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Effect of Pre-Harvest Melatonin and Salicylic acid treatments on Decay, Maintaining Quality and Extend the Shelf life of Strawberry fruits

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ABSTRACT

Fresh strawberry fruits are highly perishable and have a short marketing life after harvest due to their high level of respiration and deterioration of quality characteristics during storage. Therefore, the purpose of the study was to examine the effect of pre-harvest treatments of melatonin (M) solutions at 80, 100, and 120 µM and salicylic acid solutions (SA) at 2, 4, and 6 mM and control on decay, quality attributes, and shelf life extending of fresh strawberries after harvest and during cold storage at 4˚C and 90-95% relative humidity for 15 days, during two successive seasons of 2021 and 2022. The obtained results revealed that application of melatonin at 120 µM was notably effective in reducing decay and weight loss as well as giving a good general appearance (score) after 15 days at 4°C; on the contrary, untreated control had a poor general appearance after 9 days of storage, as well as maintaining taste index and total soluble solids. Moreover, maintaining acidity, the content of ascorbic acid, the total content of anthocyanin, and the total phenol content increased compared to the untreated control during storage at 4 °C for 15 days. Followed by salicylic acid (SA) at 4 mM. Whereas the remaining treatments were less effective in this concern in two seasons.

Keywords: strawberry fruits, melatonin, salicylic acid, postharvest life, quality, decay, firmness, total phenolic and total anthocyanin.

1. Introduction

Strawberry (*Fragaria* × *Ananassa* dutch) is one of the most important and popular vegetable crops in Egypt and the Arab world. It has an important place among vegetable crops due to its diverse use in local fresh consumption, food processing, and export. Strawberries are a valuable crop rich in bioactive compounds such as beta-carotene, phenolic compounds, and vitamins, especially vitamin C and E. It has great health benefits, as it lowers cholesterol and blood pressure, reduces inflammation, and reduces oxidative stress. Important characteristics of strawberry fruit are aroma, taste, and flavor (Giampieri *et al.,* 2012; Manganaris *et al.,* 2014).

The main storage problem is the rapid metabolic activity within the fruits, decomposition caused by fungi, and strawberry gray rot disease (Hernandez-Munoz *et al.,* 2006). Strawberries are also highly perishable due to their extreme softness, high level of respiration, and susceptibility to fungal spoilage (Almenar *et al.,* 2006).

Rapid deterioration of the quality of strawberry fruits after harvest occurs due to loss of water and loss of soft texture, so strawberries should be kept at a temperature of 0–4 °C after harvest to maintain fruit quality (Khreba *et al.,* 2014). Strawberries have a very short shelf life due to their high perishability and susceptibility to gray fungal attacks. Therefore, the quality of strawberry fruits deteriorates rapidly after harvest due to rapid metabolic activity. Therefore, proper storage is an effective way to maintain the quality of strawberries after harvest (Cordenunsi *et al.,* 2005). Therefore, there is a need for a treatment that maintains the quality and extends the shelf life of strawberry fruits after harvest.

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Salicylic acid is considered a signaling hormone in the cell. It provides resistance against oxidative stresses within the living cell, prevents the production of the hormone ethylene, and also delays the aging process in fruits during storage (Asghari and Aghdam, 2010). It also has the ability to delay the ripening process, maintain the quality of fruits, and control growth. Post-harvest diseases (Zhang *et al.,* 2010). It also extended the shelf life and maintained the quality characteristics of strawberries during 15 days of storage (Sana *et al.,* 2020). It is also used as an alternative to chemical fungicides to extend their shelf life and enhance the defense system. It increases the activities of antioxidant enzymes that improve resistance against fungal attack (Khademi and Ershadi, 2013; Xu and Tian, 2008). This acid also works to induce acquired systemic resistance at the site of pathogen attack and opposes the production of associated proteins that cause diseases in plants (Beckers and Spoel, 2006). The acid treatment also increased antioxidant compounds, ascorbic acid content, and TSS and prevented fungal infection in strawberries (Amborabe *et al.,* 2002).

Melatonin (N-acetyl-5-methoxytryptamine) is an indoleamine compound produced endogenously in all plant species (Reiter *et al.,* 2015). It is a healthy component found in the environmental diet, and many fruits and vegetables, including tomatoes, apples, cherries, bananas, and strawberries, provide natural melatonin from their cells (Sturtz *et al.,* 2011; Feng *et al.,* 2014). In an experiment, treatment with external melatonin was tested as an effective treatment after harvest to enhance ripeness and improve the quality of tomato fruits, and its results were effective (Sun *et al.,* 2015), reduced decomposition, and maintained the nutritional quality of strawberry fruit (Aghdam and Fard, 2017; Liu *et al.,* 2018; and El-Mogy *et al.,* 2019). Post-harvest application of exogenous melatonin reduced decay and weight loss while increasing total phenolic compounds, resulting in higher antioxidant content (Liu *et al.,* 2018). In addition, Liu *et al.* (2016) revealed that pre-harvest treatment (M) led to higher fruit weight, significantly increased the accumulation of sugars, and coincided with a higher accumulation of organic acids with a favorable flavor. Moreover, there is an increase in the accumulation of plant pigments that are also considered antioxidants, such as lycopene and ascorbic acid, which are beneficial to human health. Pang *et al.,* 2020, indicated that strawberries treated with melatonin showed a good quality appearance, represented by lower weight loss, higher firmness, higher phenols, anthocyanins, ascorbic acid accumulation, and a higher DPPH scavenging capacity.

The purpose of the present study was to evaluate the impact of pre-harvest treatments of melatonin and salicylic acid on decay, quality attributes, and the shelf life of strawberry fruits after harvest and during storage at 4˚C and 90-95% relative humidity for 15 days.

2. Materials and Methods

The experiment was carried out on strawberry plants (*Fragaria × ananassa*) of the cultivar "Sensation at a private farm in Bader Center, Behera Governorate, Egypt. To investigate the effect of pre-harvest melatonin and salicylic acid treatments on decay, maintaining quality, and extending the shelf life of fresh strawberry fruits during cold storage. The seedlings were planted on 15th and 18th September in the 2021 and 2022 seasons, respectively. The experimental unit area included three beds, 120 cm wide, 25 m length and 50 cm high. Each bed contains two dripper lines for irrigation and four rows of plants, and the distance between the plants is 25 cm. The treatments were randomized complete block design (RCBD) on beds, which included seven treatments and three replicates. Treatments were pre-harvest-sprayed on whole strawberry plants,

Salicylic acid solutions (SA) at concentrations of 2, 4, and 6 mM were prepared by dissolving powdered salicylic acid in hot water that was allowed to cool before applying to the strawberry plants. Melatonin (M) solutions at 80, 100,100,120 µM were prepared using distilled water and control (tap water). Applications were sprayed four times at different stages of strawberry plant development. full flowering, green fruits, the beginning of the pink stage, and two days before harvest. The spraying treatment was repeated twice, with a 7-day interval in each stage. The fruits were harvested in the 15th and 20th December 2021 and 2022 seasons, at the 75% red color stage, and transported immediately within 1.3 hours to the laboratory of the Department of Vegetable Handling and Postharvest Research Section, Horticultural Research Institute, Agriculture Research Center, Giza Governorate, Egypt. The fruits were selected for uniformity of size and being free from any visual defects for all field treatments of (M) 80, 100, 120 µM, (SA) 2, 4, and 6 mM and control, then packed in plastic punnets, and each packed was approximately 250 g, represented as an experimental unit (EU). Fifteen EU were prepared for each treatment. Samples were arranged in a complete randomized design. All treatments were placed

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inside carton boxes (40 × 30 × 12.5 cm) and stored at 4°C and 95% RH for 15 days. Samples of 3 replicates (EU) were randomly taken and examined at three-day intervals (0, 3, 6, 9, 12, and 15 days) for the following properties:

2.1. Physical Analysis:

2.1.1. Weight loss (%): Fruit weight loss was recorded before and during each storage period interval of 3 days by the following equation: weight loss % = initial weight of fruit – weight of fruit at sampling date / the initial weight of the fruit x 100.

2.1.2. General Appearance: It was determined according to the scale of the scoring system: 9: excellent, 7: good, 5: fair, 3: poor, and 1: unsalable, depending on morphological defects and pathological defects (Gorny *et al.,* 2002).

2.1.3. Decay (%) was determined the number of decayed fruits due to fungus or any microorganism infection was recorded periodically (every 3 days) and calculated as a percentage from the total number of fruits using the following equation, decay percentage (%) = (Number of decayed fruits/Total number of fruits) ×100.

2.1.4. Fruit firmness was recorded using a TA-1000 texture analyzer instrument using a penetrating cylinder of 1mm diameter. Firmness was expressed as pound per square inch (Lb/in^2).

2.1.5. Total soluble solids percentage (°Brix) was determined by using PR- 101 digital refractometer.

2.1.6. Taste index (TI) was calculated with the equation using the TSS and TA values: TI = (TSS value/20×TA value) + TA value (Pezzarossa *et al.,* 2014).

2.2. Chemical Composition:

2.2.1. Titratable acidity (TA) (%) was determined by titration of the juice of fruits against 0.1 N NaOH to pH 8.1 and expressed as a percent of citric acid by A.O.A.C. (2000).

2.2.2. Ascorbic acid content (mg/100g FW) was determined by the titration method using 2, 6, and phenol indophenols as described by A.O.A.C. (2000).

2.2.3. Anthocyanin content (mg/100g): It was determined by using HCl (1.5N) spectrophotometer as described by A.O.A.C. (2000).

2.2.4. The total phenolic content (mg GAE $100g^{-1}$) was determined according to Aaby *et al.* (2005).

2.3. Statistical Analysis

The experiment was factorial with 2 factors in a complete randomized design (CRD) with 3 replicates. The comparison between means was evaluated by Duncan's Multiple Range Test at the 5% level of significance. The statistical analysis was performed according to Snedecor and Cochran (1982).

3. Results and Discussion

3.1. Weight loss

As depicted in Table 1, there were significant differences between all treatments in the percentage of weight loss during cold storage. The weight loss of fresh strawberries increased with the prolongation of storage time. Similar results were reported by Sana *et al.* (2020); Omaima *et al.* (2021); El-Mogy *et al.* (2019); Liu *et al.* (2018) and Mahsa (2015). Weight loss that occurs during storage may be a result of respiration, moisture transfer, and some oxidation processes (Wills *et al.,* 1998). The high metabolic activity of the fruit occurs as a result of the depletion of moisture from the surface of the fruit during the high transpiration process that continues during complete cold storage (Cordenunsi *et al.,* 2005).

Fresh strawberries are highly susceptible to water loss due to their very thin skin structure (Hernandez-Munoz *et al.,* 2006). Furthermore, strawberries are highly perishable due to rapid water loss due to their thin skin, which leads to tissue shrinkage and weakening (Otoni *et al.,* 2017).

For pre-harvest treatments, the data showed significant differences between all treatments and the untreated control treatment during storage. Moreover, the maximum weight loss (9.50–9.65%) was observed in the control treatment, while the minimum (3.10–3%) was observed in the fruits treated with M 120 μM after 15 days of storage in both seasons, followed by fruits treated with SA 4 mm and 6 mm, with no significant differences between them. M 80 μM and SA 2 mM treatments were the least effective treatments in this regard. Our results were achieved in both seasons and were consistent with them (El-Mogy *et al.,* 2019; Shafiee *et al.,* 2010; Salari *et al.,* 2012 and Lolaei *et al.,* 2012) in strawberry fruits. Liu *et al.* (2018) noted that melatonin may play a major role in improving the skin strength properties of strawberries, which is necessary to reduce weight loss.

A similar result was obtained by Gao *et al.* (2016), who showed that weight loss was significantly reduced by melatonin treatment during storage. On the other hand, due to the superiority of salicylic acid in reducing weight loss, it acts as an electron donor and produces free radicals that inhibit normal respiration and can also reduce the rate of respiration and fruit loss by closing stomata (Zhang and Zhang 2003). In general, the interaction between pre-harvest treatments and storage periods had a significant effect on the percentage of weight loss in two seasons after 15 days of storage at 4º C. The lowest value of weight loss percentage was recorded in strawberry fruits treated with 120 μM, while the highest values were obtained from the untreated control.

Table 1: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on weight loss (%) of strawberry fruits during cold storage at 4°C in 2021 and 2022 seasons.

Treatments	Storage period (days)					
	3	6	9	12	15	Mean
			2021			
M 80 μM	0.95 pr	1.50 mq	2.50 jl	3.90 fh	5.30 ed	2.83C
M 100 μM	0.70 qr	1.30 nr	2.00 ko	3.60 gi	4.30 fg	2.38 D
M 120 μM	0.50 r	1.00 pr	1.80 lp	2.80 ik	3.10 hj	1.84 E
SA 2 mM	1.00 pr	2.60 jl	3.60 gi	3.80 fh	5.80 d	3.36 B
SA 4 mM	0.90 pr	2.30 jm	2.80 ik	3.80 fh	4.60 ef	2.88 C
SA 6 mM	1.05 or	2.10 kn	2.60 jl	3.60 gi	4.65 ef	2.80 C
Control	2.00 ko	4.00 fh	6.90 c	8.30 b	9.50 a	6.14 A
Mean	1.01 E	2.11 D	3.17 C	4.26 B	5.32 A	
			2022			
M 80 μM	0.99 mo	1.60 kn	2.7 ij	4.10 ef	5.60 d	3.00 C
M 100 μM	0.75 no	1.33 lo	2.13 il	3.80 eg	4.15 ef	2.43 D
M 120 μM	0.55 o	1.10 mo	1.83 jm	2.88 hi	3.00 gi	1.87 E
SA 2 mM	1.12 mo	2.66 ij	3.70 fh	3.85 eg	5.82 cd	3.43 B
SA 4 mM	0.93 mo	2.35 ik	3.00 gi	3.85 eg	4.63 e	2.95 C
SA 6 mM	0.99 mo	2.30 ik	2.51 ij	3.60 fg	4.60 e	2.80 C
Control	2.30 ik	4.00 ef	6.50 c	8.60 b	9.65 a	6.21 A
Mean	1.09 E	2.19 D	3.20 C	4.38 B	5.35A	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.2. General appearance (GA)

The data presented in Table 2 show that the GA of fresh strawberry fruits decreased with the prolongation of the storage period. These results were in agreement with those obtained by Wang *et al.* (2022); Suni, and Kaur (2019).

Fernández-León *et al.* (2013) pointed out that the decrease in overall appearance during cold storage is associated with loss of hardness and loss of weight, and this greatly affects the taste and nutritional value of the fruits after harvest (Liu *et al.,* 2018). It was reported that metabolic activities, such as transpiration, respiration, and other key factors, influence increased weight loss and decreased firmness with the extension of the strawberry fruit storage period. Regarding the effect of pre-harvest treatments, results showed that there were significant differences between all treatments and the untreated control in the general appearance of strawberry fruits stored at 4°C. M 120 µM treatment was most effective for maintaining general appearance (score) and gave the highest score during storage at 4°C for 15 days, followed by SA4 mM and M 100 µM with no significant differences between them. Whereas, M 80 µM, SA 2 mM, and SA 6 mM were less effective in this concern. While the lowest value of general appearance was recorded in untreated control in two seasons, these results were achieved in the two seasons and were in agreement with Liu *et al.* (2018); Babalar *et al.* (2007) and Promyou *et al.* (2023). SA treatment plays an important and effective role in controlled fruit fungal decay and decreased ethylene production, thus decreasing metabolic activity as respiration (Wills *et al.,* 1998). Also, Aghdam and Fard (2017) showed that exogenous melatonin treatments led to improved fruit quality and disease resistance in strawberry fruits during cold storage (Promyou *et al.,* 2023). reported that strawberry fruit dipping in M 100 µM was most effective in maintaining brightness and firmness, delaying the change in color, reducing weight loss, and reducing the decay of strawberry fruits. MT inhibited the ripening process and delayed the physicochemical changes during storage.

As for the interaction between pre-harvest treatments and storage periods, it was significant in both seasons. Results showed that fresh strawberry fruits treated with M 120 µM gave good GA after 15 days at 4°C; on the contrary, untreated control had poor GA after 9 days of cold storage in two seasons.

Table 2: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on general appearance (score) of strawberry fruits during cold storage at 4°C in 2021 and 2022.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
				2021			
M 80 µM	9.00 a	8.33 ab	7.00 cd	6.33 de	3.00 ij	2.33 jk	6.00 C
M 100 µM	9.00 a	9.00 a	8.33 ab	7.00 cd	5.67 ef	4.33 gh	7.22 B
M 120 µM	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	8.67 A
SA 2 mM	9.00 a	8.33 ab	7.67 bc	5.67 ef	4.33 gh	3.00 ij	6.33 C
SA 4 mM	9.00 a	9.00 a	9.00	7.67 bc	6.33 de	3.67 hi	7.44 B
SA 6 mM	9.00 a	8.33 ab	7.67 bc	5.00 fg	3.67 hi	3.00 ij	6.11C
Control	9.00 a	7.67 bc	5.00 fg	3.67 hi	1.67 kl	1.00 l	4.67 D
Means	9.00 A	8.52 A	7.67 B	6.33 C	4.71 D	3.57 E	
				2022			
M 80 µM	9.00 a	9.00 a	7.00 cd	6.33 de	2.33 j	2.33 j	6.00 C
M 100 µM	8.33 ab	9.00 a	8.33 ab	7.67 bc	5.67 ef	4.33gh	7.22 B
M 120 µM	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	8.67 A
SA 2 mM	9.00 a	8.33 ab	7.67 bc	5.67 ef	5.00 fg	3.00 ij	6.44 C
SA 4 mM	9.00 a	9.00 a	9.00 a	7.00 cd	6.33 de	3.67 hi	7.33 B
SA 6 mM	9.00 a	8.33 ab	7.67 bc	5.00 eg	3.67 hi	3.00 ij	6.11 C
Control	9.00 a	7.67 bc	5.00 eg	3.00 ij	1.00 k	1.00 k	4.44 D
Mean	8.90 A	8.62 A	7.67 B	6.24 C	4.62 D	3.57 E	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.3. Decay percentage

Data in Table 3 show that the decay percentage of strawberry fruits was significantly increased with the prolongation of the storage period in the two seasons. The decay percentage of strawberry fruits increased gradually during storage and reached its highest percentage at the end of the storage period. These results are consistent with those obtained by Sana *et al.* (2020) and Sunil and Kaur (2019).

Concerning the effect of pre-harvest treatments, there was no decay percentage on the surface of fruits after 6 days of storage in any of the treatments, while the strawberry fruit treated with M 120 µM showed greater resistance to decay% compared to the other treatments and control after 15 days of storage at 4°C, followed by M 100 µM and SA 4 mM treatments. M 120 µM showed minimum decay (2.67–2.83%), whereas untreated control showed maximum fungal decay (11.33–11.67%). These results were consistent with El-Mogy *et al.* (2019) and Sunil and Kaur (2019) on strawberry fruits in two seasons. Melatonin treatment could be due to its effects on reactive oxygen species, resulting in increased cell wall rigidity. Higher superoxide dismutase enzyme activity in parallel with lower ascorbate peroxidase and catalase enzyme activity in fruits was shown to result in H_2O_2 accumulation as a result of melatonin treatment of strawberry fruit (Aghdam and Fard 2017). The role of SA in controlling postharvest spoilage is likely due to its role in increasing hydrogen peroxide (H_2O_2) in plants, which acts as a signal molecule to activate plant resistance systems against pathogen attack (Asghari and Aghdam 2010). Salicylic acid reduced decay incidence during storage because it increased the activity of pathogenesis-related proteins (chitinase and β-1, 3-glucanase), which played a significant role in enhancing the defense mechanism in fruits against oxidative damage caused by ROS species (Hussain *et al.,* 2015). Postharvest application of SA also delays fruit softening, fruit ripening, and the senescence process due to inhibition of the ethylene process and is also beneficial for reducing the fungal decay of strawberries (Zhang *et al.,* 2010). This might be due to the fact that salicylic acid leads to plant defense systems against pathogens by rapidly increasing H_2O_2 (hydrogen peroxide) production in plants, which behaves as a signal molecule and thereby activates the plant's systemic resistance against pathogens (Cai and Zheng 1999).

Regarding the interaction between pre-harvest treatments and storage periods, there was a significant effect on decay% after 15 days of storage at 4°C. Fresh strawberry fruits treated with M 120 µM were most effective in reducing decay compared to the other treatments and controls in two seasons.

Table 3: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on decay (%) of strawberry fruits during cold storage at 4°C in 2021 and 2022 seasons.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
				2021			
M 80 µM	0.00 m	0.00 m	0.00 m	1.33 kl	4.00 gh	6.33 d	1.94 C
M 100 µM	0.00 m	0.00 m	0.00 m	0.67 lm	2.33 ij	4.67 fg	1.28 E
M 120 µM	0.00 m	0.00 m	0.00 m	0.00 m	1.83 jk	2.67 i	0.75 F
SA 2 mM	0.00 m	0.00 m	0.00 m	2.67 i	3.50 h	7.83 c	2.33 B
SA 4 mM	0.00 m	0.00 m	0.00 m	1.33 kl	2.33 ij	6.00 de	1.61 D
SA 6 mM	0.00 m	0.00 m	0.00 m	2.00 ik	5.00 f	7.67 c	2.44 B
Control	0.00 m	1.96 ik	5.33 ef	6.67 d	9.33 b	11.33 a	5.77 A
Means	0.00 F	0.28 E	0.76 D	2.10 C	4.05B	6.64 A	
				2022			
M 80 µM	0.00 m	0.00 m	0.00 m	1.17 l	4.17 gh	6.50 ef	1.97 C
M 100 µM	0.00 m	0.00 m	0.00 m	0.83 l	2.50 jk	4.83 g	1.36 E
M 120 µM	0.00 m	0.00 m	0.00 m	0.00 m	2.00 k	2.83 ij	0.81 F
SA 2 mM	0.00 m	0.00 m	0.00 m	2.50 jk	3.50 hi	7.83 c	2.31 B
SA 4 mM	0.00 m	0.00 m	0.00 m	1.17 l	2.83 ij	6.00 f	1.67 D
SA 6 mM	0.00 m	0.00 m	0.00 m	2.00 k	4.83 g	7.07 de	2.32 B
Control	0.00 m	1.99 k	6.00 f	7.67 cd	9.67 b	11.67 a	6.16 A
Mean	0.00 F	0.28 E	0.86 D	2.19 C	4.21 B	6.68 A	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.4. Firmness

Results presented in Table 4 indicated that there were significant differences between all treatments in the firmness of fresh strawberry during cold storage at 4°C for 15 days in two seasons. Strawberry fruit firmness was progressively declining with the prolongation of the storage period. Similar results were found by Liu *et al.* (2018); Sana *et al.* (2020) and Pang *et al.* (2020). The decrease in hardness may be due to the decomposition of the protopectin into smaller molecular parts that become more soluble in water, causing the fruit to soften (Wills *et al.,* 1998).

Regarding the effect of pre-harvest treatments, the results showed that there were significant differences between all treatments and the untreated control treatment during storage. M 120 µM treatment recorded the lowest reductions and maintained fruit firmness during entire storage at 4°C for 15 days compared to other treatments and controls. Followed by M 100 µM and SA 4 mM treatments in two seasons. Zhai *et al.* (2018) revealed that treatment with melatonin (100 µM) maintained pear hardness by reducing the expression of poly-galactronase and cellulase genes, which have a role in reducing fruit hardness. Salicylic acid reduces the activity of the main cell wall degrading enzymes (pectin methylesterase, cellulose, and polygalacturonase) and the activity of lipoxygenase enzymes, which maintains the firmness of the fruits (Asghari and Aghdam 2010).

Regarding the interaction between pre-harvest treatments and storage periods, it was significant after 15 days of storage at 4°C in two seasons. Strawberries treated with 120 µM. It was most effective in maintaining fruit firmness at the end of the storage period, while the lowest value for strawberry fruit firmness was obtained in the untreated (control) in both seasons.

Table 4: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) firmness (Lb/in^2) of strawberry fruits during cold storage at 4°C in 2021 and 2022 seasons.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
	2021						
M 80 µM	5.27 de	4.82 i	4.51 k	4.12 mn	3.61 rs	3.54 s	4.31D
M 100 µM	5.44 b	5.11 g	4.83 i	4.51 k	4.21 m	4.00 o	4.68 B
M 120 µM	5.71 a	5.63a	5.46 b	5.41 bc	5.17 fg	4.98 h	5.39 A
SA 2 mM	5.21 ef	4.51 k	4.00 o	3.70 qr	3.40 t	3.00 v	3.97 F
SA 4 mM	5.34 cd	5.00 h	4.70 j	4.31 l	3.81 p	3.71 q	4.48 C
SA 6 mM	5.31 d	4.70 j	4.20 m	3.91 o	3.71 q	3.41 t	4.21 E
Control	5.14 fg	4.10 n	3.55 s	3.17 u	2.45 w	1.52 x	3.32 G
Means	5.34 A	4.84 B	4.47 C	4.16 D	3.77 E	3.45 F	
	2022						
M 80 µM	5.29 ef	4.83 j	4.53 l	4.14 op	3.63 t	3.56 t	4.33 D
M 100 µM	5.46 bc	5.13 h	4.85 j	4.53 l	4.21 no	4.00 q	4.70 B
M 120 µM	5.73 a	5.65 a	5.47 b	5.43 bd	5.19 gh	4.99 i	5.41 A
SA 2 mM	5.23 fg	4.53 l	4.00 q	3.73 s	3.43 u	3.00 wx	3.99 F
SA 4 mM	5.37 ce	5.00 i	4.72 k	4.34 m	3.83 r	3.74 s	4.50 C
SA 6 mM	5.34 de	4.73 k	4.23 n	3.94 q	3.73 s	3.44 u	4.23 E
Control	5.15 gh	4.09 p	3.55t	3.16 v	2.44 x	1.52 y	3.32 G
Mean	5.37 A	4.85 B	4.48 C	4.18 D	3.78 E	3.46 F	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.5. Total soluble solids (T.S.S.)

Data in Table 5 show that the TSS% of fresh strawberry fruits decreased significantly continuously during the storage period at 4°C for 15 days in two seasons. These results were consistent with those obtained (Sunil and Kaur, 2019; Liu *et al.,* 2018; Lolaei *et al.,* 2012; Hussain *et al.,* 2015; Gao *et al.,* 2016).

The effect of pre-harvest treatments showed that there were significant differences between all treatments and the untreated control treatment in the percentage of total soluble solids in strawberry fruits during storage. Strawberry fruits treated with M 120 µM retained more TSS% and reduced loss during storage at 4°C for 15 days, followed by SA 4 and SA 6 mM with no significant difference between them. While the lowest value of fresh strawberry fruits (TSS%) was obtained from the untreated control, these results were consistent with those obtained by Gao *et al.* (2016), who indicated that MA melatonin treatments led to an inhibited respiration rate, therefore maintaining and reducing loss in total soluble solids content during storage. El-Mogy *et al.* (2019) found that strawberry fruits treated with 100 μM melatonin had a higher TSS than the control after 4 and 8 days of storage. SA application reduces the activity of invertase enzymes and reduces the increase in TSS contents of banana fruit during storage (Srivastava and Dwivedi, 2000). Low TSS% after storage may be due to the fermentation of sugars into ethyl alcohol, carbon dioxide, and water (Hussain *et al.,* 2015).

In general, the interaction between pre-harvest treatments and storage periods showed that the 120 μM M treatment was the most effective in reducing TSS% compared to the other treatments or the untreated control after 15 days of storage at 4°C in two seasons.

Table 5: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on total soluble solids (°Brix) of strawberry fruits during cold storage at 4°C in 2021 and 2022 seasons.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
				2021			
M 80 μM	11.40 d	10.90 f	10.30 lm	9.70 o	8.66 r	7.43 u	9.73 D
M 100 μM	11.80 b	11.40 d	10.90 f	10.50 ik	10.26 lm	9.70 o	10.76 B
M 120 μM	12.10 a	11.86 b	11.63 c	11.43 d	11.13 e	10.46 jk	11.44 A
SA 2 mM	11.16 e	10.60 hj	10.00 n	9.40 pq	8.50 s	7.20 v	9.48 E
SA 4 mM	11.50 cd	11.16 e	10.63 hi	10.36 kl	10.00 n	9.50 o	10.53 C
SA 6 mM	11.60 c	11.10 e	10.50 ik	10.20 m	10.80 fg	9.30 q	10.58 C
Control	10.70 gh	9.50 o	8.30 s	7.00 w	6.00 x	5.00 y	7.75 F
Means	11.47A	10.93 B	10.32 C	9.80 D	9.34 E	8.37 F	
				2022			
M 80 μM	11.50 fg	10.96 k	10.40 op	10.16 q	9.33 t	7.96 v	10.05 D
M 100 μM	11.90 cd	11.63 ef	11.12 ij	10.56 mn	10.46 no	10.00 q	10.95 B
M 120 μM	12.30 a	12.12 b	11.70 e	11.50 fg	11.20 ij	10.50 no	11.55 A
SA 2 mM	11.33 hi	10.80 l	10.30 pq	9.70 s	9.16 u	7.70 x	9.83 E
SA 4 mM	11.93 c	11.50 fg	10.83 kl	10.43 np	10.36 op	9.40 s	10.74 C
SA 6 mM	11.77 de	11.40 gh	10.70 lm	10.30 pq	10.20 q	9.80 s	10.70 C
Control	10.83 kl	9.80 s	8.40 u	7.40 y	6.00 z	5.10 a	7.93 F
Mean	11.67 A	11.17 B	10.49 C	10.01 D	9.53 E	8.64 F	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.6. Taste index %

Data in Table 6 indicated that the taste index (%) of fresh strawberry fruits decreased significantly continuously with the storage period at 4°C for 15 days in two seasons. Similar results were obtained by Sunil and Kaur (2019) and Salari *et al.* (2012) in strawberry fruits.

The results of the effect of pre-harvest treatments showed that there were significant differences between all treatments and the untreated control treatment in the taste index (%) of strawberry fruits during storage. Strawberry fruits treated with M 120 μM were most effective in maintaining the taste index (%) during storage at 4°C for 15 days, followed by SA 4 mM, and the lowest value of that taste index (%) was from the untreated control in two seasons. These findings were in agreement with Prasanna *et al.* (2007). showed that fresh strawberry fruits treated with MA were significantly higher than untreated controls; the higher taste index might be due to a general increase in total sugars and organic acids.

The interaction between the pre-harvest treatments and storage periods showed that. M 120 μM treatment was the most effective in maintaining taste index % compared with the other treatments and untreated control after 15 days of storage at 4°C in two seasons.

Table 6: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on taste index % of strawberry fruits during cold storage at 4°C in 2021 and 2022.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
				2021			
M 80 µM	1.49 ce	1.33 gi	1.15 lm	0.91o	0.72 p	0.53 q	1.02 D
M 100 µM	1.58 bc	1.46 df	1.37 gi	1.17 kl	0.94 o	0.78 p	1.22 C
M 120 µM	1.77 a	1.61 b	1.51 cd	1.42 dg	1.35 gi	1.33 hi	1.50 A
SA 2 mM	1.32 ij	1.24 jk	1.08 mn	0.92 o	0.76 p	0.58 q	0.98 E
SA 4 mM	1.57 bc	1.42 eh	1.36 gi	1.19 kl	1.15 km	1.04 n	1.29 B
SA 6 mM	1.42 dg	1.38 fi	1.30 ij	1.18 kl	1.12 ln	0.91 o	1.22 C
Control	1.32 ij	1.05 n	0.88 o	0.70 p	0.50 q	0.38 r	0.81 F
Means	1.50 A	1.36 B	1.23 C	1.07 D	0.94 E	0.79 F	
				2022			
M 80 µM	1.51 bd	1.36 gh	1.19 kn	0.93 qr	0.74 st	0.55 u	1.05 D
M 100 µM	1.60 b	1.50 be	1.34 hi	1.19 kn	0.97 pq	0.77 st	1.23 C
M 120 µM	1.81 a	1.57 bc	1.48 bf	1.40 dh	1.36 gh	1.31 hj	1.49 A
SA 2 mM	1.39 eh	1.29 hk	1.11 mo	0.95 qr	0.83 rs	0.56 u	1.02 D
SA 4 mM	1.60 b	1.46 cg	1.32 hj	1.22 jm	1.15 ln	1.07 np	1.30 B
SA 6 mM	1.49 be	1.37 fh	1.29 hk	1.19 km	1.10 mo	0.94 qr	1.23 C
Control	1.23 il	1.03 oq	0.93 qr	0.70 t	0.52 u	0.32 v	0.79 E
Mean	1.52 A	1.37 B	1.24 C	1.08 D	0.95 E	0.79 F	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.7. Titratable acidity TA (%)

Results presented in Table 7 showed that the titratable acidity% of fresh strawberries decreased significantly and continuously throughout the storage period at 4 degrees Celsius for 15 days in both seasons. These findings were in line with those of Liu *et al.* (2018), Sunil and Kaur (2019) and Wang *et al.* (2022).

The results of the effect of pre-harvest treatments showed that there were significant differences between all treatments and the untreated control treatment in the titratable acidity percentage of strawberry fruits during storage. Strawberry fruits treated with M 120 µM were most effective in reducing titratable acidity % loss during storage at 4°C for 15 days, followed by SA 4 mM, and the lowest value of titratable acidity (%) was obtained from untreated control in two seasons. These findings were in agreement with Liu *et al.,* (2018), who indicated that melatonin treatments could delay ripening by reducing respiration and ethylene production and senescence during storage at 4 °C. It was shown that delayed fruit softening and color change caused changes in TSS and TA content. Promyou *et al.,* (2023) reported that MT maintained titratable levels and slowed the increase of TSS% in stored strawberries. Bal (2019) reported that melatonin treatments on plum fruits reduced the SSC values and raised the titratable values, which slowed down the senescence of the fruits. The sugar/acid ratio is calculated as an important indicator of fruit flavor and the extent of consumer acceptance and appreciation (Sana *et al.,* 2020). A decreasing trend was observed with respect to the sugar acid content of strawberries during storage due to the conversion of acids into sugars, but the response of SA (5 mM) was very effective in retaining the acid content of strawberries (Sana *et al.,* 2020).

The interaction between pre-harvest treatments and storage periods was effective on the results, and the M 120 µM treatment was the most effective in maintaining a reduction in titratable acidity loss % compared to the other treatments or the untreated control after 15 days of storage at 4°C in two seasons.

Table 7: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on titratable acidity (%) of strawberry fruits during cold storage at 4°C in 2021 and 2022.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
				2021			
M 80 µM	0.95 cd	0.86 fh	0.76 il	0.61 n	0.50 o	0.39 p	0.68 D
M 100 µM	0.99 bc	0.93 de	0.89 eg	0.77 ik	0.62 n	0.53 o	0.79 C
M 120 µM	1.10 a	1.01 b	0.95 cd	0.91 d-f	0.87 fg	0.87fg	0.95 A
SA 2 mM	0.85 gh	0.81 hi	0.72 km	0.63 n	0.53 o	0.42 p	0.66 D
SA 4 mM	1.00 bc	0.91 df	0.89 eg	0.79 i	0.77 ik	0.71 m	0.84 B
SA 6 mM	0.90 dg	0.89 eg	0.85 gh	0.78 ij	0.73 jm	0.62 n	0.80 C
Control	0.86 fg	0.71 lm	0.62 n	0.52 o	0.39 p	0.31 q	0.57 E
Means	0.95 A	0.88 B	0.81 C	0.71 D	0.63 E	0.55 F	
				2022			
M 80 µM	0.96 bc	0.88 dg	0.78 ij	0.62 no	0.51 p	0.39 q	0.69 D
M 100 µM	1.00 b	0.95 bd	0.86 fh	0.78 jk	0.64 no	0.51 p	0.79 C
M 120 µM	1.12 a	0.98 b	0.93 bf	0.89 cg	0.87 eh	0.86 fh	0.94 A
SA 2 mM	0.89 cg	0.84 gj	0.73 kl	0.64 no	0.57 op	0.40 q	0.68 D
SA 4 mM	1.00 b	0.93 bf	0.85 gi	0.80 hk	0.76 kl	0.73 kl	0.84 B
SA 6 mM	0.94 be	0.87 eg	0.84 gj	0.78 ik	0.73 km	0.63 no	0.55 E
Control	0.80 hk	0.69 ln	0.65 mn	0.51 p	0.40 q	0.25 r	
Mean	0.96A	0.88 B	0.81 C	0.72 D	0.64 E	0.54 F	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.8. Ascorbic acid content:

Data presented in Table 8 revealed that ascorbic acid content decreased significantly during storage at 4°C for 15 days in two seasons. Similar results were reported by Liu *et al.,* (2016), Gao *et al.,* (2016), and Sana *et al.,* (2020) on strawberry fruits. Wills *et al.* (1998) reported a reduction in ascorbic acid contents during storage because of sugar loss through respiration.

Regarding the effect of pre-harvest treatments, the results of our research showed that there were significant differences between all treatments and the untreated control treatment in ascorbic acid content during storage. Strawberry fruits treated with M 120 µM retained more ascorbic acid content, reducing loss during storage at 4°C for 15 days, followed by SA 4 mM in two seasons. Whereas, the lowest value of fresh strawberry fruits ascorbic acid content was obtained from untreated control. These results were achieved during two study seasons (Rodríguez *et al.,* 1999). Who reported that the melatonin treatments (MT) lead to delay the development of senescence and enhanced the retention of quality characteristics such as ascorbic acid content of peach fruit. Wang *et al.* (2006) reported that SA activates ascorbate peroxidase enzyme, which increases antioxidant ability and ascorbic acid amount in fruits. Lolaei *et al.* (2012) indicated that (SA) treatment leads increase ascorbic acid content and then decrease antioxidant in strawberry fruits. Also, Hung *et al.* (2007) showed that SA treatments leads to acceleration of biosynthetic pathways or reduction in catabolism through accumulation of dehydroascorbate, thus causing higher ascorbic content in fruits.

The interaction between pre-harvest treatments and storage periods was significant during the two seasons of the study after 15 days of storage at 4°C. Strawberries treated with 120 µM were most effective in maintaining and reducing the loss of ascorbic acid content during storage. Whereas the lowest value for strawberry fruit ascorbic acid content was obtained in the untreated (control) in two seasons.

Table 8: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on ascorbic acid content (mg/100g FW) of strawberry fruits during cold storage at 4°C in 2021 and 2022.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
				2021			
M 80 µM	93.98 fg	93.17 i	92.40 kl	91.50 n	90.93 o	89.83 q	91.97 E
M 100 µM	95.10 d	94.63 e	94.10 f	93.50 h	92.87 j	91.03 o	93.54 C
M 120 µM	96.54 a	96.23b	96.00 b	95.63 c	95.00 d	94.10 f	95.58 A
SA 2 mM	93.17 i	92.56 k	92.03 m	91.33 n	90.50 p	89.43 r	91.51 F
SA 4 mM	95.57 c	95.20 d	94.57 e	93.93 fg	93.07 ij	92.03 m	94.06 B
SA 6 mM	94.04 f	93.70 gh	93.03 ij	92.40 kl	91.03 o	90.03 q	92.37 D
Control	92.24 lm	91.53 n	90.07 q	89.00 s	87.83 t	84.60 u	89.21 G
Means	94.38 A	93.86 B	93.17 C	92.47 D	91.60 E	90.15 F	
				2022			
M 80 µM	94.31 fi	93.20 jn	92.37 nr	91.43 rt	90.90 tu	89.73 vw	91.99 E
M 100 µM	95.43 be	94.67 dh	94.07 hj	93.43 im	92.90 lp	90.94 tu	93.57 C
M 120 µM	96.87 a	96.27 ab	95.97 ac	95.57 bd	95.10 cg	94.27 gi	95.67 A
SA 2 mM	93.50 im	92.60 mq	92.00 ps	91.30 su	90.47 uv	89.37 w	91.54 F
SA 4 mM	95.90 bc	95.23 cf	94.53 eh	93.90 hk	93.00 ko	92.13 os	94.12 B
SA 6 mM	94.37 fi	93.73 hl	92.97 ko	92.33 nr	90.97 tu	89.90 vw	92.38 D
Control	91.91 qs	91.20 su	89.73 vw	87.63 x	86.37 y	84.10 z	88.49 G
Mean	94.61 A	93.84 B	93.09 C	92.23 D	91.39 E	90.06 F	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.9. Total Anthocyanin Content

Data in Table 9 showed that the total anthocyanin content of fresh strawberry fruits increased significantly continuously within the first 9 days of storage and then began to decrease during storage periods at 4°C for 15 days in two seasons. These findings were in agreement with Omaima *et al.* (2021), El-Mogy *et al.* (2019) and Aghdam and Fard (2017).

The effect of pre-harvest treatments showed an effect on the results, and there were significant differences between all treatments and the untreated control treatment in the total anthocyanin content of strawberry fruits stored at a temperature of 4 degrees Celsius. Application of M 120 µM was most effective in maintaining total anthocyanin content and reducing loss during storage at 4°C for 15 days, followed by SA4 mM in strawberry fruits in both seasons. Whereas, the strawberry fruit untreated control recorded the lowest value of total anthocyanin content. These results were achieved in the two seasons and were in agreement. Zhang *et al.* (2016) reported that strawberry fruits treated with melatonin showed higher activity of the PAL enzyme, and there was an accumulation of phenols as well as anthocyanins, which have an essential role for the nutritional quality of fruits and vegetables. Hadian-Deljou *et al.* (2017) reported that the pre-harvest SA treatments exhibited an increasing tendency toward anthocyanin content in apple fruits stored, due to the role of SA in activating the main enzyme in the biosynthetic pathway of anthocyanin. Sayyari *et al.* (2009) who reported that SA treatments increase the synthesis of plant hormones, enzymes, and photosynthesis and thus accumulate pigments such as the total carotenoids and anthocyanin content, The interaction between pre-harvest treatments and storage periods showed this. The M 120 µM treatment was most effective in increasing and maintaining total anthocyanin content compared to the other treatments and the untreated control after 15 days of storage at 4°C in both seasons.

Table 9: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on total Anthocyanin content (mg/100g) of strawberry fruits during cold storage at 4°C in 2021 and 2022.

Treatments	Storage period (days)						Mean
	0	3	6	9	12	15	
	2021						
M 80 µM	78.98 w	79.22 u	79.39 s	81.36 i	79.98 m	79.72 p	79.78 D
M 100 µM	79.14 t	79.58 r	79.92 o	83.36 f	81.15 j	80.25 k	80.57 C
M 120 µM	81.34 i	83.31 g	84.16 d	97.62 a	88.34 b	85.93 c	86.79 A
SA 2 mM	78.85 y	78.96 w	79.14 v	79.98 m	79.55 r	79.35 t	79.31 F
SA 4 mM	79.24 u	79.65 q	79.96 mn	83.58 e	81.64 h	80.44 k	80.75 B
SA 6 mM	78.95 w	79.16 v	79.33 t	81.12 j	79.94 no	79.69 p	79.70 E
Control	76.92 c	77.82 b	78.03 y	78.90 u	78.51 x	76.23 z	77.74 G
Means	79.06 F	79.67 E	79.99 D	83.70 A	81.30 B	80.23 C	
	2022						
M 80 µM	77.97 t	78.21 rs	78.38 p	80.35 i	78.97 m	78.77 n	78.78 D
M 100 µM	78.14 s	78.56 o	78.92 m	88.35 b	80.14 j	79.25 l	80.56 B
M 120 µM	80.34 i	82.24 g	83.16 e	96.37 a	87.34 c	84.94 d	85.73 A
SA 2 mM	77.83 u	77.96 tu	78.14 s	78.97 m	78.57 o	78.35 pq	78.31 F
SA 4 mM	78.24 qs	78.65 no	78.97 m	82.57 f	80.64 h	79.44 k	79.75 C
SA 6 mM	77.94 tu	78.17 s	78.33pr	80.13 j	78.94 m	78.69 no	78.70 E
Control	75.92 wx	75.81 x	76.03 w	77.87 tu	76.51 v	75.20 y	76.22 G
Mean	78.06 F	78.51 E	78.85 D	83.52 A	80.16 B	79.23 C	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

3.10. Total phenolic content:

Results presented in Table 10 showed that the total phenolic content of fresh strawberries increased significantly and continuously during the first nine days of storage and then began to decrease at a temperature of 4 degrees Celsius for 15 days in both seasons. Two results were consistent with Sirvan *et al.* (2023); El-Mogy *et al.* (2019); Liu *et al.* (2018) and Geransayeh *et al.* (2015).

The effect of pre-harvest treatments showed good results, and significant differences were found between all treatments and the untreated control treatment in the total phenolic content of strawberry fruits during storage. Strawberry fruits treated with M 120 µM were most effective in increasing total phenol content and reducing loss during storage at 4°C for 15 days, followed by SA 4 and SA 6 mM with no significant difference between them. Untreated strawberry fruits recorded the lowest value for total phenol content. These results were achieved in both seasons and were in agreement with Sun *et al.* (2015) who also reported that melatonin treatment up-regulates the expression of enzyme genes that regulate the phenylpropanoid pathway, such as PAL, which contributes to the accumulation of total phenols within the cell. Aghdam and Fard (2017) revealed in their research that the increase in the total contents within strawberry fruits is caused by an increase in the activity of the enzyme phenylalanine ammonia lyase (PAL) caused by melatonin treatment, which in turn leads to the accumulation of total phenols within the cells. This was confirmed by Sharafi *et al.* (2019) who indicated that melatonin treatments led to increased activity of PAL enzymes, which increased the accumulation of phenolics and increased ATP and carbon skeleton in tomato fruits. Moreover, Asghari and Aghdam (2010) showed that the retention of total phenol content is due to salicylic acid treatments, in which high concentrations of SA enhance the efficiency of antioxidant systems in plants. Champa *et al.* (2015) indicated that pre-harvest treated with SA may increase the rate of phenylpropanoid metabolism, leading to the formation and accumulation of total phenolics and stimulation of enzymes involved in phenylpropanoid metabolism, such as PAL.

Regarding the interaction between the pre-harvest treatments and storage periods, the results revealed that M 120 µM treatment was the most effective in increasing and maintaining total phenolic content compared with the other treatments and untreated control after 15 days of storage periods at 4°C in two seasons.

Table 10: Effect of pre- harvest treatments of melatonin (M) and salicylic acid (SA) on total phenolic content (mg GAE $100g^{-1}$) of strawberry fruits during cold storage at 4°C in 2021 and 2022.

Treatments	Storage period (days)						
	0	3	6	9	12	15	Mean
	2021						
M 80 µM	151.00 qs	160.00 mq	166.67 jn	171.67 hk	161.67 lp	153.33 ps	160.72 D
M 100 µM	153.00 ps	170.00 il	181.67 dg	180.00 eh	170.00 il	153.33 ps	168.00 C
M 120 µM	154.00 ps	177.00 fi	200.00 b	210.00 a	190.00 cd	186.67 de	186.28 A
SA 2 mM	149.00 rs	155.00 os	175.00 gj	180.00 eh	158.33 nr	146.67 s	160.67 D
SA 4 mM	150.00 rs	170.00 il	185.00 df	199.00 bc	183.00 dg	168.77 im	175.96 B
SA 6 mM	152.00 qs	171.00 hl	184.50 dg	196.50 bc	182.00 dg	163.67 ko	174.94 B
Control	148.33 s	150.00 rs	170.00 il	180.00 eh	120.00 t	100.00 u	144.72 E
Means	151.05 D	164.71 C	180.40 B	188.17 A	166.43 D	153.20 C	
	2022						
M 80 µM	151.33 oq	159.67 lo	167.33 jl	173.00 hj	162.00 kn	157.33 mq	161.78 D
M 100 µM	152.33 oq	170.33 ik	182.33 dh	180.67 eh	171.00 ik	153.67 nq	168.39 C
M 120 µM	154.33 mq	176.00 fj	199.33 b	212.67 a	191.00 bd	187.00 ce	186.72 A
SA 2 mM	150.33 oq	156.00 mq	175.00 gj	180.67 eh	158.67 lp	148.00 q	161.44 D
SA 4 mM	150.00 pq	169.67 ik	184.00 dg	199.33 b	183.33 dg	169.67 ik	176.00 B
SA 6 mM	152.33 oq	170.00 ik	185.00 df	196.33 bc	183.33 dg	163.33 km	175.06 B
Control	148.67 q	150.67 oq	170.67 ik	179.00 ei	122.00 r	96.67 s	144.61 E
Mean	151.33 D	164.62 C	180.52 B	188.81 A	167.33 C	153.67 D	

Values with the same letters are not significantly different at P≤ 0.05 level; Tukey's multiple range test.
M: Melatonin, **SA:** Salicylic acid

4. Conclusion

From the previous results, it could be concluded that melatonin treatments at 120 µM were notably effective in reducing decay and weight loss, as well as giving a good general appearance and maintaining taste index and total soluble solids. Moreover, maintaining titratable acidity, ascorbic acid content, and total anthocyanin content increased the total phenol content during storage at 4˚C for 15 days.

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