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Brassinosteroids: A Novel Green Molecules for Postharvest Shelf-Life Extension of Fruits and Vegetables

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Abstracts

Fruits and vegetable are highly perishable in nature having high moisture content around 80-90%. This high moisture leads to rapid deterioration leads to limits the shelf life so its need to use ecofriendly approaches that enhances the shelf life. Brassinosteroids (BRs), naturally occurring plant hormones, are found in all plants and affect a wide range of molecular, physiological, and biochemical processes. BRs regulate the ripening of climacteric and non-climacteric fruits, influence color development, and reduce chilling injury. By inhibiting enzymes like peroxidase and polyphenol oxidase, they delay enzymatic browning. Exogenous BR application prevents cell wall breakdown and slows fruit softening. These effects alleviate oxidative stress and extend the potential storage life of various fruits and vegetables. This article summarizes the diverse roles and mechanisms of BRs in prolonging postharvest shelf-life and preserving the quality of fruits and vegetables.

Keywords: Brassinosteroids, Browning, Delay softening, Chilling injury and Shelf life

Introduction

The demand for fresh fruits, vegetables, and flowers has increased significantly worldwide in recent years. Fresh fruits and vegetables are now recognized as essential components of a healthy human diet, while flowers play a vital role in various celebrations and events. However, ensuring a consistent supply of fresh produce to all consumers presents a significant challenge. Storing fruits and vegetables under low-temperature conditions generally extends their postharvest life, allowing them to remain fresh for a longer period. However, this practice can also lead to undesirable physiological disorders, primarily chilling injury and postharvest decay. These disorders can cause significant economic losses due to reduced marketability and consumer acceptance. Environmentally friendly and effective chemical treatments are needed to manage various postharvest problems in horticultural crops. BRs are natural plant hormones or phyto-hormones that were first discovered in rape pollen. BRs have been shown to have a significant growth-promoting effect on various crops. BRs play an important role in reducing various abiotic and biotic stresses at different levels. They have also been found to be effective in maintaining various quality attributes of fruits and vegetables. Applying Epibrassinosteroids (EBR) delayed the senescence of kiwifruit at room temperature. Postharvest EBR application also delayed chlorophyll degradation in lime fruits and leaf yellowing in broccoli florets (Cai et al., 2019).

Biosynthesis and mechanism

BRs are made from a starting material called campesterol through a series of steps. Scientists have found that there are two main pathways for making BRs: early C-6 oxidation and late C-6 oxidation. In the plant Arabidopsis, BRs are made from campesterol, which is first turned into campestanol. The campestanol is then turned into castasterone, which is finally turned into BRs. The highest levels of BRs are found in pollen and immature seeds. BRs, naturally derived plant hormones, offer a promising approach to extend the shelf life of fruits and vegetables by delaying senescence, scavenging reactive oxygen species, modulating ethylene signaling, and enhancing stress tolerance. Their multifaceted effects reinforce cell wall integrity, preserve texture and firmness, and maintain nutritional content, making them an eco-friendly solution for reducing postharvest losses of fruits and vegetables.

Role of brassinosteroids in postharvest management of fruits and vegetables Fruit ripening

BRs play crucial roles in the ripening process of various fruits. Applying EBR and Homo-Brassinolide (HBL) to tomatoes led to higher lycopene levels and faster chlorophyll breakdown. This enhanced ripening was linked to increased ethylene production, which sped up the ripening process. Applying BRs externally triggers their increased internal production due to the upregulation of the GhDWF4 gene, which ultimately accelerated ripening in tomato fruits.

Another study found that external BR application increased their internal content and upregulated FaBRI1 gene expression, which subsequently led to accelerated red color development and ripening in strawberry fruits (Chai et al., 2013)

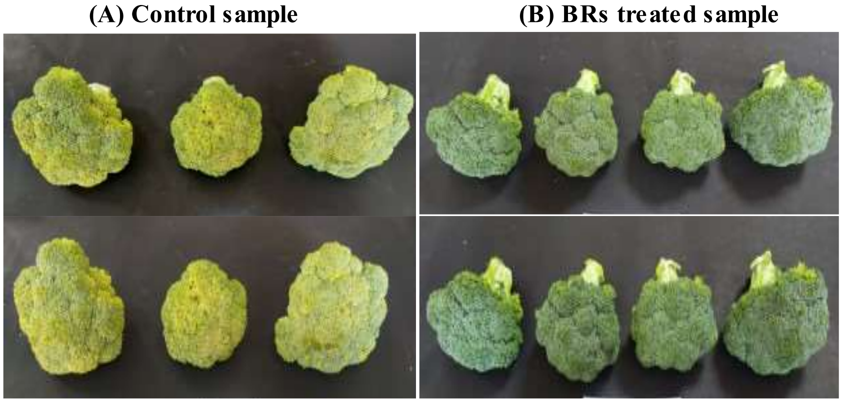

Fig 1. Effect of BRs on shelf life of broccoli during storage

Chilling injury

Chilling injury (CI) is a major postharvest physiological disorder that affects a wide variety of horticultural crops during cold storage. CI generally depends on maturity stage and cultivar. CI leads to quality degradation and limits postharvest storage life. CI also negatively affects the integrity of cell membranes. BRs play an important role in the chilling tolerance of fruit and vegetable crops. It was observed that higher BRs concentration led to cold tolerance of cucumber. Application of 15 μmol L-1 BRs alleviated CI (indicated by reduced calyx discoloration and surface pitting) in green bell pepper fruits at 3 °C storage. Treatment of eggplant with 10 μmol L-1 EBR reduced electrolyte leakage that in turn reduced the symptoms of CI at 1 °C conditions (Wang et al., 2012).

Postharvest browning

Postharvest browning is a major undesirable disorder that occurs in various fruits and vegetables. Browning not only diminishes the visual appeal of the produce but also leads to decreased market potential and purchase decisions by consumers. BRs have been found to have anti-browning properties. In eggplant, treatment with 10 μmol L-1 EBR reduced the increase in PPO and POD activities and delayed pulp browning for 15 days at 1 °C. Application of 3 μL BL treatment significantly reduced browning of white button mushrooms for 16 days during storage at 4 °C. Similarly, treatment with 80 nmol L-1 EBR suppressed quinone production and reduced PPO and POD activities, along with reduced phenols oxidation, which effectively inhibited enzymatic browning in lotus root slices (Gao et al., 2017).

Table 1: Effects of brassinosteroids on postharvest quality and shelf life of fruits and vegetables.

Crop	Concentration	Results
Asparagus	10 µML^{-1}	Reduced weight loss and respiration rate and maintained fruit quality with higher vitamin C and total phenolic contents.
Broccoli	2 µML^{-1}	Reduced yellowing of florets and extended shelf life. Increased expression of BoACO3 and BoACS4 genes
Kiwifruit	5 µML^{-1}	Retarded firmness loss, decreased ion leakage and MDA content. Reduced sugars such as sucrose, glucose and fructose accumulation
Mango	10 µML^{-1}	Alleviated chilling injury and up-regulated differential proteins. Increased ethylene production and accelerated ripening
Persimmon	10 µML^{-1}	Increased cell-wall-degrading enzymes activities and accelerated ripening. Reduced expression of DkPL1, DkEGase1, DkPE2 and DkPG1 genes
Tomato	3 µML^{-1}	Accelerated ripening due to increased respiration rate and ethylene production. Increased soluble solid content, lycopene and ascorbic acid content. Also increased ethylene biosynthesis related genes

Colour metabolism

Color in fruits and vegetables holds significant importance, influencing the purchasing decisions of consumers in the market. The color attribute plays a pivotal role in the market potential of specific crops, and any decline in color directly impacts the visual quality of the commodity. Employing a vacuum infiltration of 10 µmol L-1 BRs demonstrated a capacity to decrease chlorophyll degradation, preserving the green coloration of both 'Tahiti' and 'Persian lime' fruits by impeding the onset of yellowing. This treatment also exhibited an increased hue angle and decreased chroma values in both lime cultivars. Similarly, a 2 µmol L-1 EBR spray application had a comparable effect, reducing yellowing, elevating chlorophyll levels, and enhancing chlorophyll fluorescence in both lime cultivars. These interventions resulted in significantly diminished yellowing in broccoli florets by curbing chlorophyll breakdown and promoting higher chlorophyll fluorescence.

Ethylene biosynthesis and respiration rate

The regulation of ethylene and respiration is crucial for extending the storage and shelf life of produce, as heightened levels of these factors often lead to accelerated senescence. Implementing appropriate treatments to mitigate the climacteric peak of ethylene and respiration is essential. However, the impact of BRs on ethylene production and respiration rate appears to be complex and, at times, contradictory. In the case of 'Kensington Pride' mango fruits, an application of EBR treatment resulted in a significant increase in both respiration rate and ethylene production during ambient storage, suggesting a potential role in hastening the senescence process. Conversely, postharvest exposure of tomato fruits to 3 µmol L-1 BRs amplified the activities of ethylene biosynthesis-related genes, such as LeACS2, LeACS4, LeACO4, and LeACO1, consequently enhancing ethylene production and respiration rate. In stark contrast, the immersion of green asparagus spears in a 10 µmol L-1 BRs solution led to a substantial reduction in the respiration rate, pointing towards a potential positive impact on prolonging shelf life. These divergent effects underscore the need for a nuanced understanding of the interplay between BRs, ethylene, and respiration in different plant species.

Postharvest softening

The rapid softening of climacteric fruits poses a significant challenge in terms of their storage and shelf life potential. This softening process is closely associated with the disassembly of cell walls, and various enzymes, including pectin esterase (PE), polygalacturonase (PG), β-galactosidase (β-gal), endo-1,4-β-glucanase (EGase), and pectate lyase (PL), have been identified as key contributors to this phenomenon. Managing fruit softening necessitates a reduction in the activities of these enzymes. In the context of persimmon fruits, specific treatments were employed to achieve this goal, leading to notable outcomes. These treatments not only resulted in higher cellulose and pectin content but also increased acid-soluble pectin in persimmon fruits. Crucially, the reduced activities of EGase, PL, PG, and β-gal, coupled with the enhanced conservation of various pectin components, ultimately contributed to a significant suppression of softening in persimmon fruits during ambient storage. These findings highlight the potential of enzyme activity modulation as a targeted approach to mitigate the rapid softening that compromises the storage and shelf life of climacteric fruits (He et al., 2018).

Postharvest decay

Fresh vegetables and fruits, characterized by their perishable nature and living cells, undergo continuous respiration during ripening, which not only provides energy but also renders them more susceptible to decay in the later stages of postharvest storage. Postharvest decay poses a significant threat to the quality and quantity of produce, primarily attributed to bacterial and fungal pathogens. Among these, fungal diseases are particularly critical, resulting in substantial economic losses for commodities. The decay of fruits and vegetables after harvest can be attributed to latent infections originating in the field or through wounds incurred during harvesting and subsequent handling throughout the supply chain. Effectively controlling postharvest decay is imperative to minimize losses in the overall produce. In this regard, a postharvest treatment with 5 µmol L-1 BRs demonstrated promising results by increasing the activities of phenylalanine ammonia lyase (PAL) and polyphenol oxidase (PPO). This treatment significantly suppressed *Penicillium expansum* induced blue mold rot in jujube fruits, suggesting the potential of BRs as a control measure against postharvest decay and its associated economic ramifications.

Conclusion

The exploration of BRs as novel green molecules for postharvest shelf-life extension of fruits and vegetables represents a promising avenue in agricultural research. The unique properties of BRs, derived from plant steroids, offer an environmentally friendly and sustainable solution to address the challenges associated with postharvest losses. The positive impact of BRs on delaying senescence, preserving quality attributes, and enhancing stress tolerance in fruits and vegetables underscores their potential as a valuable tool in ensuring food security and reducing waste. Further research and practical applications will be essential to fully unlock the potential of BRs in transforming postharvest management, contributing to a more resilient and sustainable food system.

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