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Postharvest Quality Changes and Management Strategies for Differently Colored Cherry Tomatoes

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Abstract Cherry tomatoes exhibit diverse fruit colors, and different color types vary markedly in pigment composition, sugar–acid balance, nutritional components, and flavor characteristics, which in turn influence postharvest changes in weight loss, softening, fruit color, and functional compounds. This review focuses on red, yellow/orange, mature-green, and brown/black/purple-black cherry tomatoes, summarizing their basic quality traits and postharvest changes, and analyzing the effects of harvest maturity, maturity assessment, temperature, packaging, and transport distance on marketable quality. Major preservation technologies, including precooling and cold-chain management, LED light regulation, and natural edible coatings, are also reviewed. On this basis, differentiated management strategies are proposed. Red types should be managed primarily to prevent over-ripening and softening; yellow/orange types require greater attention to maintaining characteristic color and flavor; mature-green types need independent maturity assessment standards; and dark-colored types require simultaneous protection of distinctive pigmentation, texture, and functional quality. For mixed-color marketing, compatibility in shelf life among cultivars should also be considered. Future research should establish color-specific maturity evaluation systems, develop low-cost and easy-to-operate postharvest technologies, and strengthen integrated assessments of flavor, nutrition, marketability, cost, and consumer acceptance under real supply-chain conditions. These efforts will provide practical support for precise postharvest management and commercial utilization of differently colored cherry tomatoes.

Keywords Cherry tomato; Fruit color; Postharvest quality; Maturity; Preservation technology; Differentiated management; Supply chain

1 Introduction

Cherry tomatoes are a high-value group of small-fruited tomatoes in the fresh-market sector. Their eating quality is determined not only by fruit appearance and size, but also by sweetness, acidity, aroma, texture, and nutritional composition. Compared with conventional large-fruited fresh-market tomatoes, cherry tomatoes generally contain higher levels of glucose, fructose, total soluble solids, dry matter, and glutamate, and consumers are particularly sensitive to traits such as sweetness, acidity, juiciness, and fruit color (Casals et al., 2019). Tomato is a typical climacteric fruit and continues to undergo respiration, ethylene production, softening, water loss, and color changes after harvest. It is also susceptible to mechanical injury and microbial infection. Therefore, the length of time for which marketable quality can be maintained after harvest directly affects the fresh-market sales window and the level of losses during distribution (Ilahy et al., 2019; Damas-Job et al., 2023).

As breeding objectives and market demand for fresh-market tomatoes have gradually shifted from an emphasis on yield and storability toward flavor, nutrition, and differentiated appearance, the commercial fruit colors of cherry tomatoes have expanded from traditional red to yellow, orange, mature green, brown-black, purple-black, striped, and other types. Differences in fruit color are not merely external visual traits, but result from differences in pigment synthesis, degradation, and accumulation. Ripening of traditional red-fruited tomatoes is generally accompanied by chlorophyll degradation and substantial lycopene accumulation, whereas yellow, orange, mature-green, and dark-colored materials may possess different compositions of carotenoids, chlorophylls, flavonoids, and anthocyanins. Red, green, and yellow cherry tomatoes already exhibit distinct transcriptomic and metabolic characteristics at maturity, with differences in color and taste involving carotenoid, phenylpropanoid,

flavonoid, and other related metabolic pathways (Li et al., 2022). Differences in carotenoid composition between red- and orange-fruited tomatoes are also closely associated with changes in the expression of genes involved in carotenoid biosynthesis and regulation (Hu et al., 2024). Fruit color can therefore serve as an intuitive phenotypic indicator for distinguishing quality types of cherry tomato, but it actually reflects more complex differences in pigment, sugar–acid, nutritional, and flavor metabolism.

These quality differences established by the time of harvest may further influence the trajectories of fruit quality during subsequent storage and transportation. Comparative studies of small-fruited tomatoes with different fruit colors have shown that, even under the same packaging conditions and storage at 10 °C, red 'Angelle', orange 'Santy Naranja', and dark red-green striped 'Melange' exhibit different storage responses in terms of weight loss, firmness, color, ascorbic acid, phenolics, and carotenoids (Cannata et al., 2024). Meanwhile, temperature, humidity, and light conditions continue to regulate fruit ripening and pigment metabolism after harvest. Fluctuations in temperature and relative humidity along actual cold chains can cumulatively accelerate weight loss, softening, and overall quality deterioration in cherry tomatoes (Garrido-López et al., 2026). Elevated temperatures can alter postharvest carotenoid metabolism, with 40 ℃ markedly suppressing lycopene biosynthesis (Chen et al., 2026). Red and blue light can regulate postharvest coloration by affecting chlorophyll degradation, carotenoid accumulation, and hormonal balance, with red light showing a stronger promotive effect on color development (Xu et al., 2024). Consequently, postharvest management of differently colored cherry tomatoes should not focus solely on extending shelf life in a uniform manner, but should also consider whether their characteristic color, flavor, nutritional value, and texture can be maintained simultaneously during storage and distribution.

Accordingly, this review provides a comprehensive analysis of postharvest quality changes and management strategies in differently colored cherry tomatoes. It first compares the basic quality differences in sugar–acid balance, pigments, nutritional composition, and flavor among red, yellow/orange, mature-green, brown-black, and purple-black types, and then systematically summarizes postharvest changes in weight loss, softening, color, sugars and acids, antioxidant-related compounds, pigments, and volatile flavor compounds. The effects of harvest maturity, maturity assessment, temperature, packaging, and transport conditions on quality retention and suitable marketing distance are further analyzed, together with the application characteristics of major preservation approaches, including precooling and cold-chain management, LED treatment, and natural edible coatings. On this basis, differentiated postharvest management strategies are proposed according to the principal quality targets of different fruit-color types and the practical conditions of family farms and other agricultural operators. Future research needs are also discussed, including the establishment of color-specific maturity standards, development of low-cost postharvest technologies, and validation under real supply-chain conditions. The aim is to provide a practical reference for precise management of differently colored cherry tomatoes from harvest grading and storage packaging to market distribution.

2 Basic Quality Differences among Differently Colored Cherry Tomatoes

2.1 Red types

The most typical quality characteristic of red cherry tomatoes is the relatively high accumulation of lycopene in mature fruits, which contributes to their stable red appearance and pronounced carotenoid-related nutritional characteristics. Joung et al. (2025) compared 12 colored cherry tomato cultivars grown in Korea and found that red-fruited materials such as 'DOTORI RED TY' and 'KT RED TY' contained relatively high levels of lycopene. However, clear differences among red cultivars were still observed in total phenolics, total flavonoids, ascorbic acid, and other quality attributes. These findings indicate that red fruit color is a useful indicator of lycopene enrichment, but it does not mean that all red-fruited cultivars have the same overall nutritional quality.

Differences in sugar–acid balance, aroma, and texture within red-fruited types should also not be overlooked. Dong et al. (2024) compared five cherry tomato cultivars and found that, even when all fruits were evaluated at a uniform red-ripe stage, significant differences remained in firmness, total soluble solids (TSS), acidity, amino acids, and metabolite composition. Some cultivars contained higher levels of vitamin C or amino acids, whereas some red-fruited cultivars accumulated relatively high amounts of eugenol and α-tomatine, which were associated

with undesirable flavor characteristics. Red cherry tomatoes can therefore be broadly characterized by a clear lycopene advantage, while their sugar–acid balance, aroma, and overall nutritional quality remain strongly cultivar-dependent.

2.2 Yellow and orange types

The most obvious difference between yellow/orange and red cherry tomatoes lies in carotenoid composition, with some orange-fruited materials being characterized primarily by β-carotene accumulation. Stommel et al. (2005) directly compared two high-β-carotene orange cherry tomato lines with two lycopene-rich red cherry tomato lines and found that the orange materials had higher sugar and soluble-solids contents, whereas titratable acidity was not necessarily lower; some individual volatile compounds were also present at higher levels. Therefore, the stronger perceived sweetness of yellow/orange fruits cannot simply be attributed to "lower acidity," but may result from higher sugar levels combined with a different sugar–acid balance.

Some yellow-fruited materials show a more pronounced "high-sugar, low-acid" profile. Guo et al. (2025) compared closely related yellow No. 19 and red No. 20 tomato lines and found that the yellow material had higher soluble sugar and TSS contents at both the breaker and mature stages, while total acidity was markedly lower. At maturity, lycopene content in the red material was significantly higher than that in the yellow material. Although this study was not specifically conducted on cherry tomatoes, it demonstrates that fruit coloration and sugar–acid metabolism can be jointly influenced by genetic background. Yellow and orange types are therefore better characterized as having diverse pigment compositions, with some materials showing higher sugar levels, higher sugar–acid ratios, or β-carotene enrichment, while substantial variation remains among cultivars.

2.3 Green types

Mature-green cherry tomatoes must be clearly distinguished from the immature green stage of conventional red-fruited tomatoes. The former are stable fruit-color types that retain a green appearance even after reaching commercial or eating maturity, and their coloration is generally associated with chlorophyll retention and a specific genetic background related to fruit-color formation. Mature-green fruits are therefore not simply "red fruits that have not yet ripened," but rather represent a distinct commercial type with their own color, flavor, and nutritional characteristics.

Baek et al. (2024) compared five cherry tomato cultivars representing different fruit colors: green 'Jocheong', yellow 'BN Satnolang', orange 'Gold Chance', black 'Black Q', and red 'Snacktom'. Green 'Jocheong' showed relatively high levels of chlorophyll, vitamin C, γ-aminobutyric acid (GABA), glutamate, essential amino acids, and total free amino acids, while its firmness and sugar–acid profile also differed from those of the other color types. In contrast, the red material was mainly characterized by lycopene enrichment, whereas the black material showed relatively high levels of several pigment classes and flavonoids. Thus, mature-green cherry tomatoes are distinguished more by chlorophyll retention and, in some cultivars, advantages in amino-acid composition and antioxidant-related nutrients than by lycopene accumulation.

2.4 Brown, black, and purple-black types

Brown, black, and purple-black cherry tomatoes should not be regarded as a single uniform pigment type. Their dark appearance may result from different combinations of anthocyanins, chlorophylls, carotenoids, and underlying fruit color, and therefore their internal compositions can vary markedly among cultivars. Hernández-Vega et al. (2025) compared three black cherry tomato cultivars, 'Indigo Rose', 'Indigo Cherry Drops', and 'Kumato', and found that 'Kumato' had relatively high levels of total phenolics, total flavonoids, and β-carotene, whereas 'Indigo Rose' contained substantially more anthocyanins. This demonstrates that a dark fruit appearance does not necessarily mean that anthocyanins are the dominant pigments in all dark-colored materials.

Some purple-fruited materials may also accumulate relatively high levels of carotenoids. Campestrini et al. (2019) reported that the peel of a purple tomato contained approximately sixfold more lutein, 1.5-fold more lycopene, and 2.5-fold more β-carotene than the Red Cherry control. Li et al. (2025a), in a comparison of 30 tomato accessions with different fruit colors, further showed that anthocyanin-rich purple cultivars often exhibited strong

overall antioxidant capacity, although lycopene and other pigments also made important contributions. Dark-colored types can therefore be characterized by complex pigment composition and relatively high phenolic and antioxidant potential, but they also show particularly strong cultivar-to-cultivar heterogeneity. Their nutritional composition cannot be reliably inferred from external fruit color alone.

Overall, differently colored cherry tomatoes have distinct quality foundations in terms of pigment composition, sugar–acid balance, flavor-related compounds, and antioxidant-related nutrients. These intrinsic differences may further influence postharvest processes such as weight loss, softening, color transition, sugar-acid metabolism, antioxidant retention, and pigment remodeling. It should be emphasized that fruit color serves only as an intuitive phenotypic indicator for distinguishing quality types, whereas actual postharvest behavior is jointly affected by cultivar, harvest maturity, and storage environment. The relationships among intrinsic quality traits, major postharvest responses, and final commercial quality in differently colored cherry tomatoes are summarized in Figure 1.

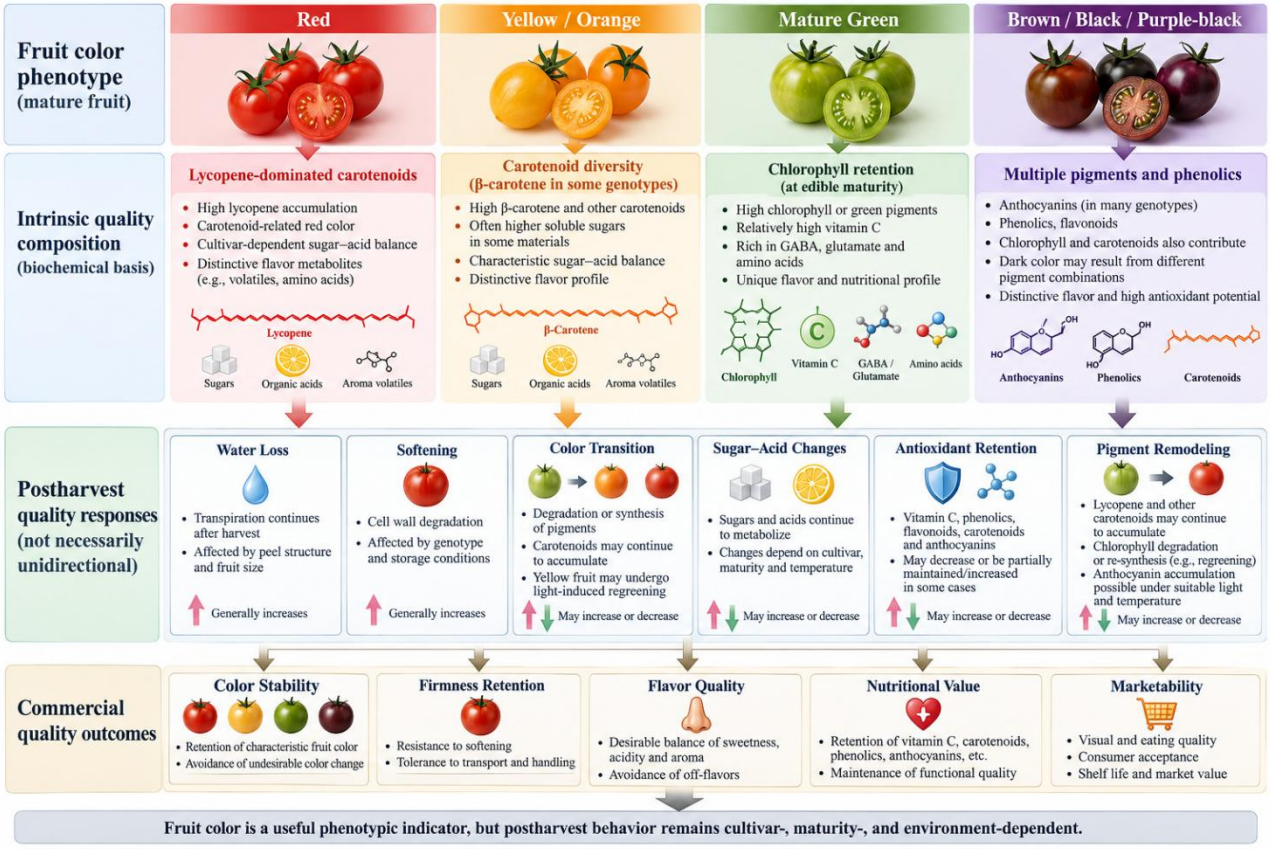


Figure 1 Framework linking intrinsic quality traits, postharvest responses, and commercial quality in differently colored cherry tomatoes

3 Postharvest Quality Changes in Differently Colored Cherry Tomatoes

3.1 Weight loss and softening

Weight loss and softening are among the most direct manifestations of postharvest quality deterioration in cherry tomatoes, but they should not be evaluated as a single parameter. Weight loss mainly reflects water loss, whereas softening is also associated with cell wall degradation, ripening progression, and changes in tissue structure. Therefore, when comparing different cultivars, both the initial firmness at harvest and the magnitude of firmness change over the same storage period should be considered. When 'Cherry 7160' was subjected to a 24 h delay in cooling after harvest and then stored at 10 ± 1 ℃, weight loss reached 13.01% after 15 d and firmness declined by 42.14%, both of which were markedly greater than those observed under immediate cooling. This indicates that conditions during the early postharvest period can significantly influence subsequent weight loss and softening (Kabir et al., 2020).

Comparisons of storability among differently colored cherry tomatoes should therefore be conducted under comparable maturity stages, harvest times, and storage conditions; otherwise, treatment effects may be incorrectly attributed to fruit color. For multicolored cherry tomato materials, it is more appropriate to record weight loss, the decline in firmness, and the proportions of shriveled, bruised, and softened fruits separately for each cultivar before assessing postharvest stability. A higher initial firmness does not necessarily mean a slower softening rate, and similarly, a lower firmness value at a single time point cannot by itself indicate a faster overall rate of deterioration during storage.

3.2 Changes in fruit color

Postharvest color changes in differently colored cherry tomatoes should be evaluated primarily in terms of whether the characteristic commercial color of each type is maintained. Cannata et al. (2024) compared red, orange, and dark red-green striped small-fruited tomatoes under the same storage condition of 10 ℃ and found that the trajectories of color change differed among cultivars, with orange 'Santy Naranja' showing relatively pronounced and persistent color changes. Characteristic fruit color should therefore be regarded as an independent commercial quality trait, although the specific pattern of color change remains strongly cultivar-dependent.

Yellow fruits may also exhibit postharvest responses that differ fundamentally from continued orange coloration. Mesa et al. (2025) found that light exposure induced postharvest regreening in the yellow cherry tomato 'SummerSun'; by day 21, total chlorophyll content in the light-treated fruit was 88% higher than that in the dark-treated control. However, firmness and weight loss did not improve accordingly. Thus, changes in fruit color, or even an apparent improvement in color, should not be interpreted directly as enhanced storability. For yellow, green, striped, and dark-colored products, color stability should be evaluated separately from softening, water loss, and decay, rather than assuming that acceptable color alone indicates overall quality retention.

3.3 Changes in sugars, organic acids, and flavor

Sugars and organic acids jointly determine the sweet–sour balance of cherry tomatoes, but their postharvest changes do not follow a single universal pattern. Tsouvaltzis et al. (2023) found that, in 'Genio F1' stored at 12 ℃, total soluble solids and titratable acidity changed only slightly between days 0, 4, and 10, and the main effect of storage duration was not significant. This suggests that, under certain cultivar and temperature conditions, sugar- and acid-related traits may remain relatively stable rather than continuously increasing or decreasing. At the same time, different maturity stages themselves can cause substantial differences in sugar and acid composition, and changes in glucose, fructose, or organic acids during ripening should not be directly interpreted as postharvest storage trends.

Flavor differences among fruit-color types are also influenced by cultivar genetic background. Chang et al. (2024) compared red, brown, yellow, and green cherry tomatoes and found that yellow materials had relatively high levels of soluble sugars and several sweet-tasting and aromatic amino acids, together with favorable overall flavor evaluation, whereas other fruit-color types showed different advantages in pigments, mineral elements, or nutritional components. Fruit color may therefore provide some indication of basic flavor type, but postharvest flavor retention should still be evaluated dynamically under comparable maturity and storage conditions, rather than inferred directly from color-associated differences at harvest.

3.4 Changes in Vitamin C, phenolics, and antioxidant quality

Vitamin C, phenolic compounds, and antioxidant capacity are important nutritional quality attributes of cherry tomatoes, but postharvest evaluation should consider both their initial levels and the extent to which they are retained during storage. Yu et al. (2023) found that vitamin C generally declined in cherry tomatoes stored for 21 d at room temperature, although the decrease was slower in fruit treated with a chitosan–curdlan composite coating. On day 21, vitamin C content in the composite-coated fruit was 23.1% higher than that in the uncoated control. A higher value after treatment therefore generally indicates slower loss rather than an actual increase caused by storage.

Season and harvest batch can also markedly alter the initial nutritional quality of fruit. In the same 'Genio F1' cultivar, antioxidant capacity differed considerably among fruits harvested in different months, indicating that harvest season can interfere with comparisons among fruit-color types (Tsouvaltzis et al., 2023). Future evaluations of nutritional stability in differently colored cherry tomatoes should therefore standardize harvest period, maturity stage, and storage conditions as far as possible, while reporting both initial values and subsequent changes. Retention of nutritional compounds should be regarded as one component of overall commercial quality and should not replace independent assessment of appearance, texture, and fresh-eating acceptability.

3.5 Changes in carotenoids, Chlorophyll, and anthocyanins

Postharvest pigment levels in cherry tomatoes do not necessarily decline continuously, and different pigment classes may even show contrasting trends. Tsouvaltzis et al. (2023) found that, during 0~10 d of storage of 'Genio F1' at 12 ℃, lycopene and total carotenoid contents generally increased, whereas β-carotene did not show a similarly pronounced significant storage-time effect. This indicates that pigment synthesis and transformation may continue after harvest.

Anthocyanin-rich materials show even stronger dependence on genotype and storage environment. Petrić et al. (2018) reported that, in Aft/Aft atv/atv anthocyanin-rich material, anthocyanins continued to accumulate during storage under light at 12 ℃, while carotenoids also increased and pH, titratable acidity, and total soluble solids remained relatively stable. This suggests that the postharvest pigment system of dark-colored materials retains considerable regulatory plasticity. Accordingly, postharvest evaluation of red, yellow/orange, mature-green, and purple-black cherry tomatoes should separately consider changes in lycopene, carotenoids, chlorophyll, and anthocyanins rather than relying on a single unified pigment indicator.

4 Harvest Maturity and Storage-Transportation Conditions Determine Postharvest Quality Trajectories and Suitable Marketing Distance of Differently Colored Cherry Tomatoes

4.1 Harvest maturity

Tomato is a typical climacteric fruit, and different harvest maturity stages correspond to different postharvest management objectives. Fruits harvested at a lower maturity stage generally have greater firmness and more capacity for subsequent ripening, making them better suited to packing, transportation, and longer turnover periods. In contrast, fruits harvested at a more advanced maturity stage usually exhibit more fully developed color and fresh-eating flavor, but they are also more susceptible to softening, mechanical injury, and over-ripening. A clear interaction exists between maturity stage and packaging method. Hossain and Ar Rashid (2021) reported that fruits harvested at the yellow maturity stage and packed in perforated plastic containers had a markedly longer shelf life than unpackaged red-ripe fruits. In addition, fruit color, TSS, ascorbic acid, and pH changed substantially as tomatoes progressed from the green to the red stage (Rawal et al., 2016).

The longer the marketing distance, the greater the need to retain sufficient firmness and ripening capacity for transportation. Bapary et al. (2024) compared breaker-stage and red-ripe tomatoes subjected to mechanical drop impact and found that red-ripe fruits experienced greater internal bruising and larger losses in firmness, TSS, acidity, and vitamin C, whereas breaker-stage fruits, particularly under low-temperature conditions, showed better quality retention. For batches expected to undergo repeated loading and unloading, e-commerce delivery, or long-distance transportation, harvest may therefore be advanced appropriately according to the cultivar's ripening capacity. By contrast, fruit intended for local picking, farm-gate sales, or short-distance marketing can be harvested at a higher maturity stage to better express cultivar-specific color and fresh-eating flavor.

4.2 Maturity assessment of different fruit-color types

Color is the most intuitive indicator of tomato maturity, but for differently colored cherry tomatoes, maturity cannot simply be equated with "the redder the fruit, the riper it is." The ripening process of conventional red-fruited tomatoes can be assessed continuously through color change, whereas yellow, orange, mature-green, and purple-black cultivars have distinctly different commercial maturity endpoints. Sharma et al. (2020) showed that the Ripening Index was more sensitive to changes in ripening rate than simply calculating the percentage of red tomatoes. Kumar et al. (2022) further demonstrated that fruit color and maturity could be identified

non-destructively using reflectance spectra in the 350~2 500 nm range. Maturity assessment should therefore gradually shift from visual color judgment alone toward integrated evaluation based on color, firmness, and internal quality.

In practical production, family farms do not necessarily need to rely on sophisticated spectroscopic equipment. A more feasible approach is to establish a simple "maturity profile" for each specialty cultivar by recording its characteristic commercial color, firmness, TSS, postharvest softening rate, and actual sensory performance. Imali et al. (2025) showed that even at similar maturity stages, commercial tomato cultivars can differ markedly in firmness, TSS, and shelf-life performance. Red, yellow/orange, mature-green, and purple-black cherry tomatoes should therefore each have cultivar-specific maturity criteria, rather than applying the breaker, turning, and red color classification system of conventional red-fruited tomatoes to all fruit-color types.

4.3 Temperature and packaging

Once fruit enters the supply chain, temperature mainly determines the overall rate of ripening and senescence, whereas packaging regulates water loss, gas exchange, and mechanical protection. Moderate low-temperature storage generally reduces respiration, water loss, and softening, but lower temperatures are not always better, particularly for fruits harvested at earlier maturity stages, where chilling injury and impaired ripening must also be considered. Küçükbasmacı Sabır et al. (2020) reported that modified atmosphere packaging (MAP) reduced weight loss and maintained firmness in breaker- and pink-stage tomatoes stored at 5 ℃. Similarly, an active modified atmosphere of 5% O_2 + 5% CO_2 reduced respiration and ethylene production in cherry tomatoes and delayed softening and changes in sugars and organic acids, although it also suppressed lycopene synthesis and red color development (Fagundes et al., 2015).

For family farms and small- to medium-sized enterprises, passive MAP is often more practical. Paulsen et al. (2019) showed that perforated packaging at 7 °C created a moderate atmosphere of approximately 14~19 kPa O_2 and 2~3 kPa CO_2, which reduced weight loss and sensory deterioration. However, D'Aquino et al. (2016) found that excessive sealing could reduce O_2 to levels that promote anaerobic metabolism and off-flavors, while excessive humidity could increase decay risk in crack-susceptible cultivars. Therefore, the objective of packaging design should not be "maximum sealing," but rather a balance among moisture retention, ventilation, and protection against compression, with packaging intensity adjusted according to cultivar maturity and expected marketing duration.

4.4 Harvest and storage–transportation strategies for different marketing distances

Marketing distance should be incorporated into management decisions before harvest, because postharvest treatments primarily slow the deterioration of existing quality rather than create new quality. For local picking, farm-gate sales, and same-day marketing, fruit can be harvested at a relatively advanced maturity stage, with priority given to characteristic color, sugar–acid balance, and flavor; careful handling, prompt grading, and short-term cooling are generally sufficient. For community group purchasing and short-distance distribution, slightly greater firmness should be retained, together with ventilated crates and simple cushioning or anti-impact packaging. For yellow, orange, mature-green, and purple-black cultivars, maturity at these market levels should be judged according to their own characteristic commercial color rather than conventional red-fruit standards.

Regional wholesale, e-commerce distribution, and longer-distance transportation require progressively greater emphasis on maturity control, precooling, packaging, and cold-chain stability. Cultivars capable of normal postharvest ripening may be harvested somewhat earlier and allowed to complete ripening under stable temperature conditions, whereas mature-green, striped, and dark-colored products should be assessed more heavily on firmness, TSS, and cultivar-specific mature color. As marketing distance increases, management priorities should gradually shift from maximizing flavor toward reducing mechanical damage and slowing quality deterioration, thereby forming a continuous management chain of harvest maturity → precooling → grading → protective packaging → stable temperature management → arrival and sale.

5 Major Postharvest Preservation Technologies and Their Applications

5.1 Precooling and cold-chain management

Precooling and a stable cold chain are among the most fundamental components of postharvest management for cherry tomatoes. After harvest, fruits continue to respire and transpire, and if field heat is not removed promptly, water loss, softening, and membrane damage can begin to accumulate before packaging and transportation. Bian et al. (2026) developed a stepwise precooling strategy combining hydrocooling and forced-air cooling, which increased the cooling rate of cherry tomatoes by approximately 50%~70% compared with forced-air cooling alone. The treatment also reduced weight loss and decay while better preserving ascorbic acid, total phenolics, lycopene, and several volatile aroma compounds. These results indicate that rapid precooling not only lowers fruit temperature but also helps reduce early postharvest quality deterioration.

In practical applications, the focus of cold-chain management should extend beyond simply maintaining a low temperature to ensuring that cooling is both timely and stable. Fruits harvested in the early morning, precooled within 2 h, and subsequently stored under refrigerated conditions showed markedly higher marketability than fruits harvested in the afternoon and subjected to delayed cooling or ambient storage (Cherono et al., 2018). Repeated fluctuations in temperature and relative humidity can also cause cumulative increases in weight loss, softening, and decay (Garrido-López et al., 2026). For agricultural enterprises and producers serving more distant markets, priority should therefore be given to rapid postharvest cooling, minimizing waiting time, and maintaining cold-chain continuity rather than simply pursuing a lower temperature set point.

5.2 LED light treatment

LED light treatment differs from basic preservation measures such as cold-chain management and edible coatings, as its main advantage lies in regulating fruit color and functional compounds. Tomatoes retain a certain capacity for pigment and carotenoid metabolism after harvest, and specific red and blue light treatments, either alone or in combination, can continue to influence the accumulation of lycopene, β-carotene, and antioxidant compounds. Baenas et al. (2021) treated mature-green 'Raf' tomatoes with red and blue LED light for 7 d at 6 ℃ and found that total carotenoid content increased to as much as approximately three times that of the dark-stored control. Antioxidant capacity also increased markedly, while conventional quality indicators such as weight loss were not adversely affected. These findings suggest that LED treatment is more suitable for improving fruit coloration and nutritional quality than for simply extending shelf life.

The effectiveness of LED treatment is also influenced by light quality, exposure duration, and fruit maturity stage. In tomatoes harvested at an early stage of coloration and treated with LED light at 15 ℃, 8 h of daily illumination was more effective than 4 h in delaying softening and decay, while a higher proportion of blue light was more favorable for maintaining firmness, ascorbic acid, and antioxidant capacity (Grzegorzewska et al., 2024). LED treatment is therefore more appropriate for controlled storage facilities, high-value fresh-market products, or batches requiring additional color regulation. For family farms selling products rapidly over short distances, it is generally unnecessary to regard LED systems as essential preservation infrastructure. In practical use, light spectrum and exposure duration should be selected according to cultivar, maturity stage, and the desired color outcome.

5.3 Natural edible coatings and plant-derived preservation treatments

Natural edible coatings mainly function by forming a semipermeable barrier on the fruit surface, thereby reducing water loss and gas exchange, while plant extracts or essential oils can additionally provide antimicrobial and antioxidant effects. Compared with mechanical refrigeration systems, dipping or spraying equipment is relatively simple, giving these technologies good potential for small- and medium-scale applications. Akhtar et al. (2023) developed a composite coating based on chitosan and chickpea hull polysaccharides and found that, after 15 d of storage at 20 ℃, fruit treated with the higher-concentration formulation showed a weight loss of approximately 5.75%, compared with about 12% in the untreated control, while firmness, vitamin C, and lycopene were also better maintained. Similarly, the multilayer polysaccharide coating developed by Carrillo-Lomelí et al. (2024) kept weight loss below 5% during 15 d of storage at 22 °C and also exhibited a certain degree of antimicrobial activity.

Agricultural by-products are also increasingly being explored as raw materials for active edible coatings. Lieu et al. (2026) produced cellulose nanocrystals from lemongrass straw and used them to stabilize a clove essential oil Pickering emulsion. Application of this coating to cherry tomatoes reduced oxygen consumption and ethylene production and helped slow weight loss, softening, and the decline of functional compounds. Such approaches combine postharvest preservation with the valorization of agricultural residues, but the preparation of cellulose nanocrystals, emulsion stabilization, and scale-up are considerably more complex than conventional chitosan dipping. For family farms, coating systems with simple compositions, clearly defined sources, and easily standardized application procedures are likely to be more practical, whereas complex nanocomposite coatings are better suited to further development by enterprises with stronger processing capabilities.

6 Differentiated Management Strategies for Differently Colored Cherry Tomatoes

6.1 Red cherry tomatoes

Once red cherry tomatoes enter the commercial maturity stage, management priorities should shift from promoting coloration to preventing over-ripening, softening, and flavor deterioration. For local pick-your-own operations, community group purchases, and same-day sales, fruits can be harvested at a relatively advanced maturity stage to better express their red appearance and fresh-eating flavor. In contrast, for regional wholesale, e-commerce distribution, and longer-distance transportation, harvest should be advanced appropriately to retain sufficient firmness and allow for subsequent ripening. Storage at around 10 ℃ has been shown to better preserve fruit weight and firmness than storage at 20 ℃, although clear cultivar-dependent differences remain; therefore, low-temperature conditions should be adjusted according to the actual storage behavior of each cultivar (Distefano et al., 2020).

Packaging should minimize compression and excessive stacking, and red fruits harvested at a more advanced maturity stage are better suited to shallow, small-volume packages. For same-day or next-day sales, ventilation and protection against compression should be prioritized. For products requiring several days of turnover, moisture retention and cold-chain measures can be strengthened, but excessive sealing should be avoided. For less mature batches that need to reach the market uniformly, ethylene-assisted ripening may be used under standardized facilities; however, ethylene treatment primarily improves ripening uniformity and cannot compensate for flavor deficiencies caused by harvesting too early (Dhall and Singh, 2016).

6.2 Yellow and orange cherry tomatoes

The management priority for yellow and orange cherry tomatoes is to maintain their characteristic yellow or orange color and sweet-acid flavor profile, rather than attempting to drive further “red coloration” according to the standards used for red-fruited tomatoes. Maturity standards should therefore be established according to the cultivar-specific mature color, while firmness and soluble solids should also be considered when determining the appropriate harvest stage. Orange ‘Santy Naranja’ showed relatively pronounced color changes during storage at 10 ℃, indicating that stability of characteristic fruit color should itself be treated as an important postharvest quality criterion for yellow and orange materials (Cannata et al., 2024).

In production, postharvest exposure to high temperatures should be minimized to reduce color drift, surface abrasion, and localized softening. For local markets, fruits can be harvested once they have reached their typical yellow or orange mature color so that both appearance and flavor are fully expressed. For more distant markets, harvest may be advanced slightly, provided that the cultivar can still complete normal ripening after harvest. Yellow and orange products are especially suitable for cultivar-specific color profiling and should not be graded directly using the breaker, turning, and red stages developed for conventional red-fruited tomatoes.

6.3 Brown, black, and purple-black cherry tomatoes

The commercial advantages of dark-colored cherry tomatoes are mainly associated with their distinctive skin coloration and functional compounds such as anthocyanins and phenolics. Their management should therefore aim to preserve both characteristic pigmentation and textural quality while minimizing water loss and softening. Maturity of dark-colored fruits should not be judged simply by whether the fruit is “dark enough,” but should also take cultivar, days after fruit set, and firmness into account. Research on the black cherry tomato ‘OG’ showed

that grafted and non-grafted plants reached their optimal nutritional quality at different harvest times, indicating a greater need for maturity standards that integrate both cultivar and cultivation method in dark-colored materials (Ha and Thuy, 2021).

Dark fruit color does not necessarily imply inherently superior storability. Purple 'Shangjiao No. 2' showed different quality-retention responses at 4 ℃, 14 ℃, and 24 ℃, with 14 ℃ providing a comparatively favorable balance between quality preservation and storage cost for this particular cultivar (Li et al., 2025b). In practical management, dark-colored fruits should therefore be evaluated simultaneously for color, firmness, shriveling, and moisture loss around the fruit shoulder. High-value purple-black fruits are better suited to shallow, small-volume packaging and should not be mixed with other fruit-color types showing markedly different firmness levels.

6.4 Management strategies for family farms under different marketing models

Postharvest management on family farms should be closely linked to marketing radius. For local pick-your-own operations, farm-gate sales, and community group purchasing, fruits can be harvested at a relatively advanced maturity stage, with emphasis on characteristic color and flavor. Regional wholesale and e-commerce distribution require greater firmness retention, together with precooling, grading, protection against compression, and stable temperature management. For longer-distance transportation, maturity stage, precooling, cold-chain continuity, packaging, and the expected time to sale after arrival should be considered as an integrated system rather than relying on any single preservation treatment.

For operators with limited equipment, priority can be given to low-cost measures such as early-morning harvest, reducing field holding time, simple precooling, evaporative cooling, and small protective packages. Combined use of harvest stage and postharvest treatments has been shown to influence shelf life and marketability; for example, mature-green-stage tomatoes treated with $CaCl_2$ showed reduced weight loss and delayed ripening (Mazumder et al., 2021). For family farms, the more appropriate strategy is to adjust postharvest investment intensity according to market distance so that additional preservation costs are converted into higher marketable yield and lower product loss.

Overall, postharvest management of differently colored cherry tomatoes is a continuous process jointly determined by fruit-color characteristics, cultivar, harvest maturity, and marketing distance. From harvest through precooling, grading, packaging, storage, transportation, and final sale, management priorities should be adjusted according to product characteristics and market radius. At shorter marketing distances, greater emphasis can be placed on eating maturity, flavor, and characteristic fruit color; as transportation distance increases, the priorities should gradually shift toward firmness retention, packaging protection, cold-chain stability, and control of mechanical damage. The relationship between supply-chain management and marketing-distance adaptation for differently colored cherry tomatoes from harvest to market is summarized in Figure 2.

7 Current Problems and Future Directions

7.1 Major problems in current production

Postharvest losses in tomatoes are rarely caused by a single factor; rather, they result from the cumulative effects of field quality, harvest maturity, mechanical injury, disease, packaging, and storage and transportation conditions. Surveys of small-scale production systems have shown that insect damage, fruit cracking, bruising, deformities, and decay are common sources of loss, and some fruits are already downgraded before entering storage and distribution. Therefore, reliance on postharvest preservation alone cannot fully compensate for quality losses that originate earlier in the production chain (Molelekoa et al., 2025). This problem is particularly evident for differently colored cherry tomatoes because cultivars vary in color, firmness, and ripening behavior; if identical harvesting and grading standards are applied to all types, inconsistency in marketable quality can arise even before the fruit enters the supply chain.

Another major challenge is that technical effectiveness does not necessarily translate into practical adoption. A survey of 1 704 tomato growers by Yami et al. (2025) showed that the adoption of improved postharvest technologies, such as reusable plastic crates, remained relatively low, and farmers' choices were influenced by

cost, access to packaging materials, and marketing distance. Future improvements in production should therefore link technical effectiveness with farmers' purchasing capacity, product price, and marketing radius. Particular attention should be given to simplifying grading standards, improving access to suitable packaging materials, and expanding the availability of low-cost cooling facilities.

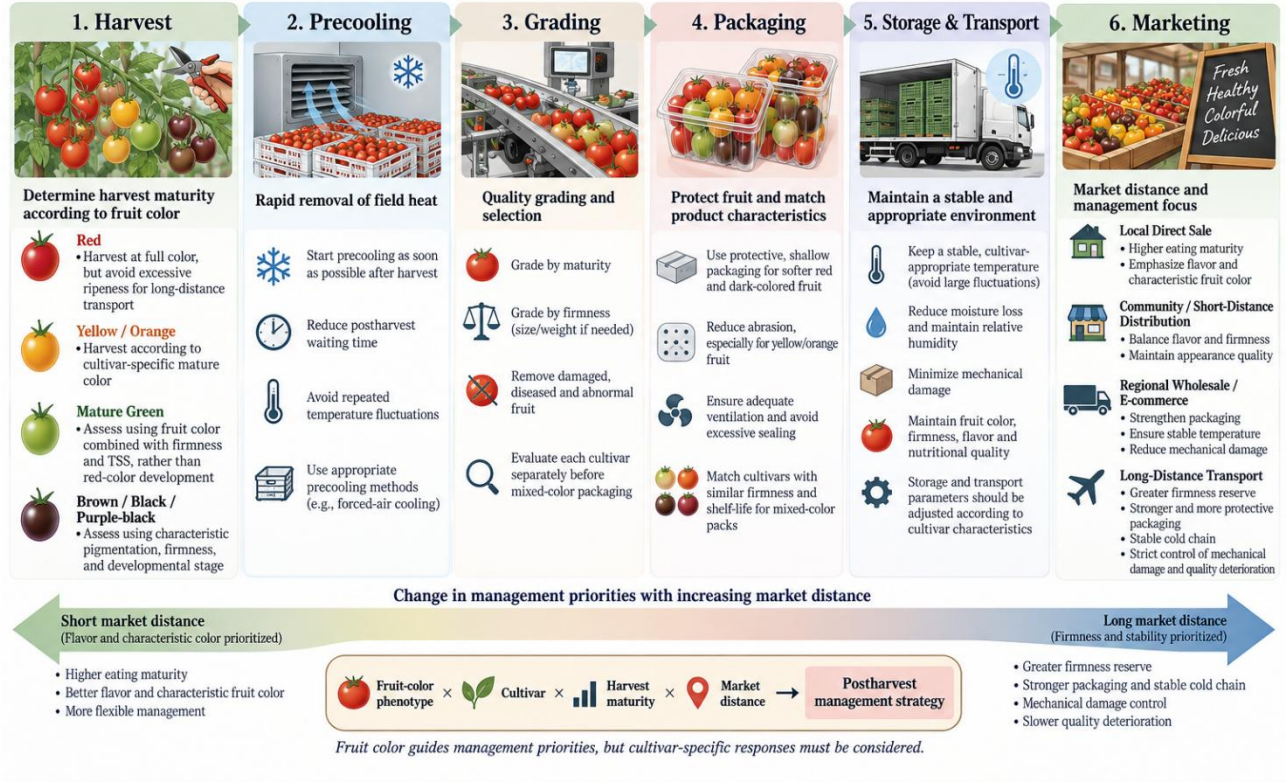


Figure 2 Postharvest supply-chain management and market-distance adaptation framework for differently colored cherry tomatoes

7.2 Establishing maturity assessment standards for different fruit-color types

One of the most fundamental issues in differently colored cherry tomatoes is that the conventional maturity assessment system based on the progression from green to red cannot be universally applied. Mature yellow, orange, green, and purple-black cultivars have their own stable commercial color endpoints, and mature-green cultivars are especially likely to be confused with immature green fruits of conventional red-fruited tomatoes. Mature-green tomatoes can retain a green appearance after physiological maturity because of specific changes in genes regulating fruit coloration, indicating that "remaining green" can itself represent a mature phenotype rather than immaturity (Cui et al., 2024).

Future maturity assessment should therefore rely on an integrated system combining fruit color, firmness, TSS/TA, and cultivar-specific characteristics rather than on color alone. Chlorophyll fluorescence, near-infrared spectroscopy, and color analysis have already shown potential for non-destructive maturity assessment. However, family farms do not necessarily need expensive equipment; simple cultivar-specific maturity profiles can first be established using color cards, soluble solids, firmness, and days after fruit set. Larger grading enterprises, by contrast, can further introduce machine vision and spectroscopic technologies. The ultimate goal should be to establish practical maturity standards specific to red, yellow/orange, mature-green, and purple-black cherry tomatoes (Kasampalis et al., 2020; Tasioulas et al., 2025).

7.3 Low-cost postharvest technologies for family farms

What family farms need most is not necessarily the technology that produces the longest shelf life under laboratory conditions, but rather approaches that are low-cost, simple to operate, and capable of clearly reducing losses while increasing marketable returns. Solar-powered cold storage, mechanical refrigeration, and complex active packaging all have potential value, but their initial investment, maintenance costs, and operational

requirements may restrict adoption by small-scale producers. Affordability, technical awareness, access to equipment, and consumer acceptance all influence the deployment of solar-powered cold-storage technologies, indicating that economic feasibility must be considered alongside preservation performance when evaluating low-cost postharvest solutions (Rutta, 2022).

More practical options for family farms include early-morning harvesting, postharvest shading, shortening field holding time, simple precooling, evaporative cooling, and reusable protective packaging. Trials conducted under real supply-chain conditions have shown that passive evaporative cooling devices can reduce fruit temperature, increase relative humidity, and slow water loss and softening, while also being directly applicable during field holding and transportation (Felicioni et al., 2025). Future evaluations of such technologies should include indicators such as treatment cost per kilogram of fruit, reduction in product loss, additional marketable days gained, and expected payback period, so that preservation benefits can be translated into practical economic criteria that family farms can use in decision-making.

7.4 Research needs under real supply-chain conditions

Experimental studies are commonly conducted under constant temperatures, fixed packaging conditions, and standardized storage periods, which is useful for comparing treatments but does not fully reflect real marketing environments. In actual supply chains, fruit may experience postharvest waiting, packing, vehicle vibration, temperature fluctuations, wholesale-market storage, repacking, and retail display. Therefore, a treatment that performs well under constant-temperature cold storage may not necessarily maintain the same advantage under real distribution conditions (Mohan et al., 2023).

Future studies on differently colored cherry tomatoes should therefore place greater emphasis on supply-chain trials that closely resemble real commercial conditions. Separate scenarios could be designed for farm-gate sales, community distribution, e-commerce transport, and regional wholesale, while simultaneously recording firmness, color, flavor, nutritional quality, loss rate, marketable proportion, packaging cost, and actual selling price. For mixed-color packages, it is particularly important to record the day on which each fruit-color type loses marketability, because the effective sales period of the entire package is often determined not by the average shelf life of all cultivars, but by the cultivar that first softens, loses water, or develops unacceptable appearance.

Overall, three major shifts deserve particular attention in future research: from a unified red-fruit maturity standard to fruit-color-specific maturity standards; from simply extending shelf life to integrated evaluation of flavor, nutrition, appearance, and consumer acceptance; and from identifying optimal treatments under laboratory conditions to validating cost, loss reduction, and economic returns under real supply-chain conditions. Only through these shifts can postharvest research on differently colored cherry tomatoes move beyond quality comparison and preservation trials toward practical and commercially applicable management systems.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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