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Investigation of the effects of melatonin application on storage in plums (*Prunus domestica* L.) grown under organic and conventional conditions

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Abstract

This study was carried out to investigate the effects of melatonin applications on postharvest quality changes of organic and conventionally grown plum fruit. Melatonin was applied in 0, 50, and 100 µmol L^{-1} for organic and conventional samples. The fruits were stored at +2.0 °C and 90% relative humidity for 28 days. During the storage period, the color, weight loss, firmness, Soluble solids concentration (SSC), titratable acidity (TA), pH, total antioxidant content, and total phenolics were evaluated at 7-day intervals. While no effect of melatonin applications on weight loss of organically grown plums was observed, it was determined that weight loss decreased as the dose of melatonin increased in conventionally grown plums. The lowest weight loss during storage was determined in conventionally grown plums treated with 100 µmolL^{-1} melatonin. It was observed that the firmness values decreased as the storage period increased in both cultivation methods. The firmness decreased as the dose of melatonin application increased in organically grown plums, while the firmness increased as the dose of melatonin application increased in conventional cultivation. Melatonin application did not positively affect SSC, pH, and color values. However, it was determined that the mean TA values decreased as the dose of melatonin increased in both cultivation methods. When the total phenol content of organic and conventional plums was examined, it was determined that melatonin application decreased the number of phenolic compounds. The highest phenolic content was determined in the control samples. The total amount of antioxidants was 1.71 µmol TE g^{-1} on the 28th day in the highest (100 µmol L^{-1}) melatonin-treated conventionally grown plums.

Keywords Fruit Storage, Fruit Firmness, Organic agriculture, Total antioxidant capacity

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Background

Plum is a type of fruit with a wide distribution cultivated in Turkiye as well as all over the world. Plum is generally consumed fresh and processed and consumed as syrup, jam, molasses, and marmalade [1]. Plum is rich in antioxidant substances, vitamins A and C, magnesium, potassium, and fiber content [2, 3]. It is essential for human health and nutrition due to its rich vitamin and nutritional content. Plum, which can be grown in many different ecologies worldwide, has many species and varieties. 'Giant' 'Grant Prize, ' 'President,' 'R.C.Violet,' 'Black Diamond,' 'Stanley,' 'Papaz,' 'Can,' and 'Mürdüm' can be given as examples of plum varieties [4, 5].

Organic and conventional plum cultivation is increasing every year in Turkiye. Traditional production of plums has increased by approximately 31,467 tons in the last five years, and 892,048 plums were produced in 2020 [6]. Organic plum production, on the other hand, was 7684.78 tons, according to 2019 statistics. The highest certified organic plum production in 2019 was 3267 tons in Adana. 6.97 tons of certified organic plums were produced in Tokat [7].

A significant amount of conventional and organic plum production is carried out in Turkiye. Post-harvest preservation of a fruit produced in this amount is also essential. The biochemical and physiological changes of plum fruit that occur with fruit ripening after harvest differ depending on the environmental conditions and2 variety [8, 9]. Different research results have demonstrated that the ripening of plum fruit, which has a short storage life due to its physiological sensitivity, is delayed by some growth regulators, or its shelf life is extended. It has been determined that post-harvest losses are significantly reduced with such applications [9–11].

Melatonin (N-acetyl-5-methoxy tryptamine) has pleiotropic effects in different organisms. It performs many essential functions in humans, plants, and animals; these range from controlling aging in plants to regulating circadian rhythms in animals [12, 13]. In recent years, melatonin has been used in many studies where it has essential roles in regulating plant growth, protecting against different types of biotic and abiotic stresses, activating seed germination, increasing yield, regulating rhizogenesis, regulating photoperiod, delaying leaf senescence and controlling fruit ripening [13–15].

In some literature results on postharvest melatonin application, Cao et al. [16] determined that the application of melatonin increased peach fruit's nutritional quality and chill tolerance. In another study, Aghdam et al. [17] found that applying melatonin to strawberry fruit reduced post-harvest rot and preserved its nutritional value. Liu et al. [18] applied melatonin at 0.1 or 1 µmol L^{-1} to strawberry fruit after harvest. They reported that this application reduces the incidence and severity of rot and weight loss and is most effective in delaying fruit aging by maintaining fruit firmness and titratable acidity (TA). Bal [13] applied different doses of melatonin to Santa Roza plum variety in his study and examined the effect of application doses on plum fruit during storage. He found that melatonin applied at a dose of 1000 µmol L^{-1} significantly reduced the degradation rate from high biochemical compounds and predicted that this dose of melatonin applied could be a valuable technique to extend the postharvest life of plums with acceptable fruit quality. These findings suggest that melatonin may be an essential postharvest application in regulating physiological processes in harvested crops [19]. As seen in the literature studies examined, the positive effects of postharvest melatonin application on agricultural products were observed during storage, and the importance of the application dose was indicated. However, no study has been found on the effects of melatonin application on the quality of President plum fruit. For this reason, the effect of postharvest application of different doses of melatonin on maintaining the quality and extending the storage life of 'President' plum fruit grown as organic and conventionally was investigated.

The main purpose of the study is to investigate and reveal the effects of melatonin applied to President plum fruit grown with organic and conventional methods during storage on the storage life of the fruit. Thus, the effects of melatonin application on fruit quality and storage time were evaluated.

Materials and methods

Plant materials and post-harvest treatments

Organic fruits were hand-harvested from the orchard certified by the control and certification company, and conventional fruits were hand-harvested from the conventional orchard located near the organic orchard with the same climate and soil conditions. The fruits were hand-picked from the 8-year-old President cultivar grafted on Myrobolan rootstock. Conventional and organic fruits were harvested at the commercial maturity period; taste and color were considered as harvest criteria. The hand-harvested fruits were brought to the laboratory. Healthy and uniform fruits were selected and precooled for 24 h at 4.0 °C and 90% relative humidity (RH). After pre-cooling, the fruits were immersed in the melatonin solution prepared with distilled water for 3 min. Melatonin was applied to organic and conventional fruits at three concentrations of 0 (control), 50, and 100 ppm. The fruits extracted from the melatonin solution were kept on blotting paper for one minute, then placed in the fruit boxes and put into storage. Because the water remaining on the fruits can damage the fruits during storage. Plastic boxes were used for conventional plums, and wooden boxes were used for organic plums.

Plums were stored at +2.0 °C temperature and 90% RH for 4 weeks. Measurements were made by taking fruit samples once a week in stored fruits.

Weight loss

Fruit samples were taken at 7^{th}, 14^{th}, 21^{th}, and 28^{th} days of storage, and weight losses were determined with the following formula.

$$WL = \frac{Wi - Wf}{Wi} \times 100 \quad (1)$$

Wi: Weight at start of storage (g), Wf: Weight at the measurement date (g), WL: Weight loss (%).

Fruit firmness

Fruit firmness was measured from the stem pit region (two cheeks) of each fruit material with the help of a penetrometer (Model FT-327; McCormick Fruit Tech, Yakima, WA).

Fruit color

The L*, a*, b* values of the inner and outer colors of the fruits were measured before storage and on the 7th, 14th, 21th, and 28th days of storage. Minolta CR-300 model Chroma Meter device was used for color measurement.

Chemical analysis

Titratable acidity and pH measurement

Briefly summarized below, the titration method determined the fruit's acidity and expressed it as % in terms of malic acid. 5 g of the homogenized fruit samples were weighed, 45 ml of distilled water was added, and the pH value was measured with the help of a pH meter. Then, 0.1 N sodium hydroxide (NaOH) was added until the pH value reached 8.1. A pH meter measured the pH value by directly immersing the glass electrode in the homogenized fruit samples [20].

Soluble solids content (SSC)

After the pureed samples were homogenized with the help of a blender, they were placed in the centrifuge, and the juices were extracted. The first drops of juice-extracted samples were taken on a calibrated digital refractometer (0–53 scale, Refractometer PAL-1) based on distilled water, and the results were expressed as % [21].

Total phenolics

The total amount of phenolic substance was made using Folin-Ciocalteu's chemical, as stated in [22]. Of the homogenized samples, 2 g were weighed with a 0.05 g, sensitive digital balance, and 18 ml of acetone buffer (acetone 70% - water 29.5% - acetic acid 0.5%) solution was added and kept in a dark environment at room temperature for 2 h. 0.5 ml of Folin-Ciocalteu chemical and 9 ml of distilled water were added to 0.5 ml sample and kept at room temperature for 8 min. Then, 2.5 ml of salt (7% sodium carbonate) was added, and after 2 h, the solution that formed a blue color was read in the spectrophotometer at a wavelength of 750 nm. The results were calculated using gallic acid [23].

Total antioxidant capacity (TAC)

For TAC analysis Özgen and Scheerens [24], , 7 nm ABTS (2.2'-Azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) was mixed with 2.45 mM and kept in the dark for 12–16 h. Then, this solution was simplified to 0.700±0.01 absorbance at 734 nm wavelength in a spectrophotometer with 20 mM sodium acetate (pH 4.5) buffer. Finally, 20 µL of the extract was mixed with 2.98 mL of prepared copper, and the absorbance was measured after 10 min at a wavelength of 734 nm in the spectrophotometer. Obtained absorbance values were calculated as Trolox (10–100 µmol/L) standard curve chart and calculated as µmol Trolox equivalent/g wet weight [25].

Total anthocyanin

The total anthocyanin in the plum fruit was made using the pH difference (pH 1.0 and 4.5) method (33). By adding 300 µL and 2700 µl pH 1.0 solution from the extracts, measurements were made at 520 and 700 nm wavelengths. The exact process was done in a pH 4.5 solution. Total anthocyanin amount (molar extinction coefficient of 28000 cyanidin 3-glycoside) absorbances [(A520–A700) pH 1.0-(A520–A700) pH 4.5] was calculated as µg anthocyanin/g dry matter [23].

Statistical analysis

The research was established according to the experimental design of the randomized plots with three replications in factorial order and ten plums in each replication. After the data were analyzed using variance analysis, the application averages were compared with the Duncan multiple comparison test. All statistical analyses were done using SAS 9.1. statistical package program.

Results and discussion

Weight loss

Post-harvest weight loss in fruits and vegetables is due to metabolic activity, respiration, and perspiration. When the weight losses given in (Table 1) are examined, it is seen that the weight loss of plum fruits increases as the storage period gets longer in all applications. When the average storage time was compared with the cultivation methods, it was found to be statistically significantly different, and it was determined that organically grown plums lost more weight than conventional plums in all

Table 1 Effects of different doses of melatonin applications on weight loss values during cold storage and shelf life of President plum variety

Weight Loss	Melatonin (μmol L^{-1})	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	-	2,73 A	4,51 A	6,18 A	7,35 A	5,19 A
	50	-	2,73 A	4,41 A	6,10 A	7,70 A	5,24 A
	100	-	2,59 A	4,59 A	6,49 A	7,98 A	5,41 A
Average		**-**	**2.68 I***	**4.50 I***	**6.26 I***	**7.68 I***	**5,28 I***
Conventional	**0**	-	2,24 A	3,90 A	5,48 A	6,68 A	4,58 A
	50	-	1,79B	3,20B	4,46B	5,40B	3,71B
	100	-	1,51 C	2,68 C	3,80 C	4,65 C	3,16 C
Average		-	**1.85 II**	**3.26 II**	**4.58 II**	**5.58 II**	**3,82 II**

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is essential

Table 2 Effects of different doses of melatonin applications on fruit firmness during cold storage and shelf life of President plum cultivar

Firmness Volues	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	70,40 A	65,35 A	54,45 A	48,43 A	49,05Ab	57,54 A
	50	70,40 A	63,37 A	53,20 A	41,42B	50,77 A	55,83 A
	100	70,40 A	61,17 A	51,78 A	43,57B	49,50 A	55,28 A
Average		**70,40 I***	**63,29 I***	**53,14 I***	**44,47 II**	**49,77 I**	56,21 **II**
Conventional	**0**	72,50 A	69,18 A	57,73B	51,53 A	54,93 A	61,17 A
	50	72,50 A	66,92 A	65,57 A	52,70 A	53,98 A	62,33 A
	100	72,50 A	71,78 A	60,60B	52,53 A	52,25 A	61,93 A
Average		**72,50 I***	**69,29 I***	**61,30 I***	**52,26 I***	**53,72 I***	61,81 **I***

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is essential

storage periods. While the effect of melatonin applications on weight loss during storage in organically grown plums was not significant, it was found to be significant in conventionally grown plums. It was determined that the weight loss decreased as the melatonin dose increased in conventionally grown plums. The lowest weight loss during storage was found in conventionally grown plums treated with 100 μmol L^{-1} melatonin. Melatonin application was determined to delay weight loss in conventionally grown plums. Bal [13] applied different doses of melatonin to Santa Roza plum variety in his study and found that melatonin application reduced weight loss. Similarly, Gao et al. [26] and Liu et al. [18] found that applying melatonin to peach and strawberry fruits during storage significantly reduced weight loss.

Fruit firmness

As in many fruit species, firmness is a critical quality factor affecting plums' commercialization and shelf life. When the firmness values given in (Table 2) were examined, it was observed that the firmness values decreased as the storage period increased in both cultivation methods. When the average storage time was compared with the cultivation methods, there was no significant difference, and it was determined that the decrease in firmness values of organically grown plums was higher than the conventional ones in all storage periods. When the storage times were examined separately, it was determined that the firmness decreased as the dose of melatonin application increased in organically grown plums. In contrast, the firmness increased as the dose of melatonin application increased in conventional cultivation. Bal [13] determined the highest firmness value in the 'Santa Roza' plum cultivar to which different melatonin doses (0, 1, 10, 100, and 1000 μmol L^{-1}) were applied. It was observed that increasing the dose of melatonin application positively affected the firmness values. It was found that the highest firmness at the end of storage was in conventionally grown plums (54.48 N) treated with 100 μmol L-1 melatonin. In another study, Zhai et al. [27] investigated the effect of melatonin application on the aging process of pear fruit. According to the findings he obtained, it was determined that the application of melatonin preserved the firmness and integrity of the fruit cell wall during storage.

Fruit color

Color values are an essential quality criterion for agricultural products such as fruits and vegetables. The most important color values in plum fruit are L* and b*. L* and b* values are given in (Table 3. and 4) and the graphical representation of L* values is given in (Table 3.) When the color values were examined, a statistically significant difference was found when the L* and b* values were

Table 3 The effects of different doses of melatonin applications on fruit inner color L (brightness) values in President plum variety during cold storage

Inner color volue (L)	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	43,23 A	42,30 A	39,99 A	40,86B	38,74 A	41,02 A
	50	43,23 A	41,11 A	37,41 A	41,29AB	38,99 A	40,40 A
	100	43,23 A	42,78 A	39,78 A	43,20 A	38,72 A	41,54 A
Average		**43,23 I***	**42,06 I***	**39,06 I***	**41,78 I***	**38,81 II**	**40,99I***
Conventional	**0**	37,75 A	38,56 A	36,69 A	42,15 A	40,65B	39,16 A
	50	37,75 A	40,69 A	33,66 A	42,41 A	41,48AB	39,20 A
	100	37,75 A	39,36 A	35,15 A	41,45 A	42,27 A	39,20 A
Average		**37,75 II**	**39,54 II**	**35,16 II**	**42,00 I***	**41,47 I***	**39,18II**

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is essential

Table 4 Effects of different doses of melatonin applications on fruit core color b (yellow-blue) values in President plum variety during cold storage

Inner color volue (b)	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	16,88 A	15,41 A	14,48 A	13,20B	12,82 A	14,56 A
	50	16,88 A	15,26 A	15,01 A	15,16 A	14,39 A	15,34 A
	100	16,88 A	18,70 A	12,16 A	11,32 C	13,39 A	14,49 A
Average		**16,88 I***	**16,46 I***	**13,88 I**	**13,23 I**	**13,53 II**	**14,80I***
Conventional	**0**	13,76 A	14,02 A	12,78 A	15,54 A	15,44 A	14,31 A
	50	13,76 A	12,43 A	13,19 A	13,51 A	15,54 A	13,69 A
	100	13,76 A	14,02 A	12,87 A	12,98 A	14,71 A	13,67 A
Average		**13,76 II**	**13,49 II**	**12,94 I**	**14,01 I**	**15,23 I***	**13,89II**

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is essential

compared with the averages of the cultivation methods, regardless of the melatonin applications. L* and b* values of organically grown plums were higher than conventional plums. When the total averages of melatonin applications taken at the end of the storage period in both cultivation methods are examined, it is seen that there is no statistical difference between the melatonin applications of organically grown plums. In other words, it was determined that melatonin application did not affect organic plums. When the effect of melatonin applications on color values in conventional plums is examined, no statistical difference was observed between L* and b* values. Altuntas et al. [28] investigated the effects of methyl Jasmonate applications and harvesting periods on President plum fruits' physical, mechanical, and chemical properties. While the effect of methyl Jasmonate application on only a* color properties was statistically significant (P0.05), L*, b*, C*, and hue values were insignificant. According to the data obtained at the end of storage, the brightness value, significant in the fruit's inner color, was 42.27 in conventionally grown plums with the highest 100 μmol L^{-1} melatonin applied.

Chemical properties

Sugars represent a crucial component of fruit edible quality, giving predominantly sweetness and significantly affecting consumer satisfaction with plum fruit [29]. SSC and TA concentrations are important factors for assessing fruit quality. In general, an increase in the sugar content of climacteric fruits and a decrease in acidity occur during storage, in line with the progression of the ripening process. When the SSC values given in (Table 5) were examined, fluctuations occurred in both cultivation types during the storage period, and it was determined that the SSC values decreased at the end of the storage period compared to the initial values. When the averages of the two cultivation methods were compared, it was determined that the values of organic plums were higher than the conventionally grown plums. When compared statistically, it was determined that there was a significant difference between them. When the effect of melatonin applications on SSC values on plum was examined, it was observed that these application doses did not affect SSC values. It was determined that SSC values in organically grown plums ranged between 16.09 and 14.71, and conventionally grown plums ranged between 13.20 and 12.51. Cocen et al. [3] reported 17.60% SSC value in President plum variety, while Altuntas et al. [28] found SSC values between 15.58% and 16.72% and Civil [30] between 17.36% and 22.64%.

The pH value of the melatonin applications on organic and conventionally grown President plums during the storage period is shown in (Table 6). When the table was examined, it was determined that the pH values of

Table 5 Effects of different melatonin applications on the amount of Soluble solids concentration (SSC) in President plum variety during cold storage

Soluble solids concentration (SSC %)	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	14,80 A	15,60 A	16,07 A	14,47 A	13,80 A	14,95 A
	50	14,80 A	16,20 A	16,27 A	15,27 A	14,93 A	15,49 A
	100	14,80 A	16,47 A	15,33 A	16,33 A	15,40 A	15,67 A
Average		**14,80 I***	**16,09 I***	**15,89 I***	**15,36 I***	**14,71 I***	**15,37I***
Conventional	**0**	13,20 A	11,80 A	13,47 A	12,73 A	13,27 A	12,89 A
	50	13,20 A	12,73 A	11,53B	13,27 A	12,93 A	12,73 A
	100	13,20 A	13,00 A	12,60 A	12,87 A	12,93 A	12,92 A
Average		**13,20 II**	**12,51 II**	**12,53 II**	**12,96 II**	**13,04 II**	**12,85II**

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is important

Table 6 Effects of different melatonin applications on pH value of President plum variety during cold storage

pH	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	3,07 A	3,08 A	2,96 A	3,02 A	2,95 A	3,02 A
	50	3,07 A	2,91B	3,05 A	3,12 A	3,03 A	3,04 A
	100	3,07 A	3,15 A	3,06 A	3,03 A	3,04 A	3,07 A
Average		**3,07 I**	**3,05 I**	**3,02 I**	**3,06 I**	**3,01 I**	**3,04 II**
Conventional	**0**	3,13 A	3,12 A	3,05 A	3,03 A	3,02 A	3,07B
	50	3,13 A	3,09 A	3,05 A	3,18 A	3,11 A	3,11AB
	100	3,13 A	3,15 A	3,19 A	3,17 A	3,15 A	3,16 A
Average		**3,13 I**	**3,12 I**	**3,09 I**	**3,12 I**	**3,10 I**	**3,11 I***

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is essential

Table 7 Effects of different melatonin applications on total acid (TA) amount during cold storage in President plum variety

Total acid (%)	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	1,94 A	1,97 A	2,11 A	1,97 A	1,85 A	1,97 A
	50	1,94 A	2,02 A	1,89B	1,83 A	1,84 A	1,91 A
	100	1,94 A	1,71B	1,75B	1,87 A	1,85 A	1,83B
Average		**1,94 I**	**1,90 I**	**1,92 I**	**1,89 I**	**1,85 I**	**1,90 II**
Conventional	**0**	2,05 A	2,06B	2,07 A	2,09 A	2,18 A	2,09 A
	50	2,05 A	2,18 A	2,03 A	2,05 A	2,00B	2,06 A
	100	2,05 A	2,00B	2,08 A	2,08 A	2,02AB	2,05 A
Average		**2,05 I**	**2,08 I**	**2,06 I**	**2,07 I**	**2,06 I**	**2,06 I***

The difference between the averages denoted by the same letter in the same row and column is not significant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is important

each organic and conventionally grown fruit group fluctuated until the end of the storage period and decreased compared to the initial pH value at the end of the storage period. There was no significant difference in melatonin applications on both cultivation forms. When the means of cultivation methods were compared, they were found to be different, and the pH value of the conventionally grown plums was determined to be higher than the organic plums. At the end of storage, the highest pH value of 100 µmol L^{-1} melatonin application was determined as 3.15 in conventionally grown plums. Subaşı [31] reported the pH value as 2.93. Çöçen et al. [3] found 3.24, while Ergun [20] reported it as 3.38 in their study on the Stanley plum variety.

Total acidity (%) values of organic and conventionally grown plums are given in (Table 7) When the values were examined, fluctuations occurred in the total acidity values during the storage period in both cultivation types. TA values of organic plums were lower than those at the end of the storage period, while TA values of conventional plums were higher than those of the initial values. When the averages of both cultivation methods were compared, it was determined that the conventionally grown plums differed significantly from the organic plums. Regardless of melatonin applications, when the averages of conventional and organic plums were compared, it was determined that the TA value of conventional plums was higher than that of organic plums. When the average of all storage times was compared with the melatonin applications, it was determined that the TA values decreased as the melatonin dose increased in both cultivation methods. At the end of the storage

Table 8 Effects of different melatonin applications on total antioxidant (TEAC) amount during cold storage in President plum variety

Total Antioxidant (µmol TE/g fw)	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	1,34 A	1,34 A	1,37B	1,25B	1,60 A	1,38 A
	50	1,34 A	1,50 A	1,64 A	1,28B	1,44 A	1,44 A
	100	1,34 A	1,37 A	1,35B	1,40 A	1,57 A	1,41 A
Average		**1,34 II**	**1,40 II**	**1,46 I**	**1,31 II**	**1,54 I**	**1,41II**
Conventional	**0**	1,61 A	1,57 A	1,38B	1,62 A	1,56AB	1,55 A
	50	1,61 A	1,60 A	1,87 A	1,52 A	1,50B	1,62 A
	100	1,61 A	1,62 A	1,59AB	1,53 A	1,71 A	1,61 A
Average		**1,61 I***	**1,59 I***	**1,61 I**	**1,56 I***	**1,59 I**	**1,59I***

The difference between the averages denoted by the same letter in the row and column is insignificant. *The difference between the storage time and the average cultivation method, shown with different Roman numerals, is important

Table 9 Effects of different melatonin applications on total phenolic (TP) amount during cold storage in President plum variety

Total phenolic (µg GAE/g fw)	Application	0. day	7. day	14. day	21. day	28. day	Average
Organic	**0**	573,89 A	647,23 A	607,23 A	628,89 A	655,56 A	622,56 A
	50	573,89 A	670,56 A	598,89 A	515,56 A	508,89B	573,56 A
	100	573,89 A	570,56 A	510,56 A	655,56 A	580,56AB	578,23 A
Average		**573,89 I**	**629,45 I**	**572,23 I**	**600,00 I**	**581,67 I**	**591,45 I***
Conventional	**0**	525,56 A	665,56 A	578,89 A	628,89 A	608,89 A	601,56 A
	50	525,56 A	468,89B	580,56 A	545,56 A	493,89 A	522,89B
	100	525,56 A	493,89B	443,89 A	420,56B	597,23 A	496,23B
Average		**525,56 I**	**542,78 I**	**534,45 I**	**531,67 I**	**566,67 I**	**540,23 II**

The difference between the averages denoted by the same letter in the same row and column is not significant. *The difference between the storage time and the average cultivation method, which is shown with different Roman numerals, is essential

period, the highest TA value was 2.18 in the control samples of conventionally grown plums, while the lowest TA value was 1.84 in 50 µmol L -1 melatonin application of organic plums. In studies on TA amount, Altuntaş et al. [28] found values between 1.18 and 1.28%, Civil [1] 0.57-0.89%, and Subaşı [31] 1.19%.

Total antioxidant and total phenolic

Fruits are excellent sources of antioxidants, consisting of many different antioxidant components. The antioxidant activity depends on the physiological state of the fruit and decreases during aging. As seen in (Table 8) antioxidant activity fluctuated throughout storage. In organically grown plums, it increased from the start day to the 21st day, while a decrease was observed on the 21st day and then an increase occurred on the 28th day, while a decrease occurred on the 7th and 21st days in the conventional plums and an increase in the 14th day. At the end of the 28th day, an increase was observed in organic plums and a decrease in conventional plums compared to the initial value. Regardless of the melatonin applications, the cultivation patterns were found to be statistically significantly different among themselves. The highest antioxidant content was 1.71 µmol/TE g in conventionally grown plums treated with 100 µmol L^{-1} melatonin. Bal [13] stated that the antioxidant amount found by the DPPH method in the study he conducted on the Santa Rosa plum cultivar was between 15.2 µmol g^{-1} and 17.1 µmol g^{-1}. In another study, Ergun [20] reported the number of antioxidants found in the Stanley plum variety by the TEAC method as 7.77 µmol/TE g. The difference in antioxidant values is thought to be due to the type of product and the way of cultivation.

Plum fruits contain abundant natural phenolic phytochemicals such as flavonoids, phenolic acids, anthocyanins, and other phenolics that can act as effective natural antioxidants [13, 32]. In the study, fluctuations occurred during the storage period when the average storage times were examined regardless of the melatonin applications. However, the values obtained at the end of storage in both cultivation methods were higher than the initial values. When the average of all storage times of melatonin applications was examined, it was seen that the method without melatonin was higher than the method with melatonin application in both cultivation methods. The decrease in phenolic components at the end of storage may be the deterioration of cell structure as a part of aging during storage. According to the results obtained, the applied melatonin doses caused a decrease in the phenolic values. The highest phenolic value obtained at the end of the storage period was 655.56 µg GAE/g in organic plums without melatonin treatment. Ergun [20] found a total phenolic value of 685.28 µg GAE/g in their study. In the study, values close to the literature results were obtained. (Table 9)

Conclusions

The increase in demand for organic products has led to increased production quantities. The increase in production brought along the growth of trade and the market. It is essential for the sector's development that organic products can be stored for a long time without losing their quality value. It has been stated that prolonging the storage period by using products of organic origin, which is allowed in the organic agriculture regulation, will positively affect production. This study investigated the effects of melatonin applications on biochemical compounds and postharvest organic and conventional plum quality. According to the study's results, it was observed that the application of melatonin did not affect the weight loss of organic plums. However, as the dose of melatonin increased in conventionally grown plums, weight loss decreased. In terms of firmness values, it was determined that as the dose of melatonin application increased, the firmness decreased in organically grown plums. In contrast, the firmness increased as the dose of melatonin application increased in conventional cultivation. Melatonin application did not positively affect SSC, pH, and color values. However, it was determined that the mean TA values decreased as the dose of melatonin increased in both cultivation methods. When the total phenol content of organic and conventional plums was examined, it was determined that melatonin application decreased the number of phenolic substances. The phenolic content of organic plums was higher than that of conventional plums. The highest phenolic content was determined in the control samples. The study is an example of postharvest applications to increase the preservation performance of organic products. Making new studies using different varieties and applications will contribute to the potential of organic products to be preferred.

While the research provides an important foundation for discoveries in this field, melatonin's growth efficiency and economic value in commercial production requires further research and field studies.

Abbreviations

pH	Power of hydrogen
SSC	Soluble solids concentration
TA	Total acidity
TAC	Total Antioxidant Capacity

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Declarations

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