

Chitosan-based melatonin coating effects on apricot postharvest life

E. Bal

Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Horticulture, Tekirdağ, Turkey

*Corresponding author e-mail: ebal@nku.edu.tr

ABSTRACT

Apricot (*Prunus armeniaca* L.) is a climacteric and perishable fruit prone to rapid postharvest deterioration due to microbial decay, moisture loss, and chilling injury. This study investigated the combined effects of chitosan (CT) and melatonin (MLT) coatings on the postharvest quality of apricot fruits (cv. Roxana) stored at 0-1 °C for 28 days. Treatments included control, melatonin (1000 $\mu\text{mol l}^{-1}$), 1% chitosan, and a combined CT+MLT coating. Weight loss, soluble solids content (TSS), titratable acidity (TA), fruit firmness, respiration rate, total phenolic content, antioxidant content, decay rate and internal browning index were measured at 7-day intervals. CT+MLT-treated fruits showed superior retention of firmness, slower increase in TSS, reduced TA loss, and delayed respiration peaks. Furthermore, CT+MLT coating significantly preserved total phenolic content and antioxidants, which declined in control fruits over time. Importantly, CT+MLT and MLT alone effectively inhibited internal browning and decay throughout the storage period, with no incidence observed until the end of storage. These findings suggest that chitosan coating enriched with melatonin provides a synergistic effect in preserving apricot fruit quality during cold storage, by delaying senescence, maintaining bioactive compounds, and minimizing postharvest losses.

Keywords: *Prunus armeniaca* L., postharvest quality, Chitosan coating, Melatonin, storage life, bioactive compounds

INTRODUCTION

Apricot (*Prunus armeniaca* L.) is a nutritious fruit that is known for its health benefits and is highly demanded by consumers due to its high content of bioactive phytochemicals such as carotenoids, flavonoids, phenolics and antioxidants (Dragovic-Uzelac *et al.*, 2007). Apricot is a climacteric fruit that ripens quickly, is highly perishable and has a limited postharvest life. Depending on apricot cultivar, it can be stored at 0°C for 2-4 weeks after harvest (Crisosto and Kader, 1999). Postharvest losses of apricots due to rapid ripening, microbial decay, and chilling injury due to long-term storage at low temperatures pose significant economic challenges. In order to extend the storage and marketing period of apricot fruits, it is of great importance to delay and slow down these changes.

Edible coating applications have the potential to improve fruit quality and extend the shelf life of products because they provide selective barriers to oxygen, carbon dioxide and flavor compounds (Pham *et al.*, 2023). In addition, edible coatings can serve as carriers of various active ingredients such as natural or chemical antimicrobial agents, antioxidants, flavors, enzymes, functional ingredients, or nutrients (Dhall 2013).

Chitosan (CT) is a naturally abundant biopolymer that plays a key role in edible coating applications. CT coatings with semi-permeable properties can change the internal atmosphere by reducing water loss, showing antimicrobial activity and delaying fruit ripening. The semi-permeable CT film is durable, flexible and does not tear easily and forms a very good oxygen barrier, providing significant advantages to chitosan compared to other polymers (Shahidi *et al.*, 1999). It has been reported in many studies that postharvest CT coating has a significant effect on improving the sensory properties of fruits and preserving their quality (Romanazzi and Moumni, 2022; Saberi Riseh *et al.*, 2023). Melatonin (MLT) is a signaling molecule that plays a role in many plant growth and development processes (Khan *et al.*, 2024). In addition, treatment with exogenous melatonin at an appropriate dose can significantly regulate changes in postharvest respiration, ethylene release, antioxidant enzyme activity and other related physiological parameters of fruits, delay aging and extend shelf life (Saud *et al.* 2023). Studies have shown that postharvest melatonin application can delay the weight loss in sweet cherries (Wang *et al.*, 2019), control the softness of apricot (Medina-Santamarina *et al.*, 2021; Zhang *et al.*, 2024), increase the disease resistance of peach (Gao *et al.* 2016), inhibit ripening in pears (Zhai *et al.*, 2018), alleviate the chilling damage of nectarine and peach (Bal 2020) and promote the accumulation of total phenolics and ascorbic acid, resulting in higher antioxidant capacity (Bal 2019; Luo *et al.*, 2022). At present, no information is available regarding the effect of chitosan coating and melatonin on the postharvest quality of apricots. Thus, the study aimed to investigate the effects of combining chitosan with melatonin on decay, physiological properties and quality attributes of apricots (*Prunus armeniaca* cv. 'Roxana') stored at 0-1°C during storage periods.

MATERIALS AND METHODS

Apricot cv. 'Roxana' fruits were harvested at the firm maturation stage by hand-plucking, from a well-managed demonstration orchard in Turkey. Fruits were immediately taken to the laboratory and selected as homogeneous in size and color, free from visible defects. After that, fruits were randomly distributed into 4 equal parts for postharvest treatments, and then treated as follows: (1) Control: Fruits were immersed in distilled water. (2) MLT treatment: 1000 $\mu\text{mol l}^{-1}$ melatonin was dissolved in ethanol (10 ml) and then added deionized water up to the required volume. (3) CT coating: Chitosan solution was prepared by dissolving 1% (w/v) chitosan in 0.5 % (w/v) acetic acid solution (0.5 % v/v) at 45 C. Glycerol (1 %) and Tween 20 (0.1 %) were added to the solution as surfactant, respectively. After stirring, the fruits were soaked in 1% (w/v) chitosan coating solution for 5 min. (4) CT+MLT coating: Fruits were immersed in a mixed solution containing 1% chitosan and 1000 $\mu\text{mol l}^{-1}$ melatonin. All fruits were air-dried after the treatments and were packed in porous clamshell punnets and stored under 0-1°C at $90 \pm 5\%$ RH for 28 days.

Physical and biochemical analyses were performed on fruit samples removed from cold storage at the beginning of storage and at 7-day intervals. Weight loss of apricot fruits was recorded using an electronic weighing scale at periodic intervals of 7 days during cold storage. TSS and TA were determined using the juice extraction of plum fruit. TSS was measured using the handheld refractometer and TA was measured in terms of malic acid by the titration method (AOAC 2016). Fruit firmness was measured as the penetration force into the fruit flesh (expressed as Newtons (N)), and a penetrometer with a 7.9 mm probe was used to test the firmness. The respiration rate was analyzed with a CO₂ gas analyzer. For 1 hour, 500 g of fruits were enclosed in tightly sealed hermetic flasks. The sensor was used to measure CO₂ concentration, which was then used to determine the respiration rate. The amount of total phenolic substance was determined by the spectrophotometric method using Folin-Ciocalteu reagent, according to Singleton *et al.* (1999). The antioxidant

activity of the samples was analyzed by using the DPPH assay according to the procedures of Brand-Williams *et al.* (1995). The total number of rotten fruits was measured as a percentage compared to the number of fruits placed at the beginning. Fruits were visually analyzed for signs of internal browning (IB), using the following scale: 0, no browning; 1, very light browning; 2, light browning; 3, moderate browning; 4, severe browning. The experimental design was completely randomized. Groups of three replicates of 500 g of fruit per treatment for the cold storage were established. The data were analysed using *SPSS (Version 11.0)* and are reflected as the means with their standard error.

RESULTS AND DISCUSSIONS

After harvest, fruits continue to lose water through their skin, which can lead to shrinkage and weight loss, affecting the fruit's appearance and texture (Lufu *et al.*, 2020). The results showed a significant increase in the percentage of fruit weight loss during the storage in all treatments (Figure 1). Coating apricot fruits with chitosan alone or in combination was highly effective in providing a physical barrier against moisture loss; therefore, a reduced weight loss was observed in chitosan-coated fruit effective in providing a physical barrier against moisture loss. The addition of melatonin to the chitosan-based coating did not significantly alter the moisture barrier functions. At the end of the storage period, weight loss was 15.7% in control fruits and 10.2% in MLT application, while weight loss was 5.0% in CT+MLT coated fruits and 5.7% in CT coated fruits, respectively. These findings were in line with researches of Algarni *et al.* (2022) and Morsy *et al.* (2019) which showed that weight loss in chitosan-coated fruit was lower than in non-coated apricot fruit. Moreover, MLT and CT may affect the weight loss through their synergistic effect in reducing respiration and water loss from the fruit surface.

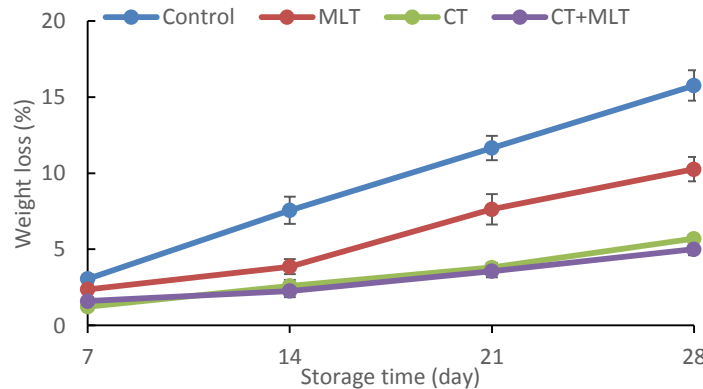


Figure 1. Effects of postharvest Melatonin and Chitosan treatments on weight loss of apricots

According to TSS (%) levels in apricots increased as fruit ripened over the postharvest period (Figure 2a). However, CT and CT+MLT coating significantly delayed the increase in TSS compared to controls, especially between days 21 and 28 postharvest. While the initial TSS value in all apricot samples was 9.8%, the TSS content in control fruits at 28 days of storage was 13%, which was higher than the CT+MLT coating group. This result is consistent with the findings that the retention of TSS content in coated apricots reflected the change in the internal environment of the fruits by coating application, which could eventually reduce the internal O_2 of the fruit and/or suppress ethylene production by increasing CO_2 (Morsy and Rayan, 2019; Riva *et al.*, 2020). TA was 1.65% at initial storage and the faster decrease in acidity led to faster senescence (Figure 2b). The lowest decrease in TA was observed at the same level of significance at the end of storage in fruits coated with CT (1.34%) and CT+MLT (1.36%). Conversely, lower TA levels were found in control

fruits compared to treated fruits (1.21%), suggesting that edible coatings form a semipermeable film around the fruit, thereby delaying the ripening process. An overall decrease in organic acids might be expected due to the consumption of organic acids as metabolic substrates during respiration (Fonseca et al., 2002). However, the rate of TA loss was found to be reduced by the incorporation of MLT into the CH coating, probably by slowing down metabolic activities as reported in banana (Al-qurashi et al., 2023) and pomegranate (Mwelase et al., 2022).

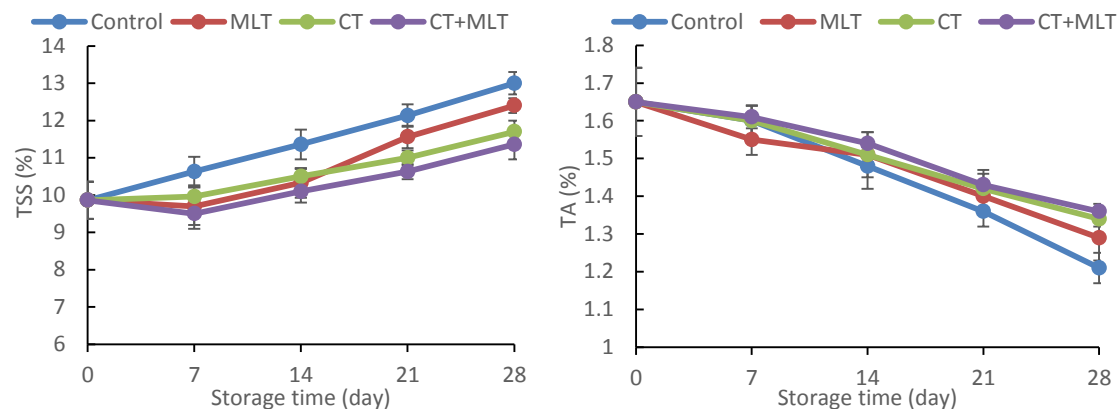


Figure 2. Effects of postharvest Melatonin and Chitosan treatments on TSS (a-left) and TA (b-right) of apricots

Apricot firmness decreased from 42.6 to 12.4 N as the postharvest ripening time increased from 0 to 28 days (Figure 3). The pattern of change in firmness in all fruits during postharvest storage was qualitatively similar, but firmness was significantly higher in MLT and CT-coated fruits compared to control fruits during 28 days of storage. Previous study on apricot fruit has shown that degradation of cell wall components leads to decreased fruit firmness as storage time increases (Morsy and Rayan, 2019). At the end of cold storage, samples with CT and CT+MLT treatments represented smaller firmness loss of apricot (19.2 and 20.3 N, respectively) compared with MLT (14 N) and control (12.4 N). Previous research also reported that ML reduced fruit softening and preserved apricot quality during storage by suppressing cell-wall degrading enzyme activity (Medina-Santamarina *et al.*, 2021; Zhang *et al.*, 2024) and also apricot coated with CTS resulted in maintenance of higher fruit firmness and soluble solids content (Han *et al.*, 2024).

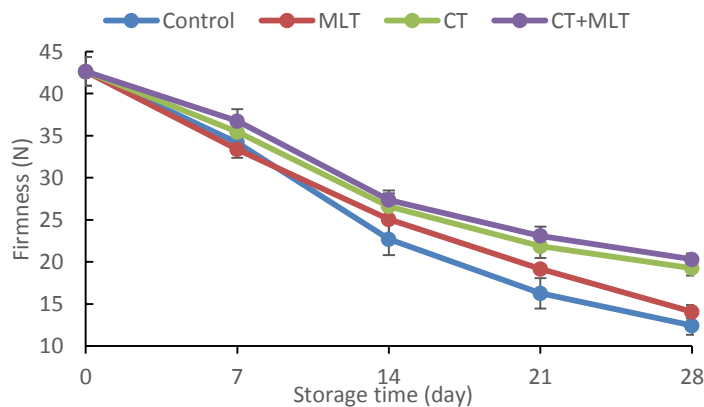


Figure 3. Effects of postharvest Melatonin and Chitosan treatments on firmness of apricots

During storage, an increase and then a decrease in respiration rates were observed in groups (Figure 4). Compared with the control and MLT treated fruits, the respiratory peaks of CT and CT+MLT treated fruits were markedly suppressed throughout the storage period. Chitosan-based coatings slowed down the respiration rate of fruits because it formed a thin layer on the surface of the fruit by acting as a physical barrier that regulates gas and atmospheric exchange (Shahidi *et al.*, 1999). The findings revealed that while CO₂ production in control and MLT applied fruits reached the highest values of 27.6 and 26.3 mg kg⁻¹ h⁻¹ on the 14th day, it reached the highest values of 20.4 and 19.03 mg kg⁻¹ h⁻¹ on the 21st day in CT and CT+MLT treatments. These results indicate that CT and CT+MLT treatments are more effective than the other two treatments in inhibition of respiration rates during storage, which are in agreement with the previous reports suggesting the beneficial effects of chitosan and chitosan coating combined with melatonin treatments in reducing respiration rates in sweet cherry (Ba,l 2024) and broccoli (Tan *et al.*, 2023).

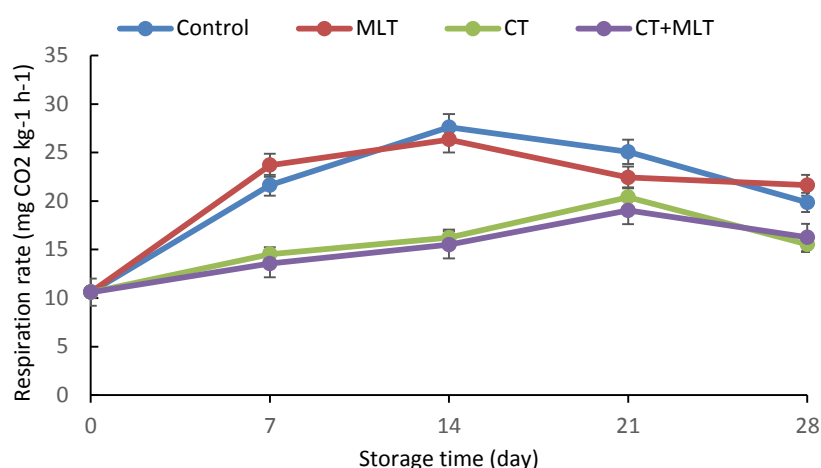


Figure 4. Effects of postharvest Melatonin and Chitosan treatments on respiration rate of apricots

According to the results, phenolic compounds in all treatments showed an increasing trend at the beginning of treatment and then decreased with storage time (Figure 5). However, CT and MLT treatments alone or in combination significantly reduced the phenol loss of apricot fruit compared with controls. After 28 days of storage, the phenolic content of MLT, CT, and CT+MLT treated apricot fruits was 111.3 mg 100 g⁻¹, 115.3 mg 100 g⁻¹, and 122.6 mg 100 g⁻¹, respectively, which were obviously lower than control samples (96.6 mg 100 g⁻¹).

The effectiveness of chitosan coated fruits combined with melatonin can be attributed to its potential to delay oxygen permeation on the fruit surface and reduce the enzymatic oxidation of phenols by melatonin treatment. The inhibitory effect of chitosan coating on polyphenoloxidase (PPO) activity was consistent with previous studies on sweet cherry (Pasquariello *et al.*, 2015) and plum (Iqbal *et al.*, 2025). Some literature also reported that melatonin treatments remarkably enhanced the phenolic content of plum (Bal 2019) and inhibited the rise of PPO activity of sweet cherry (Michailidis *et al.*, 2021).

In the study, antioxidant content of apricots exhibited trends similar to phenolics with a typical peak value (Figure 6). The antioxidant content-of the fruits gradually increased up to 7 and 14 days and then decreased, but were found to be higher in treated fruits than in control. This result is consistent with Wang *et al.* (2019), who reported that CT coating reduces the decline in antioxidant contents and melatonin, as an antioxidant or signaling molecule, has been reported to regulate the activity of the antioxidant system and mitigate cellular damage.

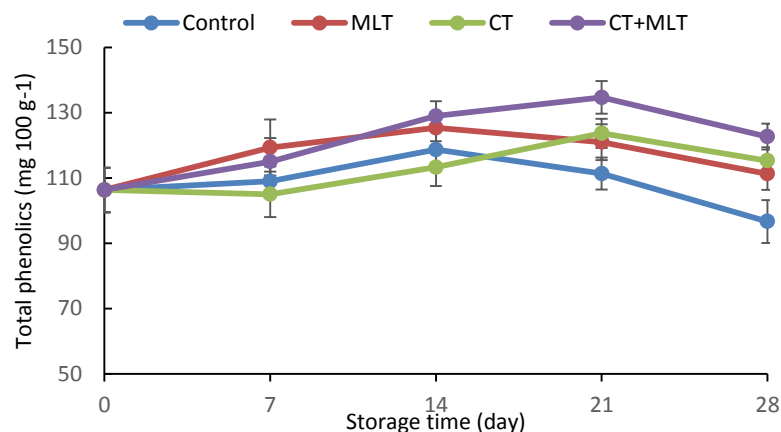


Figure 5. Effects of postharvest Melatonin and Chitosan treatments on total phenolics of apricots

At the end of storage, the CT and MLT combination ($29.06 \mu\text{mol g}^{-1}$) exhibited the highest antioxidant compared to each of them alone, and only CT+MLT treated fruits were found to be higher than the initial value ($27.96 \mu\text{mol g}^{-1}$). Due to the capability of CTS to carry functional substances (Lin *et al.*, 2008), adding melatonin into CTS-based coating showed a synergistic effect on improving non-enzymatic antioxidant defense systems and proved the relationship between MLT and CT described by Arshad and Haghshenas (2025) and Bal (2024).

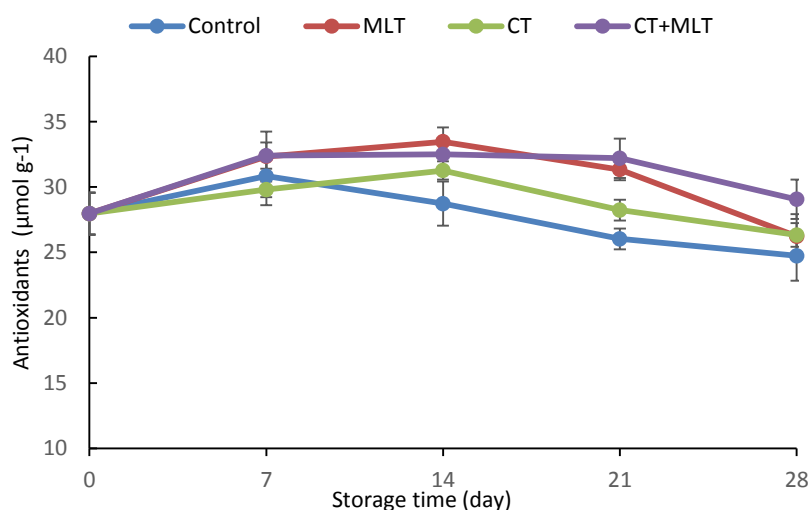


Figure 6. Effects of postharvest Melatonin and Chitosan treatments on antioxidants of apricots

In present research, apricot seldom showed rotting. The results showed that decay was first observed in the control fruits after 21 days of storage, and then, at the end of the storage period, low levels of mold were detected only in the control (5.3%) and CT-treated fruits (2%), (Figure 7a). This trend was also observed in the internal browning analysis results (Figure 7b). IB symptoms as very light browning was first detected after 21 days of storage in control and CT treatment, while in CT + MLT and MLT treatments was no observed during 28 days of storage.

These results were consistent with the observation by Demartino *et al.* (2002) that apricots could develop some physiological problems, including juiceless flesh and internal browning after 2-3 weeks of storage at $1-4^{\circ}\text{C}$.

The results of recent studies showed that the exogenous melatonin and chitosan coating treatments could reduce decays and physiological disorders of postharvest fruit during cold storage (Gao *et al.*, 2016; Bal 2021; Romanazzi and Moumni, 2022; Saberi Riseh *et al.*, 2023). It has also reported that melatonin triggers signaling molecules that play a role in disease resistance (Hao *et al.*, 2025) and chitosan has potential as an edible antifungal coating material (Dai *et al.*, 2025).

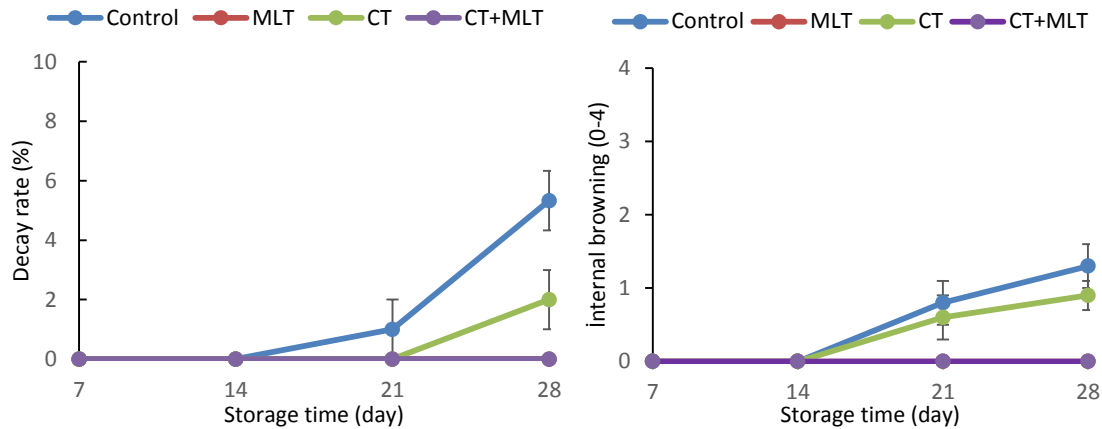


Figure 7. Effects of postharvest Melatonin and Chitosan treatments on decay rate (a) and internal browning (b) of apricots

CONCLUSIONS

This study demonstrated that the application of chitosan-based coatings, particularly when enriched with melatonin, significantly preserved the postharvest quality of apricot fruits (cv. Roxana) during cold storage at 0-1 °C for 28 days. The combined CT+MLT treatment was the most effective in reducing weight loss, maintaining fruit firmness, delaying increases in TSS, and reducing the loss of TA (%). Additionally, this treatment notably suppressed respiration rate and minimized decay and internal browning, indicating its ability to delay senescence and physiological disorders. These findings suggest that chitosan coatings incorporated with melatonin represent a promising, natural, and safe postharvest strategy to extend shelf life, reduce storage losses, and maintain the nutritional and sensory quality of apricots.

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