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Impact of postharvest LED light treatments on strawberry quality during cold storage

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Abstract

Strawberries are highly perishable, demanding effective postharvest quality strategies. This study examined initial postharvest LED light treatments on 'Elsanta' strawberry quality during 7 days of cold storage at 5±1 □C. Fruits received monochromatic LED illumination (blue, red, far-red at 80 µmol m−2s−1; UV-A at 30µmol m−2s−1) either continuously for 48 hours or intermittently (12 h/day) for two days. Dark-stored fruits served as controls. LED illumination significantly impacted quality. Intermittent blue and far-red light positively affected SSC/TA and dry matter. Continuous illumination with all LED types increased total anthocyanin content by approximately 20%. Blue and red LEDs, especially with continuous irradiation, enhanced key ester compounds, improving strawberry aroma. These results suggest targeted LED treatments can effectively enhance strawberry quality and market value.

1. Introduction

Strawberries (Fragaria × ananassa) are globally popular fruits valued for their flavor, aroma, and nutritional profile. However, their high perishability poses significant challenges for postharvest quality retention. Current postharvest methods have limitations; for instance, harvesting immature fruit for extended shelf life often compromises sensory attributes. While low-temperature storage slows metabolism, maintaining optimal conditions can be difficult, and temperatures below 0 □C risk chilling injury. Modified atmosphere packaging (MAP) and controlled atmosphere (CA) storage can delay senescence but may lead to off-flavors or uneven ripening. Unlike climacteric fruits, strawberries respond minimally to ethylene inhibitors, further limiting management options. Given these challenges, novel postharvest approaches are needed, with LED technology gaining attention for its ability to extend fresh produce shelf life and enhance quality. LEDs offer energy efficiency and spectral precision, allowing for the modulation of key physiological and metabolic processes postharvest. Previous research indicates that LED lighting can positively influence fruit quality by enhancing sugar accumulation and increasing the biosynthesis of phenolic compounds like anthocyanins, which improve color and antioxidant capacity (Xu et al., 2014a; Xu et al., 2014b; Lu et al., 2025; Zhang et al., 2018). The aim of this study was to investigate whether short (24 h or 48 h) initial postharvest treatments with red, blue, far-red, or UV-A LED light could improve 'Elsanta' strawberry quality during subsequent 7-day storage at a suboptimal temperature (5 □C). This approach sought to determine if an early, brief light treatment could trigger lasting beneficial effects on fruit quality during subsequent dark storage, offering a potentially practical and energy-efficient strategy for the supply chain.

2. Material and Methods

2.1 Plant material and treatment setup

Strawberry (Fragaria × ananassa cv 'Elsanta') fruits were harvested at commercial maturity (over 80% red surface) and immediately transferred to an experimental climate chamber. Fruits were sorted for uniform size and maturity using a DA Meter, selecting those with an IAD index between 1.75 and 2.05. Each fruit was marked with a numbered tag for tracking during non-destructive measurements. Strawberries (30 fruit per tray) were placed calyx-down in white plastic trays within separate light-proof compartments. The climate chamber was maintained at 5±1 □C and 80-85% relative humidity (RH), simulating suboptimal commercial storage conditions. Eight LED lighting treatments were applied only during the initial storage period: red (peak 660 nm), blue (peak 465 nm), far-red (peak 730 nm), and UV-A (peak 350 nm). Each spectrum was applied at two durations: 24 hours total (12h day 1 + 12h day 2) or 48 hours continuous, followed by darkness for the remainder of the 7-day experiment. A dark-stored group served as control. Photosynthetic Photon Flux Density (PPFD) was set at 80 μmol m−2s−1 for red, blue, far-red, and 30μmol m−2s−1 for UV-A, measured at the fruit surface. Dimmable LED lamps were used, and spectral distribution was measured with a spectrophotometer. Non-destructive and destructive measurements were taken at 0, 4, and 7 days.

2.2 Quality parameter assessments

Fruit weight loss was calculated using a specific equation. Surface color was determined with a colorimeter through the CIE Lab color space analysis. Firmness was assessed using a texture analyzer with a 3 mm cylindrical probe. Soluble solids content (SSC, °Brix) was measured using a digital refractometer after juicing individual strawberries. Titratable acidity (TA, g L^{-1} citric acid equivalent) was determined by automatic titration of juice to a pH 8.1 endpoint. The SSC/TA ratio was then calculated. Dry weight (%) was determined after drying strawberries at 65 °C for 72 hours. Total anthocyanin content was analyzed by HPLC-DAD, quantified at 520 nm using an external calibration curve, and expressed as mg kg^{-1} Fresh Weight (FW). Volatile organic compounds (VOCs) were analyzed by PTR-ToF-MS on frozen powdered strawberry samples (Farneti et al 2021).

3. Results

3.1 Effect of lighting treatments on fruit ripening, color, weight loss, and firmness

Strawberry fruits continued ripening during storage, indicated by a decline in the chlorophyll-related IAD index, primarily within the first four days. LED treatments did not cause statistically significant differences in IAD compared to the dark control. Colorimetric analysis revealed subtle, continuous changes, with lightness (L*) and redness (a*) gradually decreasing over 7 days, though without statistically significant differences. Fruits under 48-hour LED exposure tended to maintain higher L* values after 7 days, especially for red and UV-A treatments, which also showed a tendency towards higher a* values. Postharvest LED treatments significantly influenced fruit weight loss compared to the dark control. Across all wavelengths, 48-hour exposure resulted in significantly greater weight loss than 24-hour exposure after 4 and 7 days. Blue, red, and far-red treatments generally induced higher weight loss, particularly at 48-hour duration, while UV-A exposure caused weight loss comparable to the control. Despite increased weight loss, fruit firmness remained statistically unaffected, and no statistically significant correlation was found between weight loss and firmness changes.

3.2 Effect of lighting treatments on fruit biochemical changes

Control fruits showed a gradual decline in dry matter (DM). Fruits treated with blue and red LEDs for 48 hours maintained significantly higher DM percentages. Soluble solid content (SSC) increased throughout storage in all treatments. UV-A and red light treatments resulted in SSC levels comparable to the control. However, 24-hour far-red light exposure led to significantly higher SSC after 7 days. Blue light treatments yielded distinct, duration-dependent results: 48-hour exposure resulted in lower SSC than controls, whereas 24-hour exposure significantly enhanced SSC accumulation. These SSC variations did not correlate with fresh weight loss patterns. Titratable acidity (TA) showed a modest increasing trend during storage. All four LED wavelength treatments significantly enhanced total anthocyanin content compared to the control at both 4 and 7 days. The effect was most pronounced under 48-hour exposure, resulting in approximately 20% higher anthocyanin levels than controls after 7 days. Notably, these significant increases in anthocyanin content did not correlate with the measured colorimetric parameters (L*, a* and b* values).

3.3 Effect of Lighting Treatments on VOC Profile

PTR-ToF-MS analysis detected 109 mass peaks significantly different from blank controls. Principal Component

Analysis (PCA) revealed that LED treatments, particularly blue and red light, induced more pronounced shifts in aroma profiles compared to the dark control. When LED treatments resulted in statistically different VOC concentrations from the control, the effect was consistently an increase in the VOC concentration. The most notable impact was the significant enhancement of numerous esters, which are crucial for strawberry flavor, under blue and red light, particularly with 48-hour exposure. Blue and red light treatments were generally the most effective in promoting higher VOC concentrations, and the 48-hour exposure duration often yielded the highest concentrations at both 4 and 7 days.

4. Discussion

The observed increase in fruit weight loss under blue, red, and far-red light, especially with 48-hour exposure, suggests heightened metabolic activity stimulated by the light signals. This is supported by the enhanced synthesis of anthocyanins and VOCs in these treatments, indicating an elevated respiration rate that contributes to greater water loss as a physiological trade-off for the biosynthesis of quality-related compounds. The lack of significant effect on firmness, despite the weight loss, suggests independent regulation of water status and tissue integrity. The complex, duration-dependent response of soluble solids content (SSC) to blue light highlights a nuanced interplay between signalling duration, intensity, and the fruit's physiological state under suboptimal temperature. The significant enhancement of total anthocyanin content by all LED wavelengths, especially with 48-hour exposure, demonstrates light's role as a potent elicitor of secondary metabolism postharvest. The lack of corresponding change in instrumental color measurements despite the increase in anthocyanins can be attributed to complex interactions within the fruit tissue, such as pH and co-pigmentation effects. The positive remodelling of the aroma profile, particularly the significant enhancement of esters under blue and red light, indicates that early light signals trigger pathways that boost ester production during subsequent storage. This likely involves the upregulation of alcohol acyltransferases (AATs) and increased availability of precursor compounds.

5. Conclusions

This study unequivocally demonstrates that short, initial postharvest LED light treatments, particularly with blue and red spectra, can significantly enhance key quality attributes of 'Elsanta' strawberries during cold storage at 5 □C. While firmness remained unaffected, these treatments markedly boosted total anthocyanin content and, crucially, increased the concentration of vital aroma-active volatile organic compounds, especially esters. These lasting benefits, despite an increase in fresh weight loss, suggest an "early signal" mechanism where the initial light exposure primes the fruit's metabolic pathways for improved quality retention. This innovative approach offers a promising, non-chemical strategy to reconcile shelf-life extension with quality development, potentially allowing for earlier harvesting practices while still delivering fruit with enhanced organoleptic and nutritional value to consumers. This concept holds significant promise for strawberries and other perishable non-climacteric fruits facing similar postharvest challenges

References

- Farneti, B., Khomenko, I., Pietrella, M., Martinatti, P., Emanuelli, F., Aprea, E., Maltoni, M.L., Baruzzi, G., Biasioli, F., Giongo, L. (2021). Development of a new phenotypic roadmap to improve strawberry aroma based on direct injection mass spectrometry. Acta Hortic. 1309. ISHS 2021. Proc. IX International Strawberry Symposium.
- Lu, W., Li, W., Zhao, K., Bai, X., Zhang, Y., Li, Q., Xue, Z., Wang, X. X. (2025). Blue light irradiation combined with low-temperature storage further enhances postharvest quality of strawberries through improving antioxidant defense and cell wall metabolic activities. Food Chemistry: X, 25, 102115.
- Xu, F., Shi, L., Chen, W., Cao, S., Su, X., & Yang, Z. (2014a). Effect of blue light treatment on fruit quality, antioxidant enzymes and radical-scavenging activity in strawberry fruit. Scientia Horticulturae, 175, 181-186.
- Xu, F., Cao, S., Shi, L., Chen, W., Su, X., & Yang, Z. (2014b). Blue light irradiation affects anthocyanin content and enzyme activities involved in postharvest strawberry fruit. Journal of Agricultural and Food Chemistry, 62(20), 4778-4783.
- Zhang, Y.; Hu, W.; Peng, X.; Sun, B.; Wang, X.; Tang, H. (2018). Characterization of anthocyanin and proanthocyanidin biosynthesis in two strawberry genotypes during fruit development in response to different light qualities. J. Photochem. Photobiol. B, 186, 225–231.