies to preserve post-harvest quality and to prolong market and shelf life of the fruits. Various chemicals are applied to fruits before to store them to prolong storage durations. Such chemicals may have residue problems and exert a risk on environment and human health. Thus, new environment-friendly technologies are searched for in cherry storage and preservation. For longer preservation of post-harvest quality attributes of cherries, environment-friendly treatments are practiced and such treatments include storage at low temperatures, in controlled or modified atmosphere packages (MAP), hot water treatments, renewable film coatings and ray treatments (Lurie, 1998; Chockchaisawasdee et al., 2016).

Of these technologies, MAP do not have any additives or a few additives. Thus, MAP are widely used to prevent post-harvest biochemical changes, oxidative process, disease agents and ultimate quality losses in cherries (Wani et al., 2014). Şen et al. (2016) stored '0900 Ziraat' sweet cherries in 3 different MAP for 35 days and reported insignificant effects of MAP on color parameters (C* and *h°*), flesh firmness, TSS, TA, pH, stalk quality and taste of fruits throughout the storage duration and shelf life. Koçak and Bal (2017) applied UV-C, MAP and renewable coating treatments to '0900 Ziraat' cherries and cold-stored the fruits for 4 weeks and indicated that UV-C treatments prevented fruit decays and increased phenolics throughout the storage. Sabır et al. (2016) applied hot water treatments at 50 °C for 5 minutes and MAP treatments to '0900 Ziraat' cherries and indicated hot water+MAP treatments as the best practice to prevent weight loss, flesh softening and decays.

Post-storage analyses in cherries revealed that phenolics increased by 40-60% and chlorogenic acid was the most dominant hydrocinnamic acid. Phenolics influence color, thus the quality. Fruit taste, aroma and flavor are also closely related to high phenolics content (Serrano et al., 2009). Bal (2012) stored '0900 Ziraat' cherries at 0–1°C and reported that total phenolics slightly increased throughout the initial 15 days of storage and decreased toward to end of the storage. Kafkaletou et al. (2015) stored 'Adriana' and 'Noire de Meched' cherries at 1°C and indicated that total phenolics of 'Adriana' cherries irregularly changed and total phenolics of 'Noire de Meched' cherries did not change much. Jacobek et al. (2009) investigated the phenolic acids of cherry cultivars grown in Croatia and reported chlorogenic acid contents of cherry cultivars as between 19–62 mg kg^{-1} and indicated chlorogenic acid as the dominant phenolic acid corresponding about 26-48% of total phenolics.

This study was conducted to determine the effects of post-harvest MAP, UV-C and Hot Water treatments on fruit quality and storage durations of '0900 Ziraat' cherries.

Material and Methods

In this study, '0900 Ziraat' cherries harvested at commercial ripening period from a producer orchard in Atlılar village of Toroslar town of Mersin province were used as the material. The '0900 Ziraat' is a late cultivar with large oval or hearth-shaped fruits. Fruit skin has bright dark red color, fruit flesh is firm, juicy and tasty. In brief, fruit quality is quite high (Engin and Ünal, 2006). Production has recently increased in Turkey and fruits are largely sent to exports.

Right after the harvest, cherry fruits were subjected to a pre-cooling through cold air at 0 °C for a day. Then, fruits were immediately transported to laboratories of Horticulture Department of Van Yuzuncu Yıl University (YYU) Agricultural Faculty with frigorific vehicles. Healthy fruits with almost identical ripening levels, size and color characteristics were selected and they were divided into 4 groups. The first group fruits were control fruits. They were not subjected to any treatments and directly placed into cold storage in 500 g cups. The second group fruits were subjected to UV-C treatments for 5 minutes at 20 cm distance from the fruits. The third group fruits were subjected to hot water treatments in 50°C hot water basin for 1 minute. The forth group fruits were subjected to both UV-C and hot water treatments. Then, all treated fruits were placed into plastic cups and Xtend® modified atmosphere packages (MAP).

Following the experimental treatments, fruits were stored at cold storages of YYU

Agricultural Faculty for 20 days at 0 °C and 90-95% relative humidity. The following analyses and measurements were performed on fruits at the beginning of storage and every 4th day throughout the storage (4, 8, 12, 16 and 20th days of storage) in 3 replications.

Weight loss

In order to determine the weight loss during the storage, weight measurements were made during the four daily analysis periods following the harvest period with sensitive balance. Weight loss was calculated as % of initial weight.

Color, pH, titratable acidity (TA) and soluble solids content (SSC)

Changes in fruit color were measured with a Minolta Color Meter (Model CR-400; Osaka, Japan). The pH values were determined through inserting the probe of a pH instrument (AZ 8601, Hengxin Company, China) into the juice. Titratable acidity was measured by applying 0.1 N NaOH solution until pH became 8.1 and the results were expressed in % malic acid (Cemeroğlu, 2007). The SSC ratio was measured with a digital refractometer (Atago, Tokyo, Japan) and the results were expressed in % Brix.

Total phenolic and antioxidant

The total phenolic content was determined with a spectrophotometer (Thermo Scientific Genesys 10S UV-VIS) in accordance with the Swain and Hillis (1959) method, a modified version of Folin-Ciocaltaeu calorimetric method. The absorbance of the samples was read at 725 nm and total phenolic content was expressed in Gallic acid equivalent (GAE) mg100 g^{-1} fresh weight (FW). The method specified by Benzie and Strain (1996), Ferric Reducing Antioxidant Power (FRAP), was used to determine the total antioxidant capacity. The absorbance of the samples was read at 593 nm and total antioxidant capacity was expressed in µmol trolox equivalent (TE) g^{-1} FW.

Phenolics compounds

Protocatechic acid, vanillic acid, rutin, gallic acid, chlorogenic acid, syringic acid, p-coumaric acid, ferulic acid and c-coumaric acid compounds were determined in this study.

The method specified by Rodriguez-Delgado et al. (2001) was used for the separation of phenolic compounds in HPLC system. In this method, cherry pulps were diluted with distilled water at 1:1 ratio and centrifuged at 15000 rpm for 15 minutes. The upper portion was then filtered through 0.45µm Millipore filters and injected into HPLC. Chromatographic separation was performed in Agilent 1100 (Agilent, USA) HPLC system equipped with DAD detector (Agilent. USA) and 250*4.6 mm, 4µm ODS column (HiChrom, USA). Solvent A methanol-acetic acid-water (10:2:88) and solvent B methanol-acetic acid-water (90:2:8) were used as the mobile phase. Separation was performed at 254 and 280 nm, flow rate was 1 mL/min and injection volume was 20 µL.

Results and Discussion

Weight loss

The effects of post-harvest treatments on weight loss of cherry fruits throughout the cold storage are provided in Table 2. Except for UV-C treatments, storage durations had significant effects on weight loss of experimental treatments throughout 20 days of storage ($p \leq 0.05$). Increasing weight loss values were observed with increasing storage durations. With regard to the effects of pre-storage treatments on weight loss throughout 20 days of storage, it was observed that control treatment (3.04%) and UV-C+Hot Water treatments (3.26%) were the most successful treatments. The greatest weight loss (5.15%) was observed in UV-C group fruits.

Table 1. Effects of Hot Water and UV-C treatments on weight loss of cherry fruits stored at 0°C and 90–95% relative humidity for 20 d.

Duration (days)	Control	UV-C	Hot Water	UV-C+Hot Water
0	0.00±0.00 E	0.00±0.00 F	0.00±0.00 F	0.00±0.00 C
4	0.55± 0.00 D c	1.08±0.00 E a	1.10±0.00 E a	0.82±0.16 BC b
8	1.66±0.01 C	2.17±0.00 D	1.92±0.15 D	1.63 ±0.31 B
12	1.94b±0.17 C	3.25±0.01 C a	2.47 ±0.15 C ab	1.90±0.47 AB b
16	2.49± 0.18 B bc	3.79±0.01 B a	3.57±0.15 B ab	2.17±0.63 AB c
20	3.04±0.18 A b	5.15±0.16 A a	4.67±0.14 A a	3.26±0.63 A b

a, b, c, d: → Different small letters indicate significant differences among the treatments ($p<0.05$).
A, B, C, D: ↓ Different capital letters indicate significant differences among the storage durations ($p<0.05$) (Duncan's multiple range test).

Since cherries have a thin cuticle layer, it is hard to prevent water loss (Mitcham et al., 1997). Because the fruit physiological processes and respiration goes on during the cold storage, there

is quite high level of water loss, thus weight loss in cherries. Following the experimental treatments, all fruits including control fruits were placed into MAP and then stored in cold storage, therefore present weight loss values were quite low as it was in previous similar MAP studies **(**Wani et al., 2014; Sabır et al., 2016). Koçak and Bal (2017) carried out a study with '0900 Ziraat' cherries and reported similar low weight loss ratios for MAP treatments, but contrary to present findings, indicated that UV-C treatments increased weight losses. Such differences probably resulted from different doses and durations of UV-C treatments.

Table 2. Effects of Hot Water and UV-C treatments on color of cherry fruit stored at 0 °C and 90–95% relative humidity for 20 d.

	Duration (days)	Control	UV-C	Hot Water	UV-C+Hot Water
L*	0	21.27±0.17 C	21.76±0.32 B	22.52±0.36 B	21.67±0.22 C
	4	22.09±0.11 B	21.74±0.05 B	22.11±0.01 B	22.13±0.20 BC
	8	22.96±0.26 A	23.24±0.42 A	23.47±0.22 A	23.95±0.18 A
	12	22.52±0.04 AB	22.48±0.02 AB	22.76±0.23 B	22.77±0.05 B
	16	22.09±0.08 B	22.65±0.39 AB	22.39±0.17 B	22.20±0.21 BC
	20	22.74±0.27 A	23.23±0.19 A	23.49±0.01 A	23.57±0.42 A
a*	0	8.83b±0.14 AB	9.55±0.16 A ab	10.48±0.47 A a	10.00±0.37 B a
	4	8.91±0.66 AB	7.94±0.78 BC	9.87±0.23 AB	12.22±0.73 A
	8	9.58±0.01 A a	7.35±0.35 C c	8.55±0.08 C b	9.20±0.29 B ab
	12	8.22±0.40 B ab	9.05±0.51 AB a	8.86±0.02 C a	7.47±0.16 C b
	16	7.80±0.11 B c	8.51±0.07 ABC bc	9.41±0.19 BC a	8.98±0.39 B ab
	20	9.52±0.53 A a	8.01±0.03 BC b	7.35±0.4 2 D b	7.25±0.05 C b
b*	0	1.70±0.04 AB	1.81±0.08	1.68±0.06 AB	1.65±0.01 B
	4	1.73±0.10 AB b	1.56±0.11 b	1.92±0.02 A a	2.20±0.05 A b
	8	1.68±0.08 AB	1.54±0.09	1.66±0.05 AB	1.73±0.04 B
	12	1.51±0.03 BC b	1.86±0.09 a	1.73±0.10 AB a	1.44±0.00 C b
	16	1.36±0.03 C c	1.83±0.10 a	1.57±0.00 B b	1.69±0.04 B ab
	20	1.75±0.08 A	1.62±0.08	1.43±0.18 B	1.29±0.06 C
C	0	9.00±0.14 AB b	9.72±0.17 A ab	10.62±0.47 A a	10.14±0.37 B a
	4	9.09±0.68 AB b	8.11±0.78 BC b	8.56±1.08 BC b	12.43±0.73 A a
	8	9.73±0.03 A a	7.52±0.36 C c	8.73±0.06 BC b	9.37±0.29 B ab
	12	8.37±0.40 B ab	9.25±0.52 AB a	9.03±0.04 ABC a	7.61±0.15 C b
	16	7.93±0.11 B c	8.73±0.05 ABC b	9.55±0.19 AB a	9.15±0.39 B ab
	20	9.70±0.50 A a	8.20±0.06 BC b	7.50±0.46 C b	7.38±0.06 C b
***h*°**	0	11.75±0.13 a	11.33±0.36 b	9.36±0.01 B b	9.61±0.39 C b
	4	11.31±0.46	12.10±0.65	11.38±0.40 A	9.91±0.21 BC
	8	10.51±0.35 b	12.40±0.22 a	11.43±0.52 A ab	11.21±0.24 A ab
	12	11.07±0.18	12.02±0.15	11.35±0.78 A	11.62±0.28 A
	16	10.33±0.25 bc	12.99±0.69 a	9.54±0.22 B c	11.04±0.41 A b
	20	10.42±1.15	11.34±0.32	11.13±0.70 A	10.78±0.35 AB

a, b, c, d: → Different small letters indicate significant differences among the treatments ($p<0.05$).
A, B, C, D: ↓ Different capital letters indicate significant differences among the storage durations ($p<0.05$).

Color

Fruit skin and stalk color are the greatest indicators of ripening and quality of the fruits (Wang et al., 2012; Wani et al., 2014). Customers usually prefer fruits with bright red skin color and green stalk color. The color parameters of hue angle (*h°*), an average value for skin color, and L^* values indicating color brightness decreased throughout the storage. Storage durations and treatments had significant effects on color parameters ($p\leq0.05$). The effects of post-harvest treatments on color parameters throughout the cold storage are provided in Table 3.

The L^* values were the best preserved with UV-C+Hot Water treatments. L^* values increased until the 8th day of the storage and decreased later on. The initial L^* value of 21.67 increased to 23.95 on the 8th day of storage and decreased to 23.57 on the 20th day of storage. The least change in L^* values was observed in control fruits. Except for control fruits, a^*, b^* and chroma (C^*) values exhibited an irregular variations throughout 20 days of storage and decreases were observed in

darkness of red and blue colors as compared to the initial values.

Changes in chroma values indicate darkening in fruit skin color. Aging-induced anthocyanin degradation darkens fruit colors. Such a darkening is expressed by Hue (h^o) angles (Göksel, 2011). Present hue (h^o) angles exhibited an irregular variation based on a^* and b^* values. The value in UV-C treatments increased up to 12.99 on the 16th day of storage. In control treatments, the initial hue angle value of 11.75 decreased to 10.42 on the 20th day of storage depending on darkening in fruit skin color. Except for the control treatments, darkening in fruit skin color was preserved with the experimental treatments. Present findings on color parameters comply with the findings of earlier similar studies carried out with MAP and UV-C treatments in cherries (Wani et al., 2014; Şen and Kuzucu, 2016). MAP treatments reduce respiration rates and thus minimize enzyme activities within the package, therefore they were quite effective in preservation of color parameters.

Table 3. Effects of Hot Water and UV-C treatments on pH and TA of cherry fruit stored at 0 °C and 90–95% relative humidity for 20 d.

	Duration (days)	Control	UV-C	Hot Water	UV-C+Hot Water
pH	0	4.32±0.01 BC	4.28±0.00 D	4.30±0.02 C	4.33±0.00 C
	4	4.40±0.01 AB	4.38±0.04 BC	4.36±0.03 BC	4.35±0.03 BC
	8	4.33±0.01 BC b	4.42±0.01 AB a	4.43±0.01 A a	4.45±0.01 A a
	12	4.44±0.03 A a	4.34±0.01 C b	4.44±0.01 A a	4.41±0.00 AB a
	16	4.42±0.05 AB	4.40±0.01 AB	4.37±0.02 B	4.40±0.05 ABC
	20	4.29±0.03 C c	4.44±0.01 A a	4.32±0.00 BC bc	4.36±0.01 BC b
TA	0	0.57±0.02 A	0.59±0.01 A	0.54±0.02 A	0.53±0.00 BC
	4	0.450.03 B b	0.48±0.03 BC b	0.50±0.02 AB ab	0.58±0.00 A a
	8	0.52±0.01 AB ab	0.47±0.02 C a	0.45±0.01 B a	0.45±0.00 D b
	12	0.46±0.02 B b	0.54±0.02 AB a	0.53±0.01 A a	0.54±0.02 ABC a
	16	0.48±0.04 B	0.46±0.01 C	0.52±0.02 A	0.52±0.02 C
	20	0.52±0.01 AB	0.55±0.01 A	0.53±0.03 A	0.56±0.01 AB

a, b, c, d: → Different small letters indicate significant differences among the treatments ($p<0.05$).
A, B, C, D: ↓ Different capital letters indicate significant differences among the storage durations ($p<0.05$).

The pH, titratable acidity (TA) and soluble solids content (SSC)

Fruits have different types of organic acids and about 85% of acidity of cherries is composed of malic acid (Chockchaisawasdee et al., 2016). Treatments and storage durations had significant effects on titratable acidity and pH values of the cherries throughout the storage ($p\leq0.05$). The greatest decrease in titratable acidity was observed in control fruits. The initial value of 0.57% decreased to 0.52% at the end of storage. Apart from the control treatments, quite high decreases were observed in titratable acidity values of the other treatments between the 4th and 12th days of storage and the decreases between the 16th and 20th days of storage were also high as compared to the initial values. MAP treatments generally reduced acid losses in cherries.

Present findings on titratable acidity comply with the findings of earlier studies (Koyuncu et al., 2005; Şen and Kuzucu, 2016). Decrease in titratable acidity loses is especially significant for taste, aroma and color formation and preservation in cherries. Irregular variations were observed in pH values of all treatments and storage durations throughout the storage. As compared to the initial values, the greatest increase in pH values was observed in UV-C treatments. Present findings were supported by the findings of Çölgeçen and Aday (2015) and Şen and Kuzucu (2016). Variations in titratable acidity values were parallel to the changes in SSC values. Titratable acidity values decreased with increasing SSC values.

The effects of post-harvest treatments on SSC values throughout the storage are provided in Table 4. Effects of treatments on SSC values throughout the storage were found to be significant. Except for UV-C and UV-C + How Water treatments, effects of storage durations on SSC values were also found to be significant. In control fruits, SSC values slightly decreased on the 16th day of storage, the initial value of 25.30% decreased to 20.08% at the end of the storage. SSC was the best preserved with UV-C + Hot Water treatments. The initial value of 20.40% decreased to 19.55% at the end of the storage. Different from the other similar studies (Çölgeçen and Aday, 2015), present SSC values decreased with the experimental

treatments. Increases in SSC value of the other studies were probably because of water loss in cherry fruits (Özdemir et al., 2006). Respiration and enzyme activities initially increased SSC values, but later physiological and pathological deformations and inclusion of sugars into the respiration process reduced the SSC values toward to end of the storage. Sarı and Türk (2002) also indicated increasing and decreasing SSC values for cherries preserved in MAP and related such irregular changes to non-homogeneous nature of the fruits. Similar with the present findings, Şen and Kuzucu (2016) also indicated decreasing SSC values of 'Regina' cherries throughout the initial stages of the cold storage with UV-C and MAP treatments.

Table 4. Effects of Hot Water and UV-C treatments on SSC of cherry fruit stored at 0 °C and 90–95% relative humidity for 20 d.

Duration (days)	Control	UV-C	Hot Water	UV-C+Hot Water
0	25.30±0.35 A a	22.80±0.69 b	23.10±0.23 A b	20.40±0.58 c
4	22.75±0.66 B a	23.85±0.09 a	23.30±0.35 A b	20.10±0.52 a
8	21.55±0.14 BC	23.00±1.33	22.60±0.12 AB	19.55±0.26
12	20.15±1.13 C	20.95±0.26	20.95±0.55 CD	20.45±0.38
16	22.05±0.66 BC ab	23.15±0.03 a	21.75±0.14 BC bc	20.60±0.40 c
20	20.08±0.59 C b	21.75±0.38 a	20.25±0.03 D b	19.55±0.38 b

a, b, c, d: → Different small letters indicate significant differences among the treatments ($p<0.05$).
A, B, C, D: ↓ Different capital letters indicate significant differences among the storage durations ($p<0.05$).

Table 5. Effects of Hot Water and UV-C treatments on total phenolics and antioxidants of cherry fruit stored at 0°C and 90–95% relative humidity for 20 d.

	Duration (days)	Control	UV-C	Hot Water	UV-C+Hot water
Total antioxidant	0	20.52±0.75	20.23±0.96	27.73±5.53	14.27±0.36
	4	23.64±5.73	20.18±0.84	12.81±0.05	16.52±1.90
	8	24.06±0.96 a	21.89±0.00 b	21.52±0.26 b	18.35±0.12 c
	12	17.31±1.92	19.32±0.15	20.93±2.33	15.14±2.45
	16	28.27±1.42 a	28.93±1.18 a	22.85±2.04 b	18.31±0.48 b
	20	25.27±4.93	28.93±7.10	26.27±7.10	17.56±2.31
Total phenolic	0	62.54±0.87 ab	58.16±0.51 b	66.79±3.03 a	46.16±0.79 c
	4	58.85±6.24	58.41±1.44	55.85±0.11	44.48±7.47
	8	61.60±0.97 ab	67.79±5.63 a	54.72±3.28 b	51.79±0.58 b
	12	54.22±0.33	58.47±0.54	58.60±1.91	48.72±5.88
	16	64.48±1.62 a	65.35±1.05 a	58.60±3.64 ab	53.47±0.83 b
	20	60.54±4.47	61.54±5.20	60.04±6.64	52.29±5.85

a, b, c, d: → Different small letters indicate significant differences among the treatments ($p<0.05$).
A, B, C, D: ↓ Different capital letters indicate significant differences among the storage durations ($p<0.05$).

Total phenolics and antioxidants

The changes in total phenolics and antioxidant quantities of the fruits throughout the storage are provided in Table 5. Post-harvest treatments had significant effects on total phenolics ($p\leq0.05$). Total phenolics exhibited an irregular variation in control and Hot Water treatments and decreased at the end of storage period. However, total phenolics increased with UV-C and UV-C+Hot Water treatments. In UV-C treatments, total phenolics reached to 67.79 $mg100g^{-1}$ on the 8^{th} day of storage, but decreased to 61.54 mg 100 g^{-1} at the end of storage. This value was the greatest one among the treatments at the end of the storage. Different from the present study, Şen and Kuzucu (2016) reported decreasing total phenolics for UV-C and MAP-treated 'Regina' cherries. Such a case may be resulted from the differences in fruit cultivar and growing ecology. Similar with the present study, Koçak and Bal (2017) indicated UV-C treatments as the best one for preserving total phenolics of '0900 Ziraat' cherries. Marquenie et al. (2003) reported that UV-C treatments both killed the pathogens over the fruit surface and synthesized phenols for the defense mechanism of the fruits. Similarly in present study, UV-C treatments increased total phenols. Palma et al. (2012) also reported that MAP treatments slowed down the reductions in total phenols. Tsaniklidis et al. (2017) indicated

insignificant effects of different preservation and shelf life temperatures on total phenolics.

The greatest antioxidant quantity was achieved in UV-C treatments. The initial value of 20.23 µmol TE g^{-1} increased to 28.93 µmol TE g^{-1} at the end of 20-day storage period (Table 5). On the other hand, antioxidant quantity of Hot Water treatments (27.20 µmol TE g^{-1}) rapidly decreased and reached to 12.81 µmol TE g^{-1} on the 4th day of storage. But the value increased toward to end of storage and reached back to 26.27 µmol TE g^{-1} on the 20th day of storage (Table 6). Similar with the present study, Koçak and Bal (2017) also indicated UV-C and MAP treatments as the best one for preservation of total antioxidant quantity.

Phenolic compounds

The variations in protocatechic acid, vanillic acid, rutin, gallic acid, chlorogenic acid, syringic acid, p-coumaric acid, ferulic acid and c-coumaric acid contents throughout 20-day storage are presented in Figure 1.

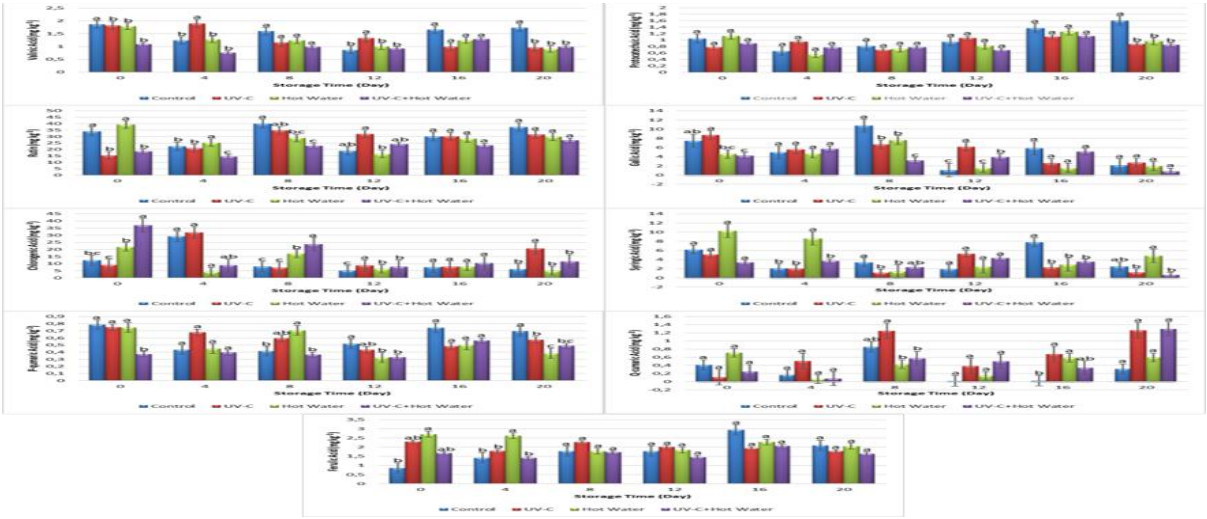

Figure 1. Phenolic compounds in sweet cherry fruits during storage.
a, b, c, d: → Different small letters indicate significant differences among the treatments (p<0.05).
A, B, C, D: ↓ Different capital letters indicate significant differences among the storage durations (p<0.05) (Duncan's multiple range test).

There were significant variations in protocatechic acid contents. In all treatments, protocatechic acid contents decreased until the 8th day of storage and increased later on. The greatest increase was observed in control treatments, the initial value of 1.05 mg kg^{-1} increased to 1.60 mg kg^{-1} at the end of storage. The effects of storage durations on protocatechic acid content of the control treatment were not found to be significant. In the other treatments, the variations were found to be significant on 20th day of storage and values decreased as compared to the 16th day of storage.

Vanillic acid contents exhibited an irregular variation throughout the storage in control treatments and the initial value of 1.86 mg kg^{-1} was quite preserved and decreased only to 1.73 mg kg^{-1} on the 20th day of storage. As compared to the initial values, the greatest decrease was observed in UV-C+How Water treatments and the initial value of 1.09 mg kg^{-1} decreased to 0.99 mg kg^{-1}on the 20th day of storage.

Rutin contents also exhibited irregular changes throughout the storage in all treatments and storage durations had significant effects on rutin contents throughout the storage ($p \leq 0.05$). At the end of storage, the lowest rutin content (27.07 mg kg^{-1}) was observed in UV-C+Hot Water treatments and the greatest rutin content (31.55 mg kg^{-1}) was observed in UV-C treatments. UV-C treatments increased rutin content as compared to the beginning of the storage.

Gallic acid contents significantly decreased in all treatments throughout the storage. Effects of treatments and storage durations on gallic acid contents throughout the storage were found to be significant ($p \leq 0.05$). The lowest value (0.83 mg kg^{-1}) was observed in UV-C+How Water treatments. As compared to the initial values, the greatest decrease in gallic acid contents was observed in UV-C treatments.

There were irregular variations in chlorogenic acid contents of the treatments throughout the storage. In UV-C treatments, the initial value of 9.00 mg kg^{-1} increased to 31.93 mg kg^{-1} on the 4th day of storage and decreased to 20.61 mg kg^{-1} at the end of the storage, which was also recorded as the greatest value at the end of the storage. The lowest value at the end of the

storage (5.08 mg kg^{-1}) was observed in Hot Water treatments. In a similar study, Jacobek et al. (2009) indicated chlorogenic acid as the dominant phenolic in cherries and reported greater values than the present values. Karadeniz and Ekşi (2001) and Göksel and Aksoy (2017) reported that chlorogenic acid contents did not decrease with the treatments. However, values decreased in this study since oxidation, color loss and decay rates were quite low in 20-days like short period of storage.

Syringic acid contents significantly decreased throughout the storage. Except for UV-C+Hot Water treatments, effects of all the other treatments and storage durations on syringic acid contents were found to be significant throughout the storage ($p \leq 0.05$). At the end of the storage period, the lowest syringic acid content (0.64 mg kg^{-1}) was observed in UV-C+Hot Water treatments and the greatest value (2.48 mg kg^{-1}) was observed in control fruits.

Except for UV-C+Hot Water treatments, P-coumaric acid contents decreased with all the other treatments. Except for storage durations of UV-C and UV-C+Hot Water treatments, effects of all the other storage durations and the treatments on p-coumaric acid contents were found to be significant ($p \leq 0.05$). At the end of 20-day storage period, the greatest p-coumaric acid content (0.70 mg kg^{-1}) was observed in control fruits and the lowest value (0.38 mg kg^{-1}) was observed in Hot Water treatments.

Except for the control treatments, decreasing ferulic acid contents were observed with all the other treatments throughout the storage. Except for Hot Water treatments and the storage durations of UV-C and Hot Water treatments, effects of all the other storage durations and treatments on ferulic acid contents were found to be significant ($p \leq 0.05$). How Water treatments preserved ferulic acid contents the best and the initial value of 2.71 mg kg^{-1} decreased to 2.05 mg kg^{-1}at the end of storage.

There were irregular changes in q-coumaric acid contents throughout the storage. Except for UV-C treatments and storage durations of Hot Water and UV-C+Hot Water treatments, effects of all the other treatments and storage durations on q-coumaric acid contents were found to be significant ($p \leq 0.05$). At the end of the storage period, the greatest q-coumaric acid content (1.30 mg kg^{-1}) was observed in UV-C+Hot Water treatments.

Conclusion

Quality attributes, rich phenolics and antioxidant activity of cherry fruits provide significant benefits to human health. Insufficient quantities of fruits are served to markets during the initial harvest seasons. Such insufficient supplies in early and late seasons increase the market value of cherries. Some post-harvest technologies, especially environment-friendly treatments, and cold storage allow growers to serve high quality fruits out of the harvest seasons. In present study, MAP, UV-C and Hot Water treatments without any chemicals were experimented for the preservation of quality attributes throughout the cold storage of cherry fruits. Present findings revealed that UV-C+Hot Water treatments together with storage in MAP at 1°C and 90% relative humidity for 20 days better preserved the quality attributes of '0900 Ziraat' cherries. Therefore, these treatments were recommended for commercial cherry culture.

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