

Research Article

Changes of quality traits and phytochemical components of jujube fruit treated with preharvest GA₃ and Parka during cold storageOrhan Karakaya ^{1*}, Erdal Aglar ^{2*}, Burhan Ozturk ¹, Sefa Gun ¹, Umut Ates ¹, Osman Nuri Ocalan ³¹ Ordu University, Faculty of Agriculture, Department of Horticulture, Ordu-Turkey² Sivas Cumhuriyet University, Susehri Timur Karabal Vocational School, Sivas-Turkey³ Tokat Gaziosmanpaşa University, Faculty of Agriculture, Department of Horticulture, Tokat-Turkey**ABSTRACT**

The study aimed to assess the effects of pre-harvest gibberellic acid (GA₃) and Parka applications on fruit quality and bioactive components of jujube (*Ziziphus jujuba* Mill. cv. 'Li') fruit during the storage. Fruit were kept at 0±0.5 °C and 90±5% RH for 45 days. Parka and GA₃ applications delayed weight losses and respiration rate in the cold storage. While the effect of the Parka application on the decrease in fruit firmness values depending on the storage time was not significant, it can be said that GA₃ application was effective in maintaining the fruit firmness in the cold storage. The increase in soluble solids content (SSC) during cold storage was less with GA₃ application. The decrease in titratable acidity with ripening in the cold storage was similar in the Parka and control applications. It can be said that GA₃ application was effective in maintaining the titratable acidity during storage and this effect increased with the combination of Parka+GA₃. The highest vitamin C at the end of the storage was recorded in fruit treated with Parka. Total phenolics, total flavonoids and antioxidant activity decreased in all applications during the storage. GA₃ and Parka applications retarded the losses in total phenolics, total flavonoids and antioxidant activity in the storage. As a result, it can be said that the pre-harvest GA₃ and Parka applications give positive results in maintaining the quality properties of jujube fruit in the cold storage.

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erdalaglar@gmail.com**1. Introduction**

Jujube plays a significant role in the treatment of some diseases such as anemia, cancer and heart (Gao et al., 2013), preventing oxidative stress (Wu et al., 2013) and strengthening the immune system (Yu et al., 2012; Pu et al., 2018). Along with these traits, it is a fruit species that is preferred by consumers due to its high vitamin C, taste and flavour, and its production is increasing day by day (San and Yildirim, 2010; Yao, 2013; Gunduz and Saracoglu, 2014; Keles, 2020). Jujube, which can be consumed in dried, it is also often consumed fresh in Turkey (Ozturk et al., 2018). It is significant to have a long marketing period in fresh consumption. Although jujube is a non-climatic fruit species with low physiological activity, some physiological disorders such as postharvest decay, dehydration, softening and browning of fruit flesh restrict the storage life of jujube and decrease its market value (Siddiq and Uebersax, 2012). Therefore, it is significant to delay or reduce fruit softening during marketing, transportation and storage, delay physicochemical changes and prevent fruit quality at postharvest. In order to maintain postharvest fruit quality in jujube, the postharvest treatments such as modified atmosphere packaging (Lin et al., 2004), Aleo vera, chitosan

coating (Qiuping and Wenshui, 2007), trisodium phosphate, dipping into calcium chloride solution and 1-MCP (1 - methylcyclopropene) are made (Gupta et al., 1987; Chen et al., 2019a; Zhang et al., 2019a; Zhang et al., 2019b).

The pre-harvest applications, which will increase the quality and firmness of the fruit, in extending the postharvest storage life play a significant role. In this sense, GA₃, which improves the fruit quality by promoting cell growth and elongation (Pharis and King, 1985) and increases fruit firmness with its effect on the cell wall (Fortes et al., 2015), is used effectively to extend the post-harvest life in many fruit species (Einhorn et al., 2013; Sharma and Pratima, 2018). It has been reported that with the pre-harvest GA₃ application in jujube, the fruit that had higher firmness values and respiration rate were obtained (Ozturk et al., 2018). It was observed that with the application of Parka (1% calcium, 5% cellulose and 7.5% stearic acid) which prevents water intake by forming a layer on the fruit, limits gas permeability and increases skin elasticity (Meland et al., 2014), jujube (Ozturk et al., 2018) and in sweet cherry (Aglar et al., 2017) fruit cracking was reduced and the fruit were more firmness and had lower respiration rate. The main objective of the study planned by considering the positive

effects of GA₃ and Parka applications on respiration rate and fruit firmness, which are two significant properties in maintaining quality in storage, to assess the role of the GA₃ and Parka sprays on quality traits and bioactive compounds in postharvest storage in jujube.

2. Materials and methods

2.1. Plant material

In the research, trees belonging to 4-year-old 'Li' jujube fruit (*Ziziphus jujuba* Mill. Li) were selected as the plant material. Cultural applications such as irrigation, fertilization and pruning were carried out regularly in trial trees. Trees are pruned as the central leader system.

2.2. Experimental design

The experiment was designed to have 3 blocks (replicate) and 16 trees were selected for each replication. In the trial, 4 applications were made as control (only water + surfactant), Parka [(1%, Cultiva, USA)], gibberellic acid (GA₃, 15 mgL⁻¹, Valentbioscience, USA) and GA₃ + Parka. The solution for each application was sprayed 4 trees on each replicate 3 and 2 weeks before the anticipated harvest (8 October, 2016). Sylgard-309 surfactant (0.05%, Dow Corning, Canada) was added to the solutions of the applications. 1 tree between the applications has been designed as a buffer tree. Applications were made in the time when a windless is and no rain, in the early morning. At the estimated harvest date, the fruit (25-50% from yellow / green skin color to red surface color) were harvested by hand, placed in plastic containers of 5 kg and transferred to the laboratory with a refrigerated vehicle within 4 h. The injured, crushed, cracked and defective fruit were selected and discarded. Then, for each application, the fruit were placed in 9 different plastic boxes, each containing approximately 1 kg of fruit. Fruit of all applications were placed in modified atmosphere packaging [MAP, StePac, Turkey] with 1 kg capacity. Jujube fruit were pre-cooled with cold air for 24 h at 4±0.5 °C and 90±5% RH. Then fruit were kept at 0±0.5 °C and 90±5% RH for 45 d. Measurements were carried out on days 15th, 30th and 45th at the cold storage. In each measurement period, 3 boxes were taken for each application. Each box represented a repeat.

2.3. Weight loss

Initially, at the starting of storage, first weights of the fruit were measured by a digital scale with a precision of 0.01 g (Radwag, Poland). Then, on 15th, 30th and 45th d of the storage, final weights were determined. The weight loss that occurs in fruit was based on the weight at the beginning of each measurement period.

2.4. Color characteristics, firmness and respiration rate

L*, chroma and hue angles were measured in 10 fruit by a colorimeter. CIE (Commission Internationale de l'Eclairage system) was used in color measurements. Then, the X, Y, Z values were converted into L*, a* and b* coordinates. The equations of $C^* = (a^{*2} + b^{*2})^{1/2}$ for chroma and $h^{\circ} = \tan^{-1} b^*/a^*$ for hue angle were used. To determine the fruit firmness (10 fruit), digital firmness tester (Agrosta® 100, France) was used. The scale ranges from 0 to 100 for very soft to very firm surfaces. To measure respiration rates, 2 L airtight chambers were fitted with a rubber septum and 4 fruit were

sealed in each chamber at 20±1 °C temperature and 80% RH for 1 h. The chambers were then connected to a gas sensor (Vernier, USA) and the amount of CO₂ produced by the fruit was considered as the respiration rate. Results were stated in mL CO₂ kg⁻¹ h⁻¹.

2.5. Vitamin C, titratable acidity (TA) and soluble solids content (SSC)

For vitamin C measurements, 0.5 mL juice was taken, and 5 mL of 0.5% oxalic acid was added on it. The ascorbic acid test strip (Merck, Germany) was taken from a collapsible sealed gas-tight tube. Reflectometer (Merck RQflex plus 10) was started. The test strip was plunged into the solution for 2 seconds, and then removed from the solution. It was then held for 8 seconds, and reading was done at the end of the 15th second. Results were presented as mg 100 g⁻¹. For titratable acidity measurements, 10 mL juice was taken and 10 mL distilled water was added on. Then 0.1 N NaOH (sodium hydroxide) was added until the pH of the solution reached to 8.2. Based on the amount of NaOH consumed in titration, acidity was determined and expressed as g malic acid 100 mL⁻¹. SSC was measured with a portable digital refractometer (Atago PAL-1, USA) and expressed as %.

2.6. Bioactive compounds

During each measurement period, 5 fruit were taken from each replication of each treatment. The fruit were washed with distilled water, and sliced with a stainless steel knife. Later, the fruit pulp was crumbled by a blender, and homogenized. About 30 mL of homogenate was taken and placed into 50 ml falcon tubes. The tubes were kept at -20 °C until the analyses.

Before the analyses, the frozen samples were dissolved under room temperature (21 °C). Pulp and juice were separated from each other by a centrifuge at 12.000 × g at 4 °C for 35 min. The resultant filtrate was used to determine total phenolics, total flavonoids and antioxidant activity of the samples.

Spectrophotometric measurements for bioactive compounds were performed in a UV-Vis spectrophotometer (Shimadzu, Kyoto, Japan). Total phenolics was measured according to the method described by Beyhan et al. (2010), and was expressed as mg gallic acid equivalent (GAE) 100 g⁻¹ fw. Total flavonoids was measured according to the method of Chang et al. (2002) and was expressed as mg quercetin equivalent (QE) 100 g⁻¹ fw.

The antioxidant activity of jujube fruit was determined according to two different procedures of 1.1-diphenyl-2-picryl-hydrazil (DPPH) (Blois, 1958) and Ferric Ions (Fe⁺³) Reducing Antioxidant Power (FRAP) (Benzie and Strain, 1996), and the results were expressed as mmol in 100 g⁻¹ Trolox equivalent (TE) fw.

2.7. Statistical analysis

Whether the data was normally distributed was checked by Kolmogorov-Smirnov Test. Homogeneity of variances was confirmed by Levene's test. After the variance analysis of the data, Tukey's multiple-comparison test was used to check whether there were significant differences (P<0.05) between treatments. The statistical analyses were performed by using SAS software (SAS 9.1 version, USA).

3. Results and discussion

3.1. Weight loss

The weight loss that occurs in the storage causes great economic losses. In some species, weight loss can be up to 25-30% (Sandhya, 2010; Chen et al., 2019b). Loss of weight in fruit is directly related to the loss of water caused by transpiration, which varies depending on the surface volume ratio of the fruit and the relative humidity of the storage atmosphere (Kader and Yahia, 2011). In the study, the weight loss occurred in the fruit of control application at the end of the cold storage was 1.83%. Parka and GA₃ applications reduced weight losses in the cold storage. There was no difference in effect between the Parka and GA₃ applications (Table 1). It is likely to be lower the loss of

weight with the application of Parka (Meland et al., 2014), which creates a layer on the fruit and limits water intake. Similarly, Valero et al. (2014) stated that the application of *Aloe vera* coating limited the water loss in fruit, thereby reducing the weight loss in storage. GA₃ application in different fruit species has positive effects on decreasing of the weight loss (Sharma and Pratima, 2018). The significant role of gibberellic acid (Fortes et al., 2015) in the formation and structure of the cuticle layer of the fruit may be the reason for the reduction in weight loss in the cold storage. However, Aglar et al. (2017) reported that the Parka application had no effect on the weight losses that occurred during storage in sweet cherry.

Table 1. Weight loss of preharvest GA₃ and Parka-treated jujube fruit during storage at 0 ± 0.5 ° C and 90 ± 5% RH

Treatments	Weight loss (%)		
	15 day	30 day	45 day
Control	0.68 a	1.63 a	1.83 a
Parka	0.28 b	1.30 b	1.55 b
GA ₃	0.38 b	1.36 b	1.56 b
Parka+GA ₃	0.33 b	1.33 b	1.53 b

Means in columns with the same letter do not differ according to Tukey's test at P<0.05.

3.2. Respiration rate

At the harvest, there was no statistically significant difference between the respiration rates of the fruit of control and Parka application and GA₃-treated fruit had a lower respiration rate (Table 2). However, Ozturk et al. (2018) reported that fruit with higher respiration rate were obtained

with GA₃ and Parka application in jujube. Respiration, which determines the postharvest life time by affecting the energy mechanism in the fruit, contains a series of oxidation-reduction reactions and the consumption of sugar and organic acid as the substrate (Chumyam et al., 2017).

Table 2. Respiration rate and firmness of preharvest GA₃ and Parka-treated jujube fruit during storage at 0 ± 0.5 ° C and 90 ± 5% RH

Quality characteristics	Treatments	Storage time			
		Harvest	15 day	30 day	45 day
Respiration rate (mL CO ₂ kg ⁻¹ h ⁻¹)	Control	40.27 a	39.34 b	74.19 a	55.33 a
	Parka	45.08 a	54.78 a	56.63 b	41.22 b
	GA ₃	22.09 b	33.14 c	35.91 c	29.64 c
	Parka+GA ₃	26.26 b	29.10 c	34.85 c	24.51 c
Firmness (*)	Control	87.78 a	74.11 a	67.54 b	64.81 b
	Parka	88.96 a	75.25 a	66.89 b	63.19 b
	GA ₃	81.33 b	74.60 a	65.37 b	64.30 b
	Parka+GA ₃	82.50 b	75.30 a	73.03 a	67.60 a

* The scale ranges from 0 to 100 for very soft to very firm surfaces. Means in columns with the same letter do not differ according to Tukey's test at P<0.05.

In jujube, which shows a non-climacteric respiration structure in cold storage (Sheng et al., 2003), an increase in respiration rate occurs depending on the storage time (Zhao et al., 2020). The changes occurred the respiration rate of all applications during the cold storage was significant. At the 15th day of the cold storage, the lower respiration rate was measured compared to the value measured at harvest while the respiration rate increased in 30th day, and decreased again in 45th day. Parka-applied fruit had the highest respiration rate on the 15th day of the cold storage, but on other measurement days, the highest values were recorded with the control application. Parka and GA₃ applications reduced the

respiration rate of fruit while the lowest values were measured with GA₃ application. In terms of the effect, the significant differences between Parka and GA₃ application occurred. However, the differences between the respiration rate values of GA₃ and Parka+GA₃ applications were not significant (Table 2). GA₃ plays significant role on certain biological processes including respiration in the plant (Pharis and King, 1985). GA₃ is used effectively to prolong post-harvest life in many fruit species (Einhorn et al., 2013; Sharma and Pratima, 2018). Edible coating applications such as Parka (Meland et al., 2014), *Aloe vera* (AV) and chitosan (Mahajan et al., 2018) reduce respiration rate by limiting

oxygen and carbondioxide gas transfer. With AV application, the ripening in fruit species such as pomegranate arils (Martínez-Romero et al., 2013), kiwifruit (Benitez et al., 2013), grapes (Chauhan et al., 2014) and raspberry fruit (Hassanpour, 2015) delayed.

3.3. Fruit firmness

Pre-harvest Parka application had no effect on the fruit firmness. The fruit with lower firmness value in GA₃ treated trees were harvested (Table 2). However, Einhorn et al. (2013) reported that by using GA₃, the fruit, which had higher fruit firmness, can be obtained. Choi et al. (2002); Clayton et al. (2006) and Correia et al. (2019) reported that GA₃ application in sweet cherry increased fruit firmness, but it has been suggested that GA₃ applications do not affect the fruit firmness in jujube (Ozturk et al., 2018) and grapes (Alrashidi et al., 2017). Again, it has been reported that with the application of Parka, fruit harvested in sweet cherry (Aglar et al., 2017) and jujube (Ozturk et al., 2018) have higher fruit firmness value. While the effect of Parka application on the decrease in fruit firmness values depending on the storage time was not significant, it can be said that GA₃ application is effective in maintaining the fruit firmness in cold storage.

In the control application, the fruit firmness, which was determined as 87.78% at harvest, became 64.81% by decreasing 22.97% on 45 days after the storage. However, the decrease in storage time with the GA₃ application was 17.01%. Again, at 30th and 45th days of storage, the highest fruit firmness values were recorded with Parka + GA₃ application (Table 2). It can be said that the effect of this application is caused by GA₃. GA₃, which promotes cell division and growth (Pharis and King, 1985), can be effective in maintaining fruit firmness during storage due to

its effect on the cell wall (Fortes et al., 2015). Indeed, Souza et al. (2016) in cashew apple, GA₃-treated fruit had higher fruit firmness values during storage; Ozkan et al. (2016), on the other hand, suggested that fruit with high firmness values were obtained with GA₃ application and the effect of GA₃ application was significant in maintaining these values during storage. Edible coating applications such as Parka, chitosan and Aleo vera delay maturation by decreasing cell wall enzyme activity (Khaliq et al., 2019) and oxygen uptake (Cha and Chinnan, 2004), and maintain cell turgor pressure by limiting transpiration (Mannozi et al., 2018). Aglar et al. (2017) reported that in the 21st day of cold storage in sweet cherry, the fruit applied to the Parka had higher fruit firmness.

3.4. Color characteristics

In the measurements performed at the harvest, when the effect of Parka and GA₃ applications on fruit color was evaluated, it was determined that the application of Parka caused a decrease in the L value of the fruit, but its effect on the Chroma and Hue angle values was not significant. GA₃ application affected all three values (L, chroma and hue angle), and with this application, fruit with low L and hue angle values and high chroma values were obtained (Table 3). However, Ozturk et al. (2018), in their study, reported that the Parka application did not affect the color of fruit in jujube. The occurrence of color loss, which is one of the symptoms of environmental stress and senescence in the fruit, can be prevented by cold storage, but the loss of color accelerates with prolonged storage time (Han et al., 2017). In the study in accordance with this explanation, it was found that the color loss increased with prolonged storage period (Table 3).

Table 3. Color characteristics (L*, chroma and hue angle) of preharvest GA₃ and Parka-treated jujube fruit during storage at 0 ± 0.5 ° C and 90 ± 5% RH

Quality characteristics	Treatments	Storage time			
		Harvest	15 day	30 day	45 day
L*	Control	86.45 a	63.47 b	58.19 b	50.73 c
	Parka	83.96 b	60.65 c	51.75 c	43.32 d
	GA ₃	84.44 b	59.51 c	58.14 b	56.55 b
	Parka+GA ₃	84.20 b	69.76 a	64.38 a	64.11 a
Chroma	Control	41.05 b	48.17 a	50.82 a	51.16 a
	Parka	42.15 b	47.26 a	49.16 a	51.89 a
	GA ₃	45.50 a	45.62 b	47.26 b	47.70 b
	Parka+GA ₃	42.95 b	47.14 a	47.42 b	47.63 b
Hue angle	Control	90.19 b	72.07 c	69.65 c	64.55 b
	Parka	89.26 b	73.13 c	63.63 d	60.16 c
	GA ₃	86.12 c	82.88 b	81.95 b	80.78 a
	Parka+GA ₃	96.69 a	89.25 a	87.71 a	83.34 a

Means in columns with the same letter do not differ according to Tukey's test at P<0.05.

GA₃ application may decrease color loss because it delays to anthocyanin degradation (Zhao et al., 2020). While L and hue angle values decreased during storage, this decrease was higher in Parka application. GA₃ application had a positive effect on maintaining these two values. Fruit chroma value increased depending on storage time and the effect of Parka

application on chroma value was not significant. However, the increase in chroma value was lower in GA₃ application (Table 3). Dong et al. (2019) have determined that GA₃ application delays fruit color change during the cold storage in sweet cherry. Coating materials affect fruit coloring because they cause changes in fruit surface properties and

limit the ripening process (Hoagland and Parris, 1996). In studies conducted, it has been reported that the coating applications such as alginate (Chiabrando and Giacalone, 2015) and Parka (Aglar et al., 2017) in sweet cherry and AV in mango (Carrillo-Lopez et al., 2000) decreased color changes in fruit after harvest.

3.5. Soluble solids content, titratable acidity and vitamin C

With the Parka and GA₃ applications, fruit with a lower SSC were obtained (Table 4). Ozturk et al. (2018) obtained similar results with the application of GA₃ and Parka in

jujube. Einhorn et al. (2013) suggested that SSC increased with GA₃ application in sweet cherry, but Ozkan et al. (2016) determined that it decreased. Alrashdi et al. (2017) reported that GA₃ application did not affect SSC content in grapes. With prolonged storage time, the rate of SSC in fruit increased (Table 4). SSC, which is one of the fruit harvest criteria, increases as a result of hydrolysis of undissolved polysaccharides in simple sugars and increased metabolic activities together with prolonging of maturity progresses (Hassanpour, 2015).

Table 4. Soluble solids content (SSC), titratable acidity and vitamin C of preharvest GA₃ and Parka-treated jujube fruit during storage at 0 ± 0.5 °C and 90 ± 5% RH

Quality characteristics	Treatments	Storage time			
		Harvest	15 day	30 day	45 day
SSC (%)	Control	21.20 a	23.45 a	24.80 a	25.85 a
	Parka	20.25 b	21.55 b	24.52 a	25.37 a
	GA ₃	20.21 b	21.80 b	22.03 b	23.27 b
	Parka+GA ₃	20.50 b	21.57 b	22.30 b	23.97 b
Titratable acidity (g malic acid 100 mL ⁻¹)	Control	0.30 b	0.25 c	0.24 c	0.22 c
	Parka	0.29 b	0.25 c	0.23 c	0.20 c
	GA ₃	0.33 a	0.28 b	0.28 b	0.27 b
	Parka+GA ₃	0.32 a	0.32 a	0.30 a	0.29 a
Vitamin C (mg 100 g ⁻¹)	Control	267.5 b	245.0 b	206.5 d	202.0 b
	Parka	285.6 a	260.0 a	245.6 a	214.5 a
	GA ₃	258.3 b	245.3 b	230.5 b	195.3 b
	Parka+GA ₃	230.3 c	222.0 c	220.0 c	217.0 a

Means in columns with the same letter do not differ according to Tukey's test at P<0.05.

The increase in SSC rate during storage was less with GA₃ application. Parka-treated fruit on 15th day of the cold storage had a lower SSC compared to control, while there was no difference between control and Parka applications on other measurement days (Table 4). Aglar et al. (2017), in their study on sweet cherry, suggested that the rate of SSC was lower in the Parka-treated fruit during storage period. Zhao et al. (2020) reported that the rate of SSC reached peak after 3 days of the cold storage in GA₃-applied fruit. With the GA₃ application, it was determined that the rate of titratable acidity in the fruit increased, and Parka application had no effect on titratable acidity. The reduction in titratable acidity rate with maturation in storage was similar in the Parka and control applications. It can be said that GA₃ application was effective in maintaining the titratable acidity ratio during cold storage, and this effect increased with the combination of Parka + GA₃ (Table 4). The acidity rate in fruit at harvest is the highest level, but it decreases as ripening progresses (Reque et al., 2014). Bahmani et al. (2015) stated that the rate of titratable acidity in the fruit decreased due to high respiration after harvest. The coating materials such as *Aleo vera* (Valverde et al., 2005) and Parka (Aglar et al., 2017) delay the reduction of titratable acidity content by lowering the respiration rate of the fruit at the postharvest storage. Zhao et al. (2020) determined that the rate of titratable acidity was lower with GA₃ application in harvested fruit, but the rate of titratable acidity was higher in fruit with GA₃ application compared to control in the storage

measurements. Dong et al. (2019) reported that fruit treated with pre-harvest GA₃ in "Lapins" sweet cherry cultivar had a lower titratable acidity rate after 4 weeks of the cold storage. The difference in the vitamin C of the fruit with GA₃ application did not occur, but fruit with the highest vitamin C were obtained with Parka application. Vitamin C decreased in proportion to the storage time. Although the highest vitamin C at the end of the cold storage was recorded in Parka-treated fruit, the highest loss of vitamin C during storage occurred in these fruit. At cold storage, vitamin C in GA₃ and control applications was determined as 63.5 and 65.5 mg 100 g⁻¹ respectively. It can be said that the application of Parka+GA₃ reduces the loss of the vitamin C in storage (Table 4). Ozturk et al. (2018) reported that a significant increase in vitamin C ratio with Parka and GA₃ applications in jujube occurred, while Zhao et al. (2020) determined that the decrease in vitamin C ratio occurred in proportion to the storage period and that at the end of the cold storage, the GA₃-treated fruit had a higher vitamin C compared to the control. Aglar et al. (2017) reported that the application of the pre-harvest Parka in sweet cherry had no effect on the decrease in vitamin C after 21 d of the cold storage.

3.6. Bioactive compounds

There is a positive correlation between the content of bioactive compounds (Serra et al., 2011) whose concentration varies depending on the genetic and

environmental factors, and the fruit ripening stage. The concentrations of bioactive compounds such as phenolic substances, anthocyanins and antioxidants at the fruit ripening stage are at the highest level (Mahmood et al., 2013). Diaz-Mula et al. (2009) and Ozkan et al. (2016) suggested that in sweet cherry, GA₃-applied fruit had lower total phenolics, antioxidant activity and total anthocyanin

content. It was determined that in the harvested fruit, GA₃ application had no effect on the total phenolic and it decreased the total flavonoids and increased the antioxidant activity. While the Parka application decreased the total phenolics and antioxidant activity, it had no effect on the flavonoids (Table 5).

Table 5. Total phenolics, total flavonoids and antioxidant activity (FRAP[·] and DPPH[·]) of preharvest GA₃ and Parka-treated jujube fruit during storage at 0 ± 0.5 ° C and 90 ± 5% RH

Quality characteristics	Treatments	Storage time			
		Harvest	15 day	30 day	45 day
Total phenolics (mg GAE 100 g ⁻¹ fw)	Control	722 a	596 c	512 c	402 c
	Parka	643 b	594 c	557 b	513 b
	GA ₃	717 a	664 a	603 a	590 a
	Parka+GA ₃	639 b	625 b	608 a	570 a
Total flavonoids (mg QE g ⁻¹ 100 fw)	Control	215 a	146 c	110 c	105 c
	Parka	223 a	168 b	129 b	115 b
	GA ₃	200 b	183 a	149 a	138 a
	Parka+GA ₃	185 c	180 a	145 a	141 a
FRAP [·] (mmol TE 100 g ⁻¹ fw)	Control	61.6 b	50.2 b	36.6 c	30.6 c
	Parka	61.1 b	44.6 c	40.2 b	36.2 b
	GA ₃	68.3 a	56.6 a	45.5 a	50.6 a
	Parka+GA ₃	67.6 a	56.5 a	44.2 a	53.7 a
DPPH [·] (mmol TE 100 g ⁻¹ fw)	Control	57.3 b	52.4 c	41.9 c	33.9 c
	Parka	58.5 b	54.6 b	46.3 b	41.5 b
	GA ₃	60.6 a	59.6 a	54.3 a	52.2 a
	Parka+GA ₃	61.3 a	58.6 a	53.9 a	51.8 a

Means in columns with the same letter do not differ according to Tukey's test at P<0.05.

Ozturk et al. (2018) reported that in jujube, Parka application has no effect on total flavonoids, but unlike our study, it increased total phenolics and antioxidant activity. Total phenolics, total flavonoids and antioxidant activity decreased in all applications during storage. GA₃ and Parka applications positively affected the losses in total phenolics, total flavonoids and antioxidant activity in storage. The highest values at the end of the cold storage were recorded with GA₃ application while the lowest values were obtained with the control application. However, Aglar et al. (2018) found that in sweet cherry, the pre-harvest Parka application had no effect on total phenolics and antioxidant activity during storage.

At the end of the study, it was concluded that higher quality fruit were obtained with pre-harvest GA₃ and Parka applications had positive effects in reducing the quality losses in the cold storage. Also, with GA₃ and Parka applications, the quality of jujube fruit was maintained until 45 days at 0 ± 0.5 ° C and 90 ± 5% RH.

Authors' Contributions

Orhan Karakaya: Validation, Writing - original draft. Erdal Aglar: Methodology, Investigation, Conceptualization, Validation, Review and editing. Burhan Ozturk: Methodology, Investigation, Conceptualization, Validation, Writing - original draft, Visualization. Sefa Gun:

Methodology, Investigation, Formal analysis, Data curation. Umut Ates: Formal analysis, Data curation. Osman Nuri Ocalan: Formal analysis, Data curation.

Conflict of Interest

The authors declare that they have no conflict of interest.

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