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FACTORS AFFECTING POSTHARVEST QUALITY AND SHELF LIFE OF KIWIFRUIT (*ACTINIDIA DELICIOSA*): A SYSTEMATIC REVIEW

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ABSTRACT

Kiwifruit *(Actinidia deliciosa)* is a highly nutritious fruit with high vitamin C content. Postharvest quality of kiwifruit is affected by its rapid softening, sugar-acid imbalances, and decay. Fruit ripening is regulated and guided by ethylene and temperature pathways. Similarly, various pre-harvest factors determine and control the stages of shelf life. Therefore, it is necessary to carefully harvest and handle it to minimize damage and early ethylene exposure. The storage technologies, such as cold storage, which slows down the ripening process, controlled atmospheres, which regulate oxygen and carbon dioxide levels, ethylene inhibitors, which block the ripening hormone, and edible coatings, which create a protective layer, will also extend the shelf life; microbial spoilage is a major cause of decay in the storage of the kiwifruit. Furthermore, packing techniques, including ethylene scrubbing sachets and natural film coating, are now famous for preserving firmness and delaying ripening. This systematic review used databases, including PubMed and Google Scholar, and articles published in English from 2015 to 2024. PRISMA guidelines were used to remove duplication and exclude irrelevant studies based on preference. The treatment of 1-MCP, edible coatings, and calcium-based solutions is discussed in terms of its impact on different cultivars. The treatment of 1-MCP is effective in preserving the firmness of the 'Hayward', while edible coatings have demonstrated effective results in maintaining the texture of the 'Zespri Gold'. This study provides an understanding of the physiological and environmental aspects affected by postharvest, which helps extend shelf life and preserve quality.

Keywords: *Actinidia deliciosa,* Postharvest shelf life; Ripening stages, Storage conditions, Edible coatings; Consumer acceptance.

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1. INTRODUCTION

The Kiwifruit (*Actinidia deliciosa*) is a highly nutritious fruit, including high vitamin A, C, E, and K, and dietary fiber, with increasing popularity in global markets and health-promoting properties (antioxidant, anti-inflammatory), which has attracted consumer demand (Asadi et al., 2024). Among the global production, around 4.5 Mt is annually produced by China, leading kiwifruit production, contributing about 2.38 million tons annually. Iran is the world's fifth-largest producer, with an annual production exceeding 300,000 Mt (FAOSTAT, 2023), while the production of Kiwifruit in Nepal is far below approximately 1,500 Mt (Rai, 2025). However, kiwifruit farming in Nepal is gaining popularity these days. *Actinidia deliciosa cv. 'Hayward'* is most produced and there is great demand for golden fleshed varieties both domestically and internationally (Ebrahimi et al., 2014). New yellow and red fleshed cultivars *(A. chinensis)* are now adopted, partly to offer novel flavor and extend marketing windows, but most remain derived from *A. deliciosa* genetics (Burdon and Lallu 2011). Though momentum is shifting for the cultivation of diverse types of kiwifruit species, including green-fleshed cultivars, yellow-fleshed cultivars, and red-fleshed cultivars, this study mainly concentrated on green-fleshed kiwifruit (Actinidia deliciosa). However, for commercial success and consumer satisfaction, high harvest volumes and a long supply chain will support consumer preference and managing postharvest quality and shelf life (Lin et al., 2023). Nevertheless, kiwifruit possesses a comparatively brief postharvest lifespan if not managed with care: swift softening, loss of sugars, and physiological issues can compromise quality.

Moreover, postharvest decay in kiwifruit is a complex process regulated by various factors, including physiological, biochemical, and microbial factors. This review synthesizes evidence from 28 peer-reviewed articles, highlighting the impact of ethylene regulation, storage temperature, microbial spoilage, antioxidant activity, and comprehensive postharvest treatments on preserving quality and extending the shelf life of kiwifruit.

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This review evaluates the existing knowledge and practices regarding the ripening biology of kiwifruit, the pre- and postharvest elements that affect firmness, flavor, and storage potential. This study identifies pre-harvest management strategies, harvesting techniques, storage and packaging practices, spoilage biology and the sensory factors that drive consumer acceptance. The objective is to provide a critical evaluation of how these elements interact and to identify knowledge gaps that help further research work.

2. MATERIALS AND METHODS

The article was prepared using the systematic review procedure based on the standard method of meta-analysis, known as the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) (Page et al., 2021).

2.1. Research Design

The review study was designed to be conducted as a systematic review for the collection, evaluation, and synthesis of available evidence on various factors affecting the post-harvest quality and shelf life of Kiwifruit (*Actinidia deliciosa*), focusing on the globally cultivated cultivar "Hayward "and other cultivated varieties of green-fleshed kiwifruit. The methodology was adopted as guidance from the PRISMA 2020 Statement to ensure transparency, reproducibility, and a comprehensive nature.

2.2. Research Questions

The review protocol was developed before the start of the study and follows a clearly defined research question.
a) Pre-harvest factors: How do different pre-harvest factors, such as climate, maturity stages, and canopy management, influence post-harvest quality and shelf life of kiwifruit?
b) Harvest maturity: What are the maturity stages and indices, such as days after full bloom, firmness, and soluble solids content (SSC), and dry matter that determine the quality and shelf life of Kiwifruit?
c) Post-harvest factors: Different post-harvest factors such as temperature ranges, controlled atmosphere (CA), modified atmosphere packaging (MAP), ethylene management, and treatments like 1-MCP, coatings, etc, affect the quality and shelf life of the kiwifruit.
d) Post-harvest disorders and decay: During storage, what types of disorders and pathogens commonly infest the kiwifruit, and how can they be prevented?

2.3. Eligibility Criteria

The details of the inclusion and exclusion are listed below

(a) Inclusion Criteria

i) Articles published between 2015 and 2025.
ii) Original journal or research articles, review articles.
iii) Studies focused on *Actinidia deliciosa.*
iv) Studies in the English language.
v) Both field and lab-based experiments.

(b) Exclusion Criteria

i) Duplication.
ii) Irreverent cases, Book section, Conference paper, Document, thesis.
iii) Language filter (other than English).
iv) Date range (1992 A.D to 2014 A.D).
v) Close access to the article database.
vi) Subscription database.

2.4. Data Extraction and Screening

The literature search/review was conducted via the databases PubMed and Google Scholar as mentioned. Keywords used for the search were:
For PubMed: ("Actinidia deliciosa" OR "kiwifruit") AND ("postharvest quality" OR "shelf life" OR "storage" OR "ethylene" OR "fruit firmness" OR "ripening").
For Google Scholar: "postharvest quality of kiwifruit" OR "shelf life of Actinidia deliciosa" OR "kiwifruit storage conditions".

All papers were searched across various databases using specific keywords and imported into the Zotero management software. A subfolder was created in Zotero according to the databases. Later, all the subfolders were exported separately into Microsoft Excel 2016 as CSV files. Then, prepared one parent Excel file for all that have different columns, including publication year (1992 to 2025), author name, article title, and article types. The table was created as a pivot table. The conditional formatting, filter option, and advanced filter option of MS Excel 2016 were used to include and exclude paper. The detailed process is based on the PRISM flowchart (Fig. 1).

The articles were 459 (n=459) total number of articles extracted till date 26/06/2025 (Fig. 1), from Google

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Scholar and PubMed, cross-references to identify the open access journal from a free database. For PubMed the search key word used were : ("*Actinidia deliciosa*" OR "kiwifruit") AND ("postharvest quality" OR "shelf life" OR "storage" OR "ethylene" OR "fruit firmness" OR "ripening"); whereas for google scholar "postharvest quality of kiwifruit" OR "shelf life of Actinidia deliciosa" OR "kiwifruit storage conditions" search keyword was used. There were 9 (n=9) duplicated data points obtained, and after removing duplication, a total of 450 (n=450) were obtained from the total number of articles within this period.

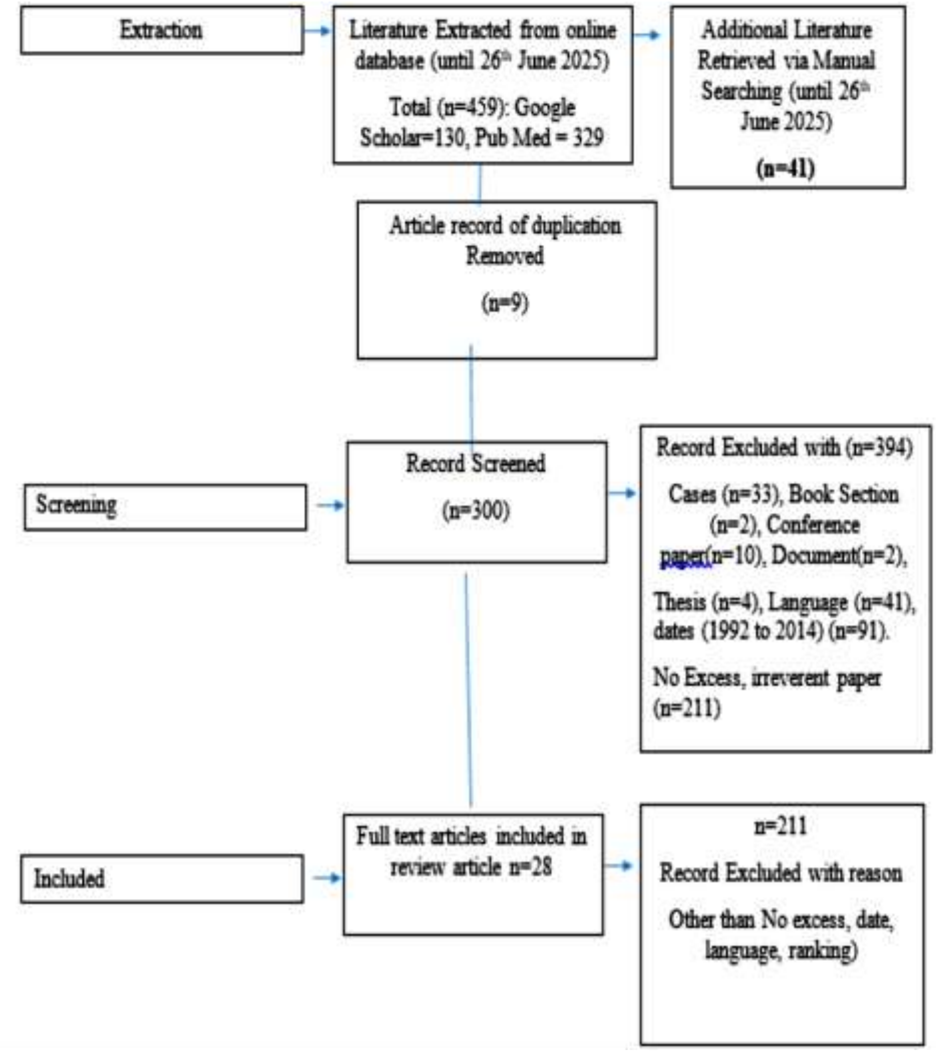

Fig. 1: PRISM flowchart of Data Inclusion and exclusion in systematic review.

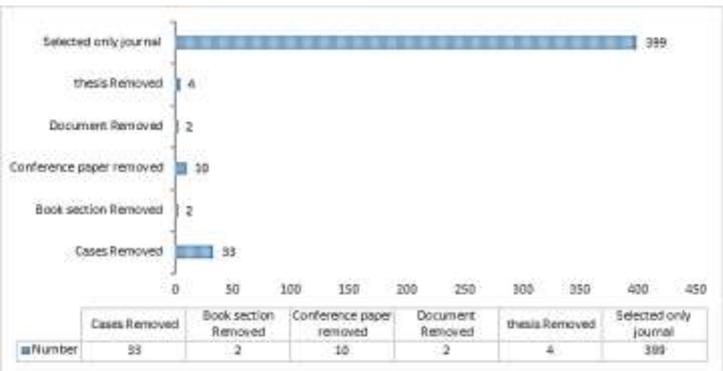

Fig. 2: Different types of publications removed from the database.

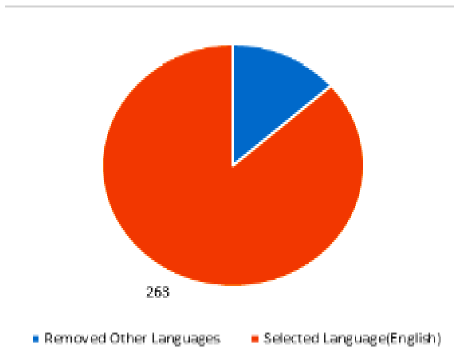

Fig. 3: Included and excluded as per preference based on the medium of publication.

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The databases, such as Springer and Science Direct, did not have a subscription while identifying research articles. The search was made from 1992 A.D. to 2025 A.D., and there were a total of 391 articles (n=391). Therefore, the article was included from 2015 A.D to 2025 A.D., in which a total of 91 (n=91) were excluded and 300 (n=300) were obtained from these dates.

Similarly, some of the articles were also excluded based on their type, where 51 articles (n=51) were removed, including (Cases n=33, Book section n=2, conference paper n=10, Document n=2, thesis n=4), and 300 (n=300) journal articles were included till date.

Likewise, the data was also removed (Fig. 2) based on the language preference because of a language barrier, where a total of 41(n=41) articles were eliminated and the rest of the English articles were selected (n=263) (Fig. 3).

Finally, after data filtration, upon access and preference out of 263 articles (n=263), the final 28 articles (n=28) were obtained for further discussions till date where the last search was conducted on June 26, 2025, where 2015 A.D n=2, 2016A.D n=2, 2017 n=1, 2019 A.D n=4, 2020 n=3, 2021 A.D n=3, 2022 A.D n= 6, 2023 A.D n=3, 2024 A.D n=4 (Fig. 4).

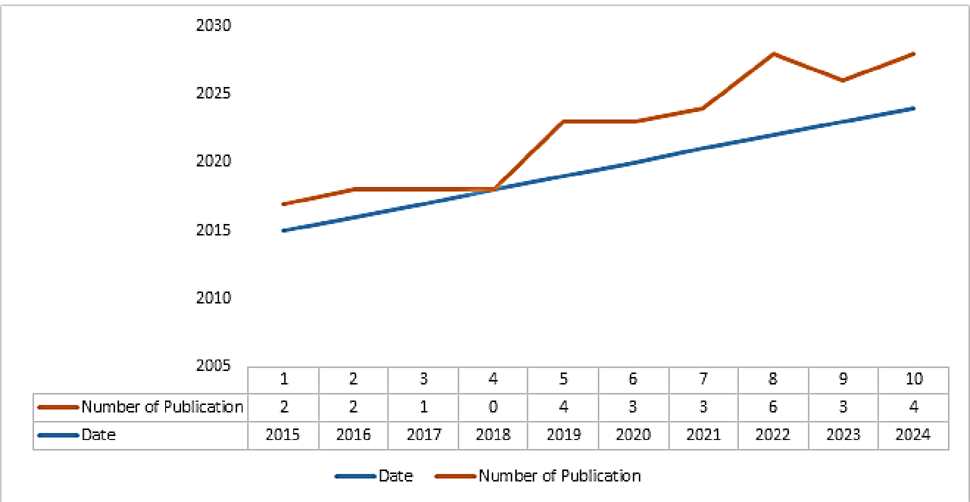

Fig. 4: Number of selected articles from 2015 to 2024 from the database.

3. RESULTS AND DISCUSSION

3.1. Physiology and Biochemistry of Kiwifruit Ripening

Kiwifruit is a climacteric fruit associated with ripening, characterized by an ethylene peak and burst respiration. ACC synthase/Oxidase and ethylene synthesis genes are upregulated at the onset of ripening, triggering starch breakdown, cell wall depolymerization and aroma production (Mitalo et al., 2019; Lin et al., 2023). Conversely, 1-methylcyclopropene (1-MCP), which acts as an ethylene-binding inhibitor, markedly postpones the softening process and the accumulation of sugars in kiwifruit (Mitalo et al., 2019). Throughout the ripening phase, kiwifruit undergoes a metabolic transformation of its starch reserves, usually accounting for 20 to 30% of the dry weight at the time of harvest, into sugars. As starch undergoes hydrolysis, the concentrations of soluble solids and dry matter rise (Nardozza et al., 2011). Kiwifruit ripening can be induced not only by ethylene but also due to exposure to low temperature, and both hormone and temperature cues regulate the ripening. (Mitalo et al., 2019). This dual regulation carries significant consequences for postharvest management (for instance, ethylene regulation in contrast to cold storage) as elaborated upon in the following sections. The Table 1 provides a summary of the impact of varying storage temperatures and ethylene exposure on the postharvest quality of 'Hayward' kiwifruit. At a temperature of 0°C with minimal ethylene exposure, kiwifruit exhibits low levels of respiration and ethylene production, maintains a high firmness of approximately 35 N, shows a gradual increase in total soluble solids (TSS), and experiences negligible rot, rendering it optimal for long-term storage.

Temperatures ranging from 5 to 10°C have a moderate impact on kiwifruit ripening. They result in moderate respiration and ethylene levels, leading to moderate softening and balanced changes in sugar and acid content. The low incidence of rot makes it suitable for short-term storage. However, at temperatures between 20 and 25°C, the addition of ethylene causes the fruit to ripen rapidly, characterized by elevated respiration and ethylene, swift sugar accumulation, acidity loss, significant softening, and high decay rate. This information deserves vital importance to understand the factors that influence fruit quality and shelf life, and it's beneficial for final market ripening due to the compromised shelf life and quality (Table 1).

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Table 1: Temperature & Ethylene Effects on Hayward Kiwifruit

Condition	Respiration Rate	Ethylene Production	Firmness Retention	TSS & Acidity Effect	Rot Incidence
0 °C (low ethylene)	Low	Minimal	High (~35 N)	Slow SSC ↑	Negligible
5–10°C	Moderate	Moderate	Moderate	Moderate	Low
20–25°C + ethylene	High	High climacteric	Low	Quick SSC ↑ & TA ↓	High

(Antunes 2007; Asiche et al., 2017)

3.2. Pre-harvest Factors Influencing Postharvest Quality

In Kiwifruit, the development conditions of the fruit have an impact on its final quality, including orchard factors such as climate, soil fertility, and water availability, which also influence kiwifruit composition at harvest. Excessive nitrogen fertilization can promote vegetative growth at the expense of fruit dry matter, diluting sugars and weakening skin toughness. On the other hand, deficit irrigation strategies often increase dry matter and antioxidant content, sometimes reducing size, the flowering position and fruit load on vine also effects where high crop loads causes tend to produce smaller fruit with lower dry matter and softer texture, well thinned vines yield bigger firmer fruits in general fruits that accumulate higher dry matter pre harvest are sweeter and firmer at ripeness (Patanè et al., 2011).

The maturity stages of Kiwifruit during harvest are essential for determining postharvest quality. Fruits that are not fully mature do not ripen adequately, whereas those that are overripe experience a decrease in shelf life and antioxidant content. In addition, climatic factors during the development of the fruit, including excessive heat, drought conditions, or extended periods of cloud cover, can interfere with the metabolism of sugars and acids, thereby affecting both flavor and storage capabilities. The application of calcium nutrition before harvest, primarily through foliar sprays, strengthens cell walls by binding pectin, which in turn enhances firmness and slows down the softening process. The various factors, such as choice of cultivar, climatic components, soil types and quality, availability of nutritional inputs, crop management practices and harvesting times, all of which play a crucial role in determining the potential for storage (Boukouvalas and Chouliaras 2005).

For kiwifruit growers, the choice of kiwifruit cultivars is a powerful tool, as the cultivars have significant variations in fruit size, sweetness, acidity, and storage potential (Guroo et al., 2017). For instance, ‘Hayward’ has global dominance due to its large fruit size and good storage characteristics. Besides, other cultivars, such as ‘Allison’ and ‘Bruno’, are superior because of their early maturity and adaptability in various climatic environments (Sharma et al., 2020). Genotype also determines susceptibility to postharvest diseases and physiological ripening changes, making cultivar selection a top priority in quality management (CABI, 2023).

Moreover, environmental factors play a significant role in the quality and storability of Kiwifruit. Harvest timing, an essential physiological attribute, is determined by factors such as days after full bloom (DAFB), soluble solids content (SSC), firmness, and skin color. Growers elsewhere frequently depend on SSC to guide harvest, but using a single measure leads to mixed maturity and unpredictable postharvest behavior (Choi et al., 2019). Recent investigations have highlighted the need to combine firmness measurements and SSC for improved timing of harvest and prolonged shelf life since fruit with higher firmness at harvest typically softens less quickly and longer retains quality after storage (Moggia et al., 2017). According to Chouliaras et al. (1995), climate, soil, and cultivation practices strongly influence kiwifruit quality. The plant physiological condition during flowering and fruit set affects fruit size and quality because of its impact on carbohydrate distribution.

Pre-harvest practices play a crucial role in shaping the quality of Kiwifruit. Practices like pruning and crop load adjustment shape photosynthetic efficiency and sugar accumulation, but excessive shading or fruit load can reduce total soluble solids, while summer pruning shortly after fruit set enhances firmness. However, it may lower TSS (Chouliaras et al., 1995). The temperature increased during ripening can boost the TSS content of the fruit, but even minor microclimate differences within an orchard can affect ripening and storability. Moderate water stress late in fruit development can improve sugar content, whereas early or prolonged drought reduces yield and quality. Nutrient-wise, excessive nitrogen accelerates softening, while adequate calcium improves firmness and reduces rot. Pre-harvest calcium chloride sprays, especially repeated applications, significantly extend shelf life compared to untreated fruit, outperforming postharvest calcium dips (Hopkirk et al., 1990; Gerasopoulos et al., 1996).

Furthermore, kiwifruit orchard management practices such as canopy management through pruning and thinning treatments, including artificial pollination and girdling, can affect fruit DMC and mineral composition, which can impact DMC in certain vine zones (Buxton, 2005). According to the findings of Kumarihami et al. (2021), pre-harvest application of chitosan has been shown to suppress ethylene production and respiration rates, thereby delaying ripening and maintaining fruit firmness and quality during storage. As findings of Denaxa et al. (2023), the application of osmoprotectants, such as Blue Stim, and reflectants, like Purshade, can boost soluble sugars and enhance postharvest quality. Commercial products like Sun Protect can mitigate the adverse effects of intense sunlight and high temperatures by enhancing fruit firmness and increasing phenolic

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content. The quality of Kiwifruit varies based on the growing locality and environment; fruits from Yalova had the lowest respiration rate and the highest vitamin C and antioxidant content. Similarly, those from Rize, Ordu, and Giresun were harder, demonstrating the influence of agroecological conditions (Korkmaz et al., 2023). Kiwifruit, which are grown in an organic environment, retained their hardness and nutrients better but showed greater signs of decay and softening during storage, compared to conventionally grown fruits (Park et al., 2009; Nezhad et al., 2012).

3.3. Harvest and Handling Practices Affecting Post-harvest Quality and Shelf Life

Appropriate harvesting and handling practices play a key role in improving the quality and extended shelf life, encompassing practices such as picking, suitable storage, and effective postharvest treatments, which aim to minimize damage and decay while preserving the fruit's desirable qualities intact.

In terms of harvesting techniques, fruit should be harvested with their stems fully attached, which helps to prevent internal rot by sealing stem wounds using liquid paraffin (Sun et al., 2016). The ideal harvest time is between 129 and 136 days after bloom, when the optimal levels for fruit quality in terms of dry matter and soluble solids are achieved (Li et al., 2018). Similarly, storage conditions affect the respiration and ethylene production of the kiwifruit as storage at low temperature slows down respiration and ethylene production while improving the shelf life of the kiwifruit (Barbir 2017; Hafeez et al., 2024). Maintaining fruit quality, the fresh specialized bags under controlled atmosphere condition helps further (Li et al., 2018). Likewise, treating with calcium and salicylic acid reduce weight loss and decay postharvest treatment, while managing ethylene is important to regulate ripening, the new technologies like pulsed light and cold plasma are practical tools to enhance quality and control diseases after harvest (Barbir 2017; Hafeez et al., 2024). For a rapid ripening schedule (e.g., for domestic markets), fruit can be treated with ethylene. Therefore, optimal harvest maturity and gentle superb handling are required to preserve quality.

3.4. Postharvest Storage Factors and Technologies affecting the quality and shelf life

In Kiwifruit, postharvest factor also influences the quality and shelf life initially through management practices and environmental factors. Optimal conditions of 0 ± 0.5°C and 90 ± 5% relative humidity have been shown to maintain firmness and bioactive compounds for extended periods (Korkmaz et al., 2023). To resolve the premature softening and decay, 1-MCP treatment can inhibit ethylene action and improve postharvest quality, whereas ethylene is necessary for ripening as well (Prencipe et al., 2015; Lim et al., 2016; Hafeez et al., 2024). *Pseudomonas syringae* can affect fruit integrity, making the fruit more susceptible to rot and reducing its firmness (Prencipe et al., 2015). According to Huang et al., (2017), the quality of the Kiwifruit is lowered due to elevated metabolic activity during storage. For maintaining quality and enhancing shelf life by decelerating cellular activities such as respiration and ethylene production, cold storage is more effective (Günther et al., 2015; Shin et al., 2018; Cha et al., 2019). For refrigeration, the techniques such as salicylic acid treatment, calcium dips, the application of 1-methylcyclopropene (1-MCP) and modified atmosphere packaging are effective in enhancing postharvest longevity for a range of crops, including kiwifruit (Fisk et al., 2008; Franco et al., 2008; Kazemi et al., 2011; Guroo et al., 2017; Kwanhong et al., 2017). Now, edible coatings are a cost-effective substitute for conventional modified atmosphere packaging (Fisk et al., 2008; Huang et al., 2017). The controlled atmosphere (CA) storage, particularly with 5% CO2 and 2%, O2 effectively maintains fruit flesh firmness in Hayward kiwifruit, with suppression of ethylene production and delaying softening compared to standard air storage, thus optimizing fruit quality (Oz & Eris 2010). Though there are various techniques available viz. cold storage, essential oils, and endophytic yeasts, which can assist in preserving the quality of postharvest Kiwifruit with the elimination of diseases, chilling injury, and oxidative damage; these methods have drawbacks, such as potential health hazards and insufficient protection against secondary infections. New technologies, such as pulsed light, cold plasma, and integrated treatments, present encouraging alternatives for future preservation (Xia et al., 2024). While many techniques can extend shelf life, such as the introduction of 1-MCP with exposure to propylene, can postpone the softening of the fruit, reduce alterations in SSC and sugar concentrations, and significantly inhibit ethylene production, the release of aroma volatiles, and the expression of associated genes. Throughout the storage period, fruit softening, rises in SSC and sugar levels, as well as increased expression of genes coupled with cell wall modification and carbohydrate metabolism, were found even in the absence of measurable ethylene production (Park et al., 2015; Mitalo et al., 2019).

3.4.1. Ethylene Regulation and Ripening: Kiwifruit is highly responsive to ethylene, in which kiwifruit contains ethylene-induced transcriptional regulation of main genes "AcACS" and "AcACO" that mediate autocatalytic ethylene production and are connected to the ripening process, including softening, starch degradation, and aroma volatile synthesis (Mitalo et al., 2019), while the inhibitors like 1-methylcyclopropene (1-MCP) can reduce softening and suppress ethylene biosynthesis (Lim et al., 2017; Xia et al., 2024).

As found by Mitalo et al. (2019), surprisingly, kiwifruit can soften during cold storage without detectable ethylene production, indicating an "ethylene-independent ripening pathway" mediated by genes such as AcEXP1 and AcPG, which remain unregulated even in low-ethylene environments (Choi et al., 2022). Afshar-Mohammadian et al. (2019) utilized qRT-PCR and other molecular tools to find that ethylene biosynthesis genes (ACS, ACO) are differentially expressed across cultivars' storage regimes and highlighted opportunities for cultivar-specific storage intervention(Zhang et al., 2020).

3.4.2. Cold Storage and Chilling Injury: The cold storage that is maintained between 0 and 1°C is usually used to reduce respiration rate and delay senescence by maintaining the quality of fruit and extending market value. Kiwifruit is prone to chilling injury that can present as browning of the tissue, granulation, and emergence of off-flavor when stored at inappropriate temperatures (Salzano et al., 2019; Xia et al., 2024).

3.4.3. Biocontrol and Antifungal Intervention**:** The microbial agents for biological control show a promising strategy to solve postharvest decay attributed to *Botrytis cinerea, Alternaria alternata,* and *Penicillium expansum*. Pang et al. (2021) enhanced the antifungal efficacy of *Bacillus amyloliquefaciens* while improving metabolite profile through optimized conditions and reduced disease incidence exceeding 60 percent. Dai et al. (2022) identify that combining curing and plant-derived antifungal treatment targets a variety of pathogens by reinforcing the movement towards environmentally friendly and residue-free solutions (Meng et al., 2022).

3.4.4. Biochemical Quality and Antioxidant Preservation: The postharvest storage significantly affects kiwifruit's antioxidant profile (Ozturk et al., 2024). Many studies report an increased level of total phenolic, flavonoids, and antioxidant capacity (DPPH and FRAP assays) in early cold storage conditions, which contribute to enhancing resistance and nutritional quality. Similarly, vitamin C in kiwifruit is either increased or decreased depending on cultivar, storage condition and ecological origin (example, superior retention of vitamin C and antioxidant activity in Yalova-grown fruit in long-term cold storage, highlights importance of genotype-environment interactions in postharvest physiology) (Ozturk et al., 2024).

3.4.5. Postharvest Disease and Biocontrol: Fungal decay, usually caused by *Botrytis cinerea, Botryosphaeria dothidea*, and *Penicillium expansum,* is a major postharvest constraint (Zhu et al., 2016; Liu et al., 2020). The use of traditional fungicides is constrained by the emergence of resistance and concerns regarding residues. There are environmental-friendly alternatives available such as antagonistic yeasts (*Candida oleophila*, *Debaryomyces hansenii)* and biocontrol bacteria (*Bacillus amyloliquefaciens, B. subtilis*), have demonstrated encouraging effectiveness by enhancing the host's antioxidant defenses and inhibiting fungal proliferation (Pang et al., 2021; Dai et al., 2022). Natural compound including chitosan, alginate oligosaccharides, and essential oils works as bio-elicitors, inducing defense enzymes and enhance shelf life without compromising sensory quality (Liu et al., 2020; Chen et al., 2023).

3.4.6. Integrated Postharvest Technologies: The enhanced effectiveness of combined treatment approaches compared to individual ones is more effective, including 1-MCP in conjunction with ozone, lysozyme paired with temperature conditioning, and biocontrol with controlled atmospheres storage (Xia et al., 2024), which contribute to increasing fruit firmness, mitigating oxidative damage, and decreasing microbial contamination during storage. Similarly, innovative technologies such as smartphone-based RGB imaging are emerging swiftly. Non-invasive techniques for evaluating firmness, SSC, and shelf life make them highly beneficial for producers and distributors (Li et al., 2022). Xia et al. (2024) identified low-temperature strategies that enhance firmness, preserve vitamin C levels, and postpone senescence. The combined application of cold treatment with ozone, 1-MCP, and bio coatings has shown additional advantages compared to individual treatments. There are various effects of key postharvest treatments on kiwifruit quality indicators, including shelf-life extension, firmness retention, and decay reduction (Fig. 5).

3.5. Microbial Spoilage and Decay

Postharvest decay is a major cause of loss of kiwifruit stored. Pathogens such as *Botrytis cinerea* (gray mold) and *Penicillium spp*. (Blue mold) in which gray mold is often initiated at stem ends or wounds, causing soft, water rot. In contrast, blue mold creates blue-green sporulation lesions, as other fungi include *Alternaria alternata Botryosphaeria* sp., *Diaporthe* spp., *Mucor*, and Sclerotinia, in which Bortrytis cinerea is the most prevalent pathogen, causing significant decay and quality deterioration because it can grow in storage temperatures (0-1°C) so chilling is insufficient to control it (Tian et al., 2023). *Bacillus velezensis LX* has demonstrated potential in decreasing the cause of decay by modifying the microbial community present on the surface of kiwifruit as biological control (Duan et al., 2024).

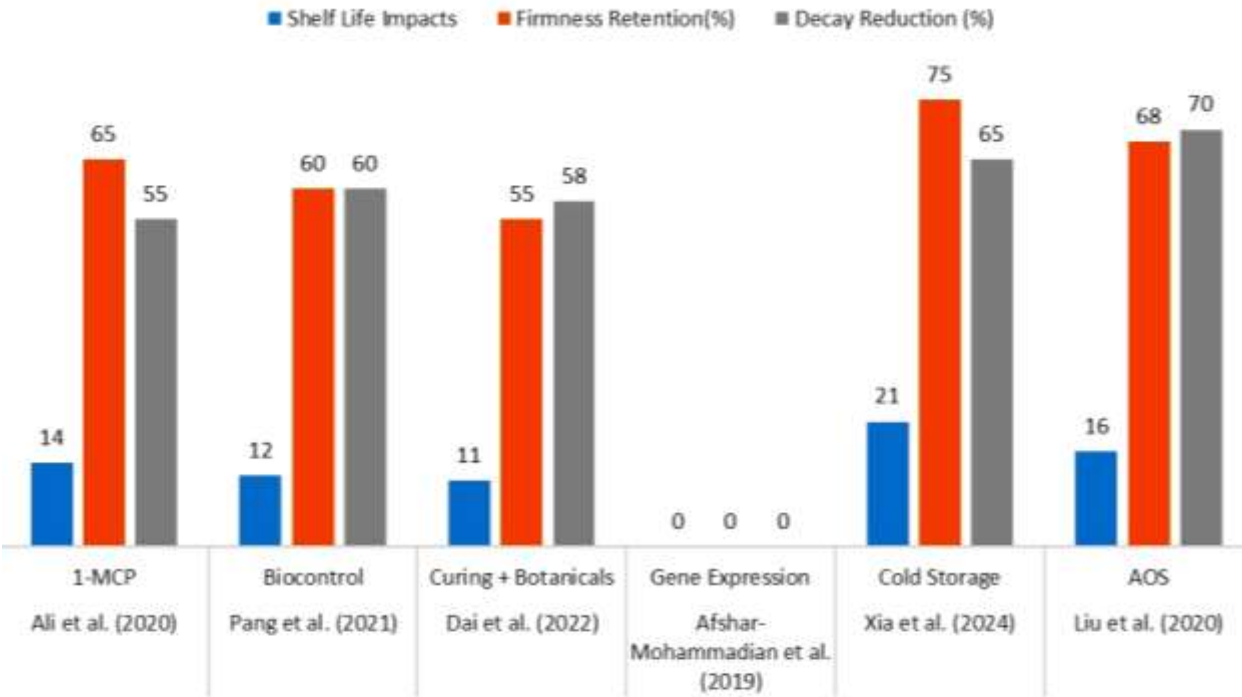

Fig. 5: Effectiveness of various studies on postharvest treatment in Kiwifruit.

The eco-friendly methods, such as hot water treatment at 45°C for 10min, can reduce fungal growth by inhibiting spore germination and enhance the fruit's antioxidant response without affecting quality (Chen et al., 2015; Peng et al., 2023). Additionally, the method including ozone treatment, edible coating, and biocontrol agent will together improve postharvest quality and resistance to decay as being eco-friendly methods (Lin et al., 2023). The advancement in packaging has gently enhanced the shelf life of kiwifruit. Active packaging utilizes elements such as sachets or inserts that capture undesirable gases or moisture. Like, Potassium permanganate sachets that function as ethylene scavengers have shown efficacy in extension in storage time and kiwifruit packaged in low-density polyethylene (LDPE) with $KMnO_4$ sachets (5g/kg of fruit) protects the quality for as long as seven months under refrigerated conditions (Thakur et al., 2018). The packaging system such as; MAP (Modified Atmosphere Packaging) works by altering the gas composition surrounding the fruit to slow down ripening and deterioration and reduces fruit softening and weight loss during both storage and display but in cold storage, MAP with specific gas concentration (12-15% O_2 and 3-4% CO_2) has been effective in maintaining the quality of kiwifruit (Dhakal et al., 2022; Han et al., 2022).

Notably consumer satisfaction for kiwifruit is influenced by it sweetness with and increased SSC(Soluble Solid Content) enhance flavor preference where fruit below 11-12% SSC are found lack of flavor preferences, although acidity contributes a degree of tartness, the levels of sugar exert a more pronounced effect on taste and fruit appearance is another factor ,the blemishes or wrinkles diminish its appeal, whereas yellow-fleshed varieties are often viewed as sweeter and more visually appealing. In summary, the most favored kiwifruit is characterized by their sweetness, moderate acidity, juiciness, and aromatic qualities (Rossiter et al., 2007).

4. CONCLUSION

Kiwifruit quality and shelf life are determined by the combination of fruit physiology, pre-harvest environment, harvest/handling practices, storage conditions, decay control, and market demands. The review reveals that the multifaceted strategies are most effective for growing fruit instantaneously under optimal orchard conditions to ensure high sugar and calcium levels. Harvesting of the kiwifruit at physiological maturity stages, then using low-temperature CA storage and maintaining ethylene control to slow aging, is also beneficial. Moreover, research and industry must align on consumer needs and preferences. The further research should focus on extending the commercial supply chain, modeling responses specific to cultivars, integrating multiple techniques to implement biocontrol methods, and utilizing digital monitoring technologies to enable technology-smart responses to post-harvest losses and decay. This review serves as a resource for scientists, researchers, and practitioners aiming to close knowledge gaps and implement integrated approaches to keep kiwifruit fresh and extend the shelf life of kiwifruit throughout the supply chain.

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