GIDA
THE JOURNAL OF FOOD
E-ISSN 1309-6273, ISSN 1300-3070

Research / Araştırma
GIDA (2022) 47 (5) 744-753
doi: 10.15237/gida.GD22063

THE EFFECT OF DIFFERENT UV-C ILLUMINATION DOSES ON POSTHARVEST QUALITY OF FRESH FIG

Hayri Üstün[1], Adem Doğan[1,2*]
[1]Department of Horticulture, Faculty of Agriculture, Akdeniz University, Antalya, Türkiye
[2]Department of Plant and Animal Production, Elmalı Vocational School, Akdeniz University, Antalya, Türkiye

Received / Geliş: 05.07.2022; *Accepted* / Kabul: 11.08.2022; *Published online* / Online baskı: 26.08.2022

Üstün, H., Doğan, A. (2022). The effect of different UV-C illumination doses on postharvest quality of fresh fig. GIDA (2022) 47 (5) 744-753 doi: 10.15237/gida.GD22063

Üstün, H., Doğan, A. (2022). Farklı dozlarda UV-C ışın uygulamalarının taze incirin hasat sonrası kalitesi üzerine etkileri. *GIDA* (2022) 47 (5) 744-753 doi: 10.15237/gida.GD22063

ABSTRACT
The aim of this study was to investigate the effects of 1.5, 3.0 and 4.5 kJ/m² UV-C illumination doses on the postharvest quality of fresh fig (cv. Bursa Siyahi). For this purpose, fruit were stored at 0 ºC temperature with 90-95% humidity for 21 days and some fruits were kept at 20 °C for 3 days to simulate a period of shelf-life. UV-C treatments did not affect fruit firmness, total soluble solids, and titratable acidity content during cold storage and shelf-life. On the other hand, UV-C doses increased total phenolic content and antioxidant activity compared to control. In both storage conditions, 3.0 and 4.5 kJ/m² UV-C doses were found to be more effective to control unmarketable fruit rate. In conclusion, a 4.5 kJ/m² UV-C illumination dose can be effective in maintaining the postharvest quality of fresh fig fruit harvested at a 2/3 maturity stage.
Keywords: Antioxidant activity, decay, commercial ripe stage, shelf-life, storage

FARKLI DOZLARDA UV-C IŞIN UYGULAMALARININ TAZE İNCİRİN HASAT SONRASI KALİTESİ ÜZERİNE ETKİLERİ

ÖZ
Bu çalışmada, farklı UV-C ışın dozlarının taze incir meyvesinin (cv. Bursa Siyahı) hasat sonrası kalitesi üzerine etkilerinin incelenmesi amaçlanmıştır. Bu amaçla incir meyvelerine 1.5, 3.0 ve 4.5 kJ/m² UV-C ışın dozları uygulanmış ve sonrasında 21 gün boyunca 0 ºC sıcaklıkta %90±5 oransal nemde depolanmıştır. Soğuk depolamaya ek olarak, raf ömrü performanslarını belirlemek için meyveler 3 gün 20°C ve %70±5 oransal nemde bekletilmiştir. Soğuk depolama ve raf ömrü koşullarında UV-C uygulamaların meyve sertliği, suda çözünebilir kuru madde ve titre edilebilir asit içeriği üzerine etkileri önemsiz bulunmuştur. Buna karşılık UV-C dozları kontrole göre toplam fenolik madde ve antioksidan aktiviteyi artırmıştır. Her iki muhafaza koşulunda da artan pazarlanamaz ürün miktarının azaltılmasında 3.0 ve 4.5 kJ/m² UV-C ışın dozları daha etkili bulunmuştur. Çalışmanın sonucunda, 2/3 olgunluk döneminde hasat edilen taze incir meyveleri için 4.5 kJ/m² UV-C ışın dozunun hasat sonrası kalitesinin korunmasında etkili olduğu tespit edilmiştir.
Anahtar kelimeler: Antioksidan aktivitesi, çürüme, ticari olum aşaması, raf ömrü, depolama

[*]*Corresponding author* / Yazışmalardan sorumlu yazar
✉: ademdogan@akdeniz.edu.tr ✆: (+90) 242 310 2482 🖷: (+90) 242 310 2479

Hayri Üstün; ORCID no: 0000-0003-1876-0481
Adem Doğan; ORCID no: 0000-0002-8578-5841

INTRODUCTION

Fresh figs are highly attractive fruit due to the delicious taste, rich biochemical and pomological properties. The total fig production is approximately 1.3 million tons and Türkiye is the main producer followed by Egypt, Morocco, Iran, and Algeria (FAOSTAT, 2022). Fresh figs are consumed worldwide and have huge potential to increase export, especially in Mediterranean countries. Unfortunately, fresh fig is perishable fruit, and its postharvest life is generally limited to 1-2 weeks in full ripe stages and 2-4 weeks in 2/3 ripe stages depending on pre- and post-harvest factors (Doğan and Erkan, 2022). For this reason, most of the fig fruits are consumed in the market close to the production areas. Developments in transportation sectors are increased to the fresh fig trade in the world.

Fresh fig fruit mostly suffers from fungal decay, weight loss, and softening in both cold storage and shelf-life conditions (Dogan, 2022). Numerous pathogens can cause deterioration and high postharvest losses under unsuitable storage conditions, especially under shelf-life. Postharvest losses can reach up to 30-50% in shelf-life following the 5-7 days cold storage period and increase when the fruit is harvested in rainy periods (Karabulut et al., 2009). The presence of ostiole opening, delicate structure, and short postharvest life of fig make it difficult to manage in postharvest operations, and to control these difficulties, alternative methods, which can be transferred into practice, are needed. Alternative treatments to chemicals have been gaining popularity due to the increase in health and environmental concerns in many countries.

Postharvest UV-C illumination is one of the alternative methods to chemicals for preventing the decay in many horticultural crops (Costa et al., 2006; González-Aguilar et al., 2010; Dogan et al., 2018; Ustun et al., 2021). According to the results of UV-C illuminations on different horticultural products, in general, UV-C illumination promotes the accumulation of antioxidant enzymes, increases the phenolic content, and improves fruit antioxidant capacity (Erkan et al., 2008; Pinheiro et al., 2015). It has been revealed that UV-C illumination also reduced weight loss, lowered respiration rate (Cote et al., 2013; Freitas et al., 2015), decreased the activity of cell wall degradation enzymes and delayed the fruit softening (Barka et al., 2000; Pombo et al., 2009). Postharvest life and fruit quality are affected by harvest maturity in many fruits and vegetables (Erkan and Dogan, 2019). Harvest time is particularly crucial in reducing postharvest losses in products with a short post-harvest life such as fig (Dogan et al., 2020). Fresh figs are harvested considering the distance to the consumption region. If the production site is close to the target market, the fig is harvested at the full maturity stage, while if they are far from the target market, they are harvested earlier. There is a few research conducted on the effects of UV-C illumination on fresh fig fruit. Bal (2012) reported that UV-C treatment for 20 min from a distance of 50 cm is effective to control decay in the 'Bursa Siyahi' fig cultivar. Usberti and Ferraz (2021) reported that 0.71, 1.32, 2.64, and 4.01 kJ/m^2 UV-C treatments did not affect fig ripening, however, UV-C treated fruits had lower decay than the control fruit. On the other hand, 4.01 kJ/m^2 UV-C treatment resulted in undesirable epidermis stains in 'Roxo de Valinhos' figs stored at 10 and 20°C. The current study aimed to determine the effects of different UV-C illumination doses on some quality parameters of the fresh fig fruit harvested at the 2/3 stage of maturity during the cold storage and shelf-life.

MATERIAL AND METHOD

Fruit materials

The fresh fig (cv. Bursa Siyahi) fruit were harvested at Fig Research Institute in Aydin, Türkiye. After harvest, the fruit were placed in carton boxes containing viols. Fresh figs were harvested at commercial maturity stage (2/3 colored peel) and were immediately transported with refrigerated truck into postharvest physiology laboratory of Department of Horticulture at Akdeniz University in Antalya, Türkiye. The fruit were selected according to size and maturity stage, and any defected fruit were excluded from the study.

UV-C illumination
UV-C treatments were performed in a specially designed illumination chamber. In this system, UV-C treatment was applied to the fruit while passing through a closed chamber. This specially designed equipment provides fruits to be turned as they move on the packaging line under a UV-C lamp. Hence, UV-C illumination can reach all fruit surfaces. UV-C dose adjustments were done with the help of a UV meter before the treatments. Harvested fruit were divided into four different groups for different UV-C illumination doses. The first group of fruit was not treated with UV-C illumination and used as a control group. The second, third and fourth group of fruit were treated 1.5, 3 and 4.5 kJ/m^2 UV-C illumination doses, respectively.

Storage conditions
UV-C treated, and control fruit were stored at 0 °C and 90-95% RH for 21 days. Fresh fig samples were taken from cold storage at 7 days intervals for different analyses. At each analysis time, the shelf-life performance was determined by removing the fruits from the cold storage to 20 °C and 70-75% RH conditions for 3 days.

Methods
The firmness of fruit was determined by using a penetrometer measuring the peeled equatorial region on 3 different sides of the fruit. Fruit firmness was shown as average of these measurements and results were given as Newton (N).

For total soluble solids (TSS) and titratable acidity (TA) contents, fig fruits were smashed with a blender and weighed 1 g of puree. There after 10 mL ddH_2O was added and samples were centrifuged at 6000 g for 10 min at 4 °C. Total soluble solid (TSS) content was measured from the supernatant. The TSS contents of the samples were measured with a digital refractometer and given as a percentage (%). The titratable acidity (TA) was determined by taking 2 mL supernatant from extraction for TSS and adding 38 mL of distilled water. The prepared samples were titrated with 0.1 N NaOH to an endpoint of pH 8.1. Each sample was titrated thrice, and the means were calculated. The TA was expressed in percent malic acid.

For total phenolic content (TPC) and total antioxidant activity (TAA) fresh figs were smashed with blender and weighed 1 g of puree. There after 10 mL 80% methanol added the tube and was centrifuged at 6000 g for 10 min at 4 °C. The supernatant was used for total phenolic content (TPC) and total antioxidant activity (TAA).

TPC in fresh figs were determined according to the Folin-Ciocalteu based method (Spanos and Wrolstad, 1990). Briefly, 0.1 mL supernatant was mixed with 0.9 mL of ddH_2O and 5 mL of 0.2 N Folin-Ciocalteau reagent in colored test tube for determined the TPC. The mixtures were incubated at the room temperature for 3 min and then 4 mL of sodium carbonate (75 g/L) was added. Before the measurement of absorbances, sample tubes were incubated in the dark for 2 h. The absorbances were measured at 765 nm by spectrophotometer against a blank. TPC in fresh figs were reported as mg of gallic acid equivalent per 100 g (mg GAE/100 g).

Total antioxidant activity (TAA) analysis was carried out according to the method specified by Benvenuti et al. (2004). Samples of 20, 40, 60, 80 and 100 μL of the extract prepared for total phenol analysis were taken and added to glass tubes in which 600 μL of DPPH radical was placed before. Immediately afterward, 80% methanol was added to give a total volume of 6 mL of the glass tube. The same method was followed by not adding a sample extract to the control sample. The tubes were mixed by vortex and incubated for 15 min at room temperature. The measurements were done at 517 nm wavelength with a spectrophotometer and the TAA activity was expressed as % inhibition. The concentration that gave 50% inhibition of the radical was calculated as EC50 fw/mg.

Each fruit was evaluated individually and any visible deterioration on the surface was rated as unmarketable. The unmarketable fruit rate was

found by proportioning the total number of fruit and expressed as a percentage (%).

The statistical analyses were conducted in a totally randomized design with three replicates and each replicate contained fifteen figs. Parameters of treatment, storage time and interaction between treatment and storage time were tested using a general linear model with using XLSTAT (version 2016.02.28451). The Tukey (HSD) test was used to compare the means and interaction ($P \leq 0.05$).

RESULTS AND DISCUSSION

Firmness is one of the most important features in determining the storage and shelf life of horticultural crops. Soft fig fruits are highly perishable compared to firm fruit. For this reason, fruit of 'Bursa Siyahi' fig cultivar is harvested in the firm stage before the fully colored stage for exportation. Fruit firmness tends to decrease during storage and shelf life. There were no statistical differences between UV-C illumination doses and firmness, however, storage time significantly affected fig firmness in both conditions (Table 1). It is thought that structural changes in cell wall components such as pectin, hemicellulose, and cellulose are responsible for firmness (Seymour et al., 1990). Barka et al. (2000) reported that UV-C illumination reduced cell wall degradation and preserves fruit firmness by decreasing the activity of cell wall degrading enzymes on tomatoes. Similarly, UV-C illumination reduced softening at strawberries (Cote et al., 2013). However, Perkins-Veazie et al. (2008) reported fruit firmness was not affected by UV-C illumination on blueberries. Hemmaty et al. (2007) reported that fruit firmness was not affected by UV-C irradiation at shelf-life on apples. This study also revealed that UV-C illuminated 'Red Delicious' apples were significantly firmer, but UV-C had no effect on the firmness of 'Golden Delicious' apples. It is thought that the differences between these studies may be due to the species, cultivar, treatment dose, maturity stage and ripeness characteristics of fruits.

Total soluble solids (TSS) content increased up to 14 days of cold storage, then decreased at the end of the storage but the concentration was still higher than harvest value at the end of the storage (Table 1). TSS content increased at the 7-day cold storage plus 3-day shelf-life but did not change remaining the shelf-life (Table 2). The increasing trend in TSS for a certain period of time is thought to be related to the maturity level of the fruit. Similarly, this increasing trend was also found by Bahar and Lichter (2018) in 'Ottomonit' fresh fig. On the other hand, there were no differences between UV-C doses on TSS content (Table 1). Similarly, UV-C illumination did not affect TSS content in lime (Pristijono et al., 2019), pineapple (Sari et al., 2016), apple (Hemmaty et al., 2007), strawberry (Cote et al., 2013) and tomato (Liu et al., 2009).

Titratable acidity (TA) content decreased during cold storage (Table 1). Similarly, TA content decreased until 7 days of cold storage plus 3 days and remained unchanged in the following shelf-life (Table 2). The reduction in TA content may be part of the maturation process and/or may be due to its use in the respiratory. UV-C doses did not affect TA content in fig fruit harvested at 2/3 maturity stage. Usberti and Ferraz (2020) were tested 0.71, 1.32, 2.64 and 4.01 kJ/m^2 UV-C illumination in 'Roxa de Valinhos' figs and they reported that TA content did not significantly change neither storage temperature (10- and 20°C) nor UV-C doses after 7-days storage. On the other hand, Bal (2012) reported that 10- and 20-min UV-C treated fig fruit had slightly higher TA content than the control and 5 min UV-C treated fruit after 28 days of storage while UV-C treatment and storage time interaction was not found significant. The application methods and fruit maturity stages can be caused these differences.

Total phenolic content (TPC) of figs increased during the storage period while it decreased after 7 days cold storage plus 3-day shelf-life. The highest TPC was determined in 4.5 kJ/m^2 UV-C treated fruit while the lowest was in control and 1.5 kJ /m^2 UV-C treated fruit at the end of the cold storage (Table 1). In the shelf-life condition, TPC increased with increasing UV-C doses and the 3.0 and 4.5 kJ/m^2 UV-C treated fruit had more

phenolic content then the 1.5 kJ/m² UV-C dose (Table 2). Similarly, UV-C treatments increased TPC in strawberry (Erkan et al., 2008), blueberry (Perkins-Veazie et al., 2008), tomato (Bravo et al., 2012, Liu et al., 2012), mandarin (Shen et al., 2013) and broccoli (Dogan et al., 2018). These findings showed that UV-C illumination causes stress and increases phenolic compounds because of the activation of the phenolic synthesis process. It was shown that UV-C treatment also increased activity and expression of the enzyme which is related to the phenolics (Ouhibi et al., 2014). UV-C treated tomatoes had higher TPC and this increment was explained phenylpropanoid pathway and phenolic accumulation (Liu et al., 2018).

Table 1. Effects of UV-C doses on fruit firmness, TSS, TA, TPC, TAA and unmarketable fruit rate of 'Bursa Siyahi' fresh figs during cold storage at 0 °C.

Parameter	Treatment	Storage time (days)				Mean
		0	7	14	21	
Fruit firmness (N)	Control	12.69^{y}	10.83	9.56	8.76	10.46^{x}
	1.5 (kJ/m²)	12.69	11.05	9.65	8.87	10.56
	3.0 (kJ/m²)	12.69	11.23	9.67	8.77	10.59
	4.5 (kJ/m²)	12.69	11.28	10.18	9.17	10.83
	Mean	12.69^{a}	11.10^{b}	9.77^{bc}	8.89^{c}	
TSS (%)	Control	15.17^{y}	15.33	16.50	16.50	15.88^{x}
	1.5 (kJ/m²)	15.17	15.33	17.17	15.67	15.83
	3.0 (kJ/m²)	15.17	16.33	16.83	16.33	16.17
	4.5 (kJ/m²)	15.17	16.67	17.00	16.33	16.29
	Mean	15.17^{c}	15.92^{b}	16.88^{a}	16.21^{b}	
TA (Citric acid)	Control	0.57^{y}	0.46	0.39	0.34	0.44^{x}
	1.5 (kJ/m²)	0.57	0.42	0.35	0.34	0.42
	3.0 (kJ/m²)	0.57	0.39	0.35	0.35	0.41
	4.5 (kJ/m²)	0.57	0.35	0.33	0.30	0.39
	Mean	0.57^{a}	0.41^{b}	0.36^{bc}	0.33^{c}	
TPC (mg/100g)	Control	39.50^{h}	42.26^{h}	64.70^{ef}	118.03^{b}	66.12^{c}
	1.5 (kJ/m²)	39.50^{h}	43.41^{h}	71.40^{de}	121.43^{b}	68.93^{c}
	3.0 (kJ/m²)	39.50^{h}	48.89^{gh}	79.25^{cd}	127.60^{ab}	73.81^{b}
	4.5 (kJ/m²)	39.50^{h}	57.35^{fg}	85.48^{c}	136.45^{a}	79.70^{a}
	Mean	39.50^{d}	47.97^{c}	75.21^{b}	125.88^{a}	
TAA (EC_{50} /mg)	Control	62.32^{y}	59.26	56.46	49.92	56.99^{a}
	1.5 (kJ/m²)	62.32	57.00	54.28	42.87	54.12^{ab}
	3.0 (kJ/m²)	62.32	56.68	53.57	41.19	53.44^{ab}
	4.5 (kJ/m²)	62.32	51.84	48.22	32.95	48.83^{b}
	Mean	62.32^{a}	56.20^{ab}	53.13^{b}	41.73^{c}	
Unmarketable fruit rate (%)	Control	-	0.00^{y}	6.67	20.00	8.89^{a}
	1.5 (kJ/m²)	-	0.00	0.00	13.33	4.44^{ab}
	3.0 (kJ/m²)	-	0.00	0.00	6.67	2.22^{b}
	4.5 (kJ/m²)	-	0.00	0.00	0.00	0.00^{b}
	Mean	-	0.00^{b}	1.67^{b}	10.00^{a}	

TSS: Total soluble solid content; TA: Titratable acidity; TPC: Total phenolic content, TAA: Total antioxidant activity

^{x} Means in the same column are not significantly different at $P \leq 0.05$ by Tukey's multiple range test.

^{y} Interaction between treatment and storage time is not significantly different at $P \leq 0.05$ by Tukey's multiple range test.

Table 2. Effects of UV-C doses on fruit firmness, TSS, TA, TPC, TAA and unmarketable fruit rate of 'Bursa Siyahi' fresh figs after storage at 0 °C plus 3 days at 20°C.

Parameter		Storage time (days)				
	Treatment	0	7+3	14+3	21+3	Mean
Fruit firmness (N)	Control	12.69[y]	7.32	7.10	6.21	8.33[x]
	1.5 (kJ/m²)	12.69	7.32	7.10	6.17	8.32
	3.0 (kJ/m²)	12.69	7.34	7.23	6.68	8.48
	4.5 (kJ/m²)	12.69	7.88	7.25	6.65	8.62
	Mean	12.69[a]	7.46[b]	7.17[b]	6.43[b]	
TSS (%)	Control	15.17[y]	17.33	18.00	16.50	16.75[x]
	1.5 (kJ/m²)	15.17	16.67	16.17	15.50	15.88
	3.0 (kJ/m²)	15.17	16.33	17.33	16.33	16.29
	4.5 (kJ/m²)	15.17	16.33	16.25	16.83	16.15
	Mean	15.17[b]	16.67[a]	16.94[a]	16.29[a]	
TA (Citric acid)	Control	0.57[y]	0.38	0.35	0.35	0.41[x]
	1.5 (kJ/m²)	0.57	0.37	0.35	0.31	0.40
	3.0 (kJ/m²)	0.57	0.35	0.33	0.31	0.39
	4.5 (kJ/m²)	0.57	0.33	0.31	0.31	0.38
	Mean	0.57[a]	0.36[b]	0.33[b]	0.32[b]	
TPC (mg/100g)	Control	39.50[y]	114.37	92.15	88.49	83.63[c]
	1.5 (kJ/m²)	39.50	121.86	100.22	95.91	89.37[bc]
	3.0 (kJ/m²)	39.50	132.83	103.91	100.93	94.29[ab]
	4.5 (kJ/m²)	39.50	134.09	113.26	110.50	99.34[a]
	Mean	39.50[c]	125.7[a]	102.38[b]	98.96[b]	
TAA (EC_{50} /mg)	Control	62.32[y]	59.00	53.97	51.85	56.78[x]
	1.5 (kJ/m²)	62.32	59.54	54.55	51.76	57.04
	3.0 (kJ/m²)	62.32	55.83	53.94	47.81	54.98
	4.5 (kJ/m²)	62.32	53.97	50.22	44.92	52.86
	Mean	62.32[a]	57.08[ab]	53.17[bc]	49.09[c]	
Unmarketable fruit rate (%)	Control	-	0.00y	20.00	40.00	20.00[a]
	1.5 (kJ/m²)	-	0.00	13.33	33.33	15.56[a]
	3.0 (kJ/m²)	-	0.00	13.33	26.67	13.33[ab]
	4.5 (kJ/m²)	-	0.00	0.00	20.00	6.67[b]
	Mean	-	0.00[c]	11.67[b]	30.00[a]	

TSS: Total soluble solid content; TA: Titratable acidity; TPC: Total phenolic content, TAA: Total antioxidant activity

[x] Means in the same column are not significantly different at $P \leq 0.05$ by Tukey's multiple range test.

[y] Interaction between treatment and storage time is not significantly different at $P \leq 0.05$ by Tukey's multiple range test.

Total antioxidant activity (TAA) of figs showed an increasing trend in both storage conditions. During the cold storage UV-C treatment slightly increased TAA but this increase was more evident in 4.5 kJ/m² UV-C treatment (Table 1). The effect of UV-C treatment was not significant at the end of the shelf-life (Table 2). The higher TAA means lower EC50 values. In our study, antioxidant activity increased during the storage time due to the UV-C illumination and similar result were also reported by Sari et al. (2016), Vicente et al. (2004), Erkan et al. (2008) and Jiang et al. (2010). Jiang et al. (2010) reported that the decrease in enzyme activity was delayed in shelf-life conditions. Liu et al. (2012) reported that 4 and 8 kJ/m² UV-C illuminations improved antioxidant activity and it

was also reported that 2 and 16 kJ/m² UV-C doses lesser extent improved. In our study, it is thought that TAA increased due to the increase in phenolic content during storage. Maharaj et al. (2014) agreed with this argument. Gonzalez-Aguilar et al. (2007) also found a TPC correlation with TAA.

Unmarketable product rate increased after 14-day storage and it reached up to 30% after 21-day cold storage plus 3 days storage at 20 °C. No UV-C damage was detected during storage and shelf-life condition however Usberti and Ferraz, (2020) reported that 4.01 kJ/m² UV-C treatment showed more wilting and stains than the lower doses. This difference between findings can be explained by the variety differences, maturity stages and height of the UV-C lamp. Control fruit showed decay symptoms after 7 days cold storage while 4.5 kJ/m² UV-C treated fruit showed no decay during the cold storage (Table 1). At the end of the cold storage and following shelf-life period 3.0 and 4.5 kJ/m² UV-C treated fruits had lower decay than the other treatments (Table 2). Fresh fig fruit suffers from many fungal decays and decay incidence was more evident especially in shelf-life conditions (Dogan, 2022). Bal (2012) reported that 20 min UV-C treatment decreased decay rate in fresh fig 'Bursa Siyahi' compared to the control and 5 min UV-C treatment. Similarly, Usberti and Ferraz (2020) reported that decay rate increased with increasing storage temperature however this increase was inhibited by UV-C treatment in fresh fig cv. Roxa de Valinhos. Furthermore, many researchers reported that UV-C illumination reduced the decay rate or disease incidence in a variety of products such as peach (Abdipour et al., 2019) strawberry (Erkan et al., 2008), persimmon (Khademi et al., 2013), red pepper (Rodoni et al., 2015) and pineapple (Sari et al., 2016). In addition, UV-C illuminated limes had more acceptability index than control fruits after 28 days of storage (Pristijono et al., 2019).

CONCLUSION

In the current study, UV-C illumination did not significantly affect fruit firmness, TSS, and TA while it increased TPC and TAA. Furthermore, decay rate decreased especially in 4.5 kJ/m² dose without no visible UV-C damage. UV-C illumination had a positive effect on reducing postharvest loss in fresh figs. Thus, UV-C illumination could be an alternative tool for improving the TPC and TAA of fresh fig. Nevertheless, future study is needed for examining the biochemical changes caused by UV-C in fig fruit at the molecular level and technological studies that will put UV-C illumination into practice at industrial levels.

CONFLICT OF INTEREST

The authors have declared that no competing interests exist.

AUTHOR CONTRIBUTION

Hayri Üstün: Writing original draft, formal analysis, data curation, statistical analysis. Adem Doğan: Conceptualization, formal analysis, data curation, writing and editing.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support of Fig Research Institute (Aydın, Türkiye) for providing the fruit material. The authors would like to thank Prof. Dr. Mustafa Erkan for the critical review of the manuscript.

REFERENCES

Abdipour, M., Hosseinifarahi, M., Naseri, N. (2019). Combination method of UV-B and UV-C prevents post-harvest decay and improves organoleptic quality of peach fruit. *Scientia Horticulturae*, 256: 108564, doi: 10.1016/j.scienta.2019.108564.

Bahar, A., Lichter, A. (2018). Effect of controlled atmosphere on the storage potential of Ottomanit fig fruit. *Scientia Horticulturae*, 227: 196-201, doi: 10.1016/j.scienta.2017.09.036.

Bal, E. (2012). Effect of postharvest UV-C treatments on quality attributes of fresh fig. *Bulgarian Journal of Agricultural Science*, 18(2): 191-196.

Barka, E.A., Kalantari, S., Makhlouf, J., Arul, J. (2000). Impact of UV-C irradiation on the cell wall-degrading enzymes during ripening of tomato (*Lycopersicon esculentum* L.) fruit. *Journal of*

Agricultural and Food Chemistry, 48(3): 667-671, doi: 10.1021/jf9906174.

Benvenuti, S., Pellati, F., Melegari, M.A., Bertelli, D. (2004). Polyphenols, anthocyanins, ascorbic acid, and radical scavenging activity of Rubus, Ribes, and Aronia. *Journal of Food Science*, 69(3): 164-169, doi: 10.1111/j.1365-2621.2004.tb13352.x.

Bravo, S., García-Alonso, J., Martín-Pozuelo, G., Gómez, V., Santaella, M., Navarro-González, I., Periago, M.J. (2012). The influence of post-harvest UV-C hormesis on lycopene, β-carotene, and phenolic content and antioxidant activity of breaker tomatoes. *Food Research International*, 49(1): 296-302, doi: 10.1016/j.foodres.2012.07.018.

Costa, L., Vicente, A.R., Civello, P.M., Chaves, A.R., Martinez, G.A. (2006). UV-C treatment delays postharvest senescence in broccoli florets. *Postharvest Biology and Technology*, 39(2): 204-210, doi: 10.1016/j.postharvbio.2005.10.012.

Cote, S., Rodoni, L., Miceli, E., Concellón, A., Civello, P.M., Vicente, A.R. (2013). Effect of radiation intensity on the outcome of postharvest UV-C treatments. *Postharvest Biology and Technology*, 83: 83-89, doi: 10.1016/j.postharvbio.2013.03.009.

Dogan, A. (2022). Effects of different oxygen levels with high-carbon dioxide atmosphere on postharvest quality of fresh fig under palliflex storage systems. *Horticulturae*, 8(5): 353, doi: 10.3390/horticulturae8050353.

Dogan, A., Ali, Q., Erkan, M. (2020). Comparison of quality attributes of fig fruit (Bursa Siyahi) harvested at two different maturity stages. *Acta Horticulturae*, 1275; 311-316, doi: 10.17660/ActaHortic.2020.1275.42.

Dogan, A., Cat, A., Catal, M., Erkan, M. (2018). First report of *Alternaria alternata* causing postharvest decay in fig (*Ficus carica* L. cv. Bursa Siyahi) fruit in Turkey. *Journal of Biotechnology*, 280: S84, doi: 10.1016/j.jbiotec.2018.06.275.

Doğan, A., Erkan, M. (2022). Postharvest Handling and Storage of Fresh Fig. In: *Ficus carica Production, Cultivation and Uses,* Dalkılıç Z. (ed.), Nova Science Publishers, USA, pp. 185-208.

Dogan, A., Topcu, Y., Erkan, M. (2018). UV-C illumination maintains postharvest quality of minimally processed broccoli florets under modified atmosphere packaging. *Acta Horticulturae*, 1194: 537-544, doi: 10.17660/ActaHortic.2018.1194.78.

Erkan, M., Dogan, A. (2019). Harvesting of horticultural commodities. In: *Postharvest Technology of Perishable Horticultural Commodities*, Elhadi, M.Y. (ed.), Woodhead Publishing, USA, pp. 129-159.

Erkan, M., Wang, S.Y., Wang, C.Y. (2008). Effect of UV treatment on antioxidant capacity, antioxidant enzyme activity and decay in strawberry fruit. *Postharvest Biology and Technology*, 48(2): 163-171, doi: 10.1016/j.postharvbio.2007.09.028.

FAOSTAT, (2022). https://www.fao.org/faostat/en/#data/QCL (Accessed: 4 July 2022).

Freitas, P.M., López-Gálvez, F., Tudela, J.A., Gil, M.I., Allende, A. (2015). Postharvest treatment of table grapes with ultraviolet-C and chitosan coating preserves quality and increases stilbene content. *Postharvest Biology and Technology*, 105: 51-57, doi: 10.1016/j.postharvbio.2015.03.011.

González-Aguilar, G.A., Ayala-Zavala, J.F., Olivas, G.I., De la Rosa, L.A., Álvarez-Parrilla, E. (2010). Preserving quality of fresh-cut products using safe technologies. *Journal of Consumer Protection and Food Safety*, 5(1): 65-72, doi: 10.1007/s00003-009-0315-6.

González-Aguilar, G.A., Villegas-Ochoa, M.A., Martínez-Téllez, M.A., Gardea, A.A., Ayala-Zavala, J.F. (2007). Improving antioxidant capacity of fresh-cut mangoes treated with UV-C. *Journal of Food Science*, 72(3): 197-202, doi: 10.1111/j.1750-3841.2007.00295.x.

Hemmaty, S., Moallemi, N., Naseri, L. (2007). Effect of UV-C radiation and hot water on the calcium content and postharvest quality of apples. *Spanish Journal of Agricultural Research*, 5(4): 559-568, doi: 10.5424/sjar/2007054-277.

Jiang, T., Jahangir, M.M., Jiang, Z., Lu, X., Ying, T. (2010). Influence of UV-C treatment on

antioxidant capacity, antioxidant enzyme activity and texture of postharvest shiitake (*Lentinus edodes*) mushrooms during storage. *Postharvest Biology and Technology*, 56(3): 209-215, doi: 10.1016/j.postharvbio.2010.01.011.

Karabulut, O. A., Ilhan, K., Arslan, U., Vardar, C. (2009). Evaluation of the use of chlorine dioxide by fogging for decreasing postharvest decay of fig. *Postharvest Biology and Technology,* 52(3), 313-315. doi: 10.1016/j.postharvbio.2009.01.006.

Khademi, O., Zamani, Z., Poor Ahmadi, E., Kalantari, S. (2013). Effect of UV-C radiation on postharvest physiology of persimmon fruit (*Diospyros kaki* Thunb.) cv. Karaj during storage at cold temperature. *International Food Research Journal*, 20(1): 247-253.

Liu, C., Zheng, H., Sheng, K., Liu, W., Zheng, L. (2018). Effects of postharvest UV-C irradiation on phenolic acids, flavonoids, and key phenylpropanoid pathway genes in tomato fruit. *Scientia Horticulturae*, 241: 107-114, doi: 10.1016/j.scienta.2018.06.075.

Liu, C.H., Cai, L.Y., Lu, X.Y., Han, X.X., Ying, T.J. (2012). Effect of postharvest UV-C irradiation on phenolic compound content and antioxidant activity of tomato fruit during storage. *Journal of Integrative Agriculture*, 11(1): 159-165, doi: 10.1016/S1671-2927(12)60794-9.

Liu, L.H., Zabaras, D., Bennett, L.E., Aguas, P., Woonton, B. W. (2009). Effects of UV-C, red light and sun light on the carotenoid content and physical qualities of tomatoes during post-harvest storage. *Food Chemistry*, 115(2): 495-500, doi: 10.1016/j.foodchem.2008.12.042.

Maharaj, R., Arul, J., Nadeau, P. (2014). UV-C irradiation effects on levels of enzymic and non-enzymic phytochemicals in tomato. *Innovative Food Science & Emerging Technologies*, 21: 99-106, doi: 10.1016/j.ifset.2013.10.001.

Ouhibi, C., Attia, H., Rebah, F., Msilini, N., Chebbi, M., Aarrouf, J., Urban, L., Lachaal, M. (2014). Salt stress mitigation by seed priming with UV-C in lettuce plants: Growth, antioxidant activity and phenolic compounds. *Plant Physiology and Biochemistry*, 83: 126-133, doi: 10.1016/j.plaphy.2014.07.019.

Perkins-Veazie, P., Collins, J. K., Howard, L. (2008). Blueberry fruit response to postharvest application of ultraviolet radiation. *Postharvest Biology and Technology*, 47(3): 280-285, doi: 10.1016/j.postharvbio.2007.08.002.

Pinheiro, J., Alegria, C., Abreu, M., Gonçalves, E.M., Silva, C.L. (2015). Use of UV-C postharvest treatment for extending fresh whole tomato (*Solanum lycopersicum* cv. Zinac) shelf-life. *Journal of Food Science and Technology*, 52(8): 5066-5074, doi: 10.1007/s13197-014-1550-0.

Pombo, M.A., Dotto, M.C., Martínez, G.A., Civello, P.M. (2009). UV-C irradiation delays strawberry fruit softening and modifies the expression of genes involved in cell wall degradation. *Postharvest Biology and Technology*, 51(2): 141-148, doi.org/10.1016/j.postharvbio.2008.07.007.

Pristijono, P., Bowyer, M.C., Papoutsis, K., Scarlett, C.J., Vuong, Q.V., Stathopoulos, C.E., Golding, J.B. (2019). Improving the storage quality of Tahitian limes (*Citrus latifolia*) by pre-storage UV-C irradiation. *Journal of Food Science and Technology*, 56(3): 1438-1444, doi: 10.1007/s13197-019-03623-x.

Rodoni, L.M., Zaro, M.J., Hasperué, J.H., Concellón, A., Vicente, A.R. (2015). UV-C treatments extend the shelf life of fresh-cut peppers by delaying pectin solubilization and inducing local accumulation of phenolics. LWT-Food Science and Technology, 63(1): 408-414, doi: 10.1016/j.lwt.2015.03.042.

Sari, L.K., Setha, S., Naradisorn, M. (2016). Effect of UV-C irradiation on postharvest quality of 'Phulae' pineapple. *Scientia Horticulturae*, 213: 314-320, doi: 10.1016/j.scienta.2016.09.049.

Seymour, G.B., Colquhoun, I.J., Dupont, M.S., Parsley, K.R., Selvendran, R.R. (1990). Composition and structural features of cell wall polysaccharides from tomato fruits. *Phytochemistry*, 29(3): 725-731. doi: 10.1016/0031-9422(90)80008-5.

Shen, Y., Sun, Y., Qiao, L., Chen, J., Liu, D., Ye, X. (2013). Effect of UV-C treatments on phenolic compounds and antioxidant capacity of minimally processed Satsuma mandarin during refrigerated

storage. *Postharvest Biology and Technology*, 76: 50-57, doi: 10.1016/j.postharvbio.2012.09.006.

Spanos, G.A., Wrolstad, R.E. (1990). Influence of processing and storage on the phenolic composition of Thompson seedless grape juice. *Journal of Agricultural and Food Chemistry*, 38(7): 1565-1571, doi: 10.1021/jf00097a030.

Usberti, F.C.S., Ferraz, A.C.D.O. (2020). UV-C radiation on fresh fig quality. *Scientia Agricola*, 78(3): e20190155, doi: 10.1590/1678-992X-2019-0155.

Ustun, H., Ali, Q., Kurubas, M.S., Dogan, A., Balkhi, M., Peker, B., Erkan, M. (2021). Influence of postharvest UV-C illumination on biochemical properties of green beans. *Scientia Horticulturae*, 289: 110499, doi: 10.1016/j.scienta.2021.110499.

Vicente, A., Repice, B., Martínez, G., Chaves, A., Civello, P., Sozz, G. (2004). Maintenance of fresh boysenberry fruit quality with UV-C light and heat treatments combined with low storage temperature. *The Journal of Horticultural Science and Biotechnology*, 79(2): 246-251, doi: 10.1080/14620316.2004.11511756.