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Opinion Article

Genetic Modification and Sustainable Solutions for Enhanced Postharvest Quality

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ABOUT THE STUDY

Postharvest losses of fruits, vegetables, and ornamentals pose significant challenges to global food security, economic stability, and environmental sustainability. The postharvest period is characterized by various physiological, biochemical, and microbial changes that lead to deterioration in quality, resulting in economic losses and reduced consumer satisfaction. Consequently, it is essential to use efficient target approaches in order to improve the postharvest quality and extend the time of use of these perishable goods.

Physiological approaches focus on managing the physiological processes occurring in harvested produce to maintain quality. One such approach is temperature management, where maintaining optimal storage temperatures slows down metabolic activities and reduces physiological disorders. Controlled atmosphere storage is another technique that involves regulating oxygen, carbon dioxide, and ethylene levels to slow down respiration rates and delay senescence. Furthermore, pre-harvest practices such as proper irrigation, nutrition management, and harvesting at the right maturity stage can significantly impact postharvest quality.

The enzymatic and non-enzymatic processes causing postharvest degradation are the focus of biochemical methods. Using both synthetic and natural antioxidants is an effective method to reduce oxidative stress and stop enzymatic browning. Furthermore, ripening and senescence processes are postponed by treatments including inhibitors of ethylene production or action, prolonging the life of the product. Moreover, the stress tolerance of harvested produce can be improved by increasing the amounts of endogenous antioxidants through genetic alteration or elicitor treatments.

Microbial approaches involve the use of beneficial microorganisms to control spoilage and pathogenic microorganisms, thereby preserving postharvest quality. Biological control agents such as antagonistic bacteria and fungi can inhibit the growth of postharvest pathogens through competition for nutrients and space or by producing antimicrobial compounds. Furthermore, bio control agents can induce systemic resistance in plants, enhancing their natural defense mechanisms against pathogens.

Physical approaches involve the application of physical treatments to minimize postharvest losses and maintain quality. Modified Atmosphere Packaging (MAP) creates a protective atmosphere around the product, reducing respiration rates and microbial growth. Furthermore, non-destructive techniques such as infrared heating, Ultra Violet-C (UV-C) irradiation, and Pulsed Electric Field (PEF) treatments can effectively control microbial growth and maintain nutritional quality without affecting the sensory attributes of the produce. Additionally, postharvest treatments such as hot water immersion, vapour heat, and cold storage can control pests and pathogens, thereby preserving quality.

Nanotechnology offers innovative approaches for improving postharvest quality by exploiting the unique properties of nanomaterial's, nano encapsulation of bioactive compounds enhances their stability, solubility, and bioavailability, thereby improving their efficacy in preserving postharvest quality. Nanocomposite packaging materials incorporating nanoparticles with antimicrobial properties inhibit microbial growth and maintain the freshness of the produce. Moreover, nanosensors and nanoprobes enable real-time monitoring of physiological and biochemical changes in harvested produce, facilitating timely interventions to preserve quality.

Genetic approaches involve the manipulation of plant genetics to enhance postharvest quality traits such as flavour and nutritional content. Breeding for improved postharvest traits such as firmer texture, reduced susceptibility to bruising, and enhanced disease resistance can minimize losses during handling and transportation. Furthermore, genetic engineering techniques enable the enhancement of key metabolic pathways involved in postharvest processes, such as ethylene biosynthesis and antioxidant metabolism, to prolong shelf life and maintain quality.

Integrated approaches combine multiple strategies to synergistically enhance postharvest quality and minimize losses. For example, combining physical treatments with natural and synthetic antioxidants can provide enhanced protection against oxidative stress and microbial spoilage. Similarly, integrating bio control agents with modified atmosphere packaging can extend product life while maintaining safety and quality. Furthermore,

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adopting a comprehensive approach that considers pre-harvest practices, postharvest treatments, and supply chain management can optimize postharvest quality throughout the entire production and distribution process.