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Smart Active Packaging to Regulate Respiration in Fruit Crops

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INTRODUCTION

Fresh fruits continue to respire after harvest, consuming oxygen (O₂) and releasing carbon dioxide (CO₂), water vapor, and heat. High respiration rates accelerate ripening, softening, and deterioration, which reduces shelf life and market quality. Smart active packaging is an emerging post-harvest technology that helps regulate the internal atmosphere of packaged fruits to slow respiration and maintain freshness during storage and transportation.

Smart packaging integrates active packaging components and intelligent monitoring systems that interact with the fruit and surrounding environment. These technologies help maintain optimal gas composition, reduce microbial growth, and extend the storage life of fruits.



2. What is Smart Active Packaging?

Smart active packaging refers to packaging systems that actively control or modify the internal conditions of the package to maintain product quality. It combines two major concepts:

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Active Packaging:

Uses materials that absorb or release substances such as oxygen, carbon dioxide, moisture, or ethylene to control fruit respiration.

Intelligent Packaging:

Uses sensors, indicators, or labels to monitor freshness, temperature, and gas composition inside the package.



3. Components of Smart Active Packaging

A) Oxygen Scavengers

Oxygen absorbers remove excess oxygen from the package, which helps slow down fruit respiration and prevents oxidation.

B) Ethylene Absorbers

Ethylene is a natural ripening hormone produced by many fruits. Ethylene absorbers remove excess ethylene and delay ripening in fruits such as banana, mango, and apple.



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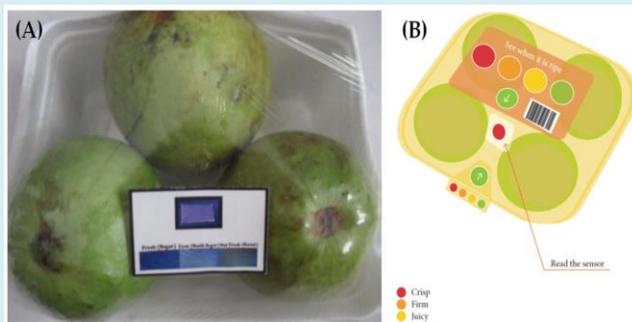
C) Moisture Regulators

Moisture regulators are important components of smart active packaging used in fruit storage. Moisture control pads absorb excess water vapor released by fruits during respiration and transpiration. By removing excess moisture, they help reduce microbial growth and prevent spoilage. These pads also minimize condensation inside the package, which helps maintain fruit firmness and texture. As a result, the overall quality and shelf life of fruits are improved during storage and transportation.



D) Freshness Indicators and Sensors

Freshness indicators and sensors are intelligent components used in smart packaging systems for fruits. These indicators respond to changes in temperature, gas composition, or storage conditions inside the package.



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They often change color to provide a visual signal about the freshness and quality of the fruit. This helps producers, retailers, and consumers easily monitor the condition of fruits during storage and transportation. By providing real-time information, these sensors help ensure better quality control and reduce post-harvest losses.

4. Advantages of Smart Active Packaging

- Extends shelf life of fresh fruits
- Reduces post-harvest losses
- Maintains fruit quality and freshness
- Slows down respiration and ripening
- Improves food safety and consumer confidence
- Facilitates long-distance transportation and export

5. Applications in Fruit Crops

Smart active packaging is widely used for high-value fruit crops such as apple, mango, banana, strawberry, grapes, and cherry. These fruits are highly perishable and continue to respire after harvest, which accelerates ripening and quality deterioration. Smart active packaging systems help regulate the internal atmosphere of the package by controlling oxygen, carbon dioxide, and ethylene levels. By maintaining an optimal gas composition inside the package, these technologies slow down the respiration rate, delay ripening, and reduce post-harvest losses. As a result, the freshness, quality, and storage life of fruits are significantly improved during storage, transportation, and marketing.

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CONCLUSION

Smart active packaging is an advanced post-harvest technology used to maintain the quality and freshness of fruit crops. It helps regulate the internal atmosphere of the package by controlling oxygen, carbon dioxide, and ethylene levels. By maintaining optimal gas composition, the respiration rate of fruits is slowed down, which delays ripening and senescence. This technology also helps reduce microbial growth and moisture accumulation inside the package. As a result, the shelf life of fruits is significantly extended during storage and transportation. Smart active packaging also helps maintain fruit texture, flavor, and nutritional quality. Adoption of this technology can reduce post-harvest losses and enhance the marketability of fruits.

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