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Nano-Technology in Post Harvest Preservation

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Fruits and vegetables can lose their freshness after harvesting due to various factors, including physical damage during harvesting, moisture loss, unfavorable weather conditions and microbial infestations by pests, molds and bacteria. Fruits, particularly, are more prone to spoilage and loss than vegetables. Several preservation techniques are used to enhance the postharvest quality and extend the shelf life of produce. A key emerging method is nano-preservation, which involves advanced technologies such as nano-edible coatings, active packaging, innovative packaging, nanocomposites, nanofilms and nano-biosensors. These techniques aim to improve the preservation of fruits and vegetables, ensuring they stay fresh longer.

Defination of Nano -technology

Nanotechnology is the study and use of materials at the nano-scale (1–100 nanometers) to create new properties and functions. At this level, materials exhibit enhanced Mechanical, thermal, and antimicrobial properties due to increased surface area and quantum effects. In post-Harvest management, it includes innovations such as antimicrobial coatings, nano-enabled sensors for Spoilage detection, and nanoemulsions for extending the shelf life of perishable produce.

Significance of Applying Nanotechnology in Post-Harvest Management

Nanotechnology offers numerous advantages in addressing the challenges of post-harvest losses.

- Nano-edabled antimicrobial coatings and films prevent microbial infections, which are responsible for significant spoilage. For example, silver nanoparticles integrated into packaging have shown to reduce microbial spoilage in strawberries by 50%, extending their shelf life by up to 10 daysunder refrigerated conditions.
- Nanosensors embedded in packaging materials can detect ethylene, moisture, and microbial activity, providing real-time feedback on the storage environment.
- Nanotechnology also supports sustainability through the development of biodegradable Nanocomposites, reducing the environmental footprint of packaging materials.

Types of Nanomaterials Relevant to Post-Harvest Applications

1. Nanoparticles

- Nanoparticles are materials with dimensions in the nanoscale and are extensively used in post-harvest management due to their antimicrobial and antioxidant properties.
- Metal and metal oxide nanoparticles such as silver (Ag), zinc oxide (ZnO), and titanium dioxide (TiO2).
- Silver nanoparticles have been shown to reduce microbial spoilage in strawberries and citrus fruits, significantly extending their shelf life during storage.

- Zinc oxide nanoparticles enhance packaging films by improving UV protection and reducing oxidative damage, thus maintaining the quality of stored produce .

2. **Nanocomposites**

- Nanocomposites are hybrid materials formed by embedding nanoscale fillers into a matrix to improve mechanical, thermal, and barrier properties.
- These materials are particularly effective in food packaging applications, where they minimize oxygen and moisture ingress, thus slowing down respiration and ethylene-mediated ripening in climacteric fruits.
- For example, nanoclay-reinforced polymer films have demonstrated superior gas barrier properties, extending the freshness of fruits like bananas and apples during storage.

3. **Nano emulsions**

- Nanoemulsions are colloidal systems with nanoscale droplets, typically less than 200 nm in size.
- These systems improve the solubility, bioavailability, and stability of active compounds, making them ideal for coatings and sprays.
- Ex- Oregano oil , have strong antifungal activity against spoilage-causing pathogens in citrus fruits.

Mechanisms of Action in Post-Harvest Preservation

Nanotechnology enhances post-harvest preservation through multiple mechanisms that address critical factors contributing to spoilage and quality degradation .

1. Antimicrobial Activity:

Nanoparticles such as silver, zinc oxide, and chitosan exhibit potent antimicrobial properties by generating reactive oxygen species (ROS) and disrupting microbial membranes. These mechanisms effectively inhibit the growth of spoilage-causing microorganisms like Escherichia coli and Pseudomonas spp., reducing contamination and extending the shelf life of horticultural produce.

2. Enhanced Gas Barrier Properties:

Nanocomposites improve the gas barrier performance of packaging materials, reducing oxygen and carbon dioxide permeability. This slows respiration and ethylene production in climacteric fruits, delaying ripening and senescence. For example, nanoclay-reinforced films have been shown to Preserve the freshness of fruits like mangoes and guavas for extended periods .

3. Controlled Release of Active Agents:

Nanotechnology enables the controlled release of active compounds such as preservatives, antimicrobial agents, and ethylene scavengers. Encapsulation systems using chitosan nanoparticles provide a gradual and sustained release of essential oils, maintaining their efficacy over longer storage periods and preventing fungal decay.

4. Real-Time Monitoring:

Nanosensors integrated into packaging systems detect spoilage indicators such as ethylene, ammonia, and microbial byproducts. These sensors provide real-time data on the storage environment, allowing for timely corrective measures to prevent quality loss. Sensors that change color in response to ethylene levels are increasingly being used in packaging systems for climacteric fruits .

5. Physical Protection

Nano-coatings create protective barriers on the surface of fruits and vegetables, reducing moisture loss, microbial infiltration, and mechanical damage. Silica-based coatings have been successfully applied to tomatoes, reducing weight loss by up to 15% during storage and enhancing their marketability. By employing these mechanisms, nanotechnology provides a comprehensive approach to improving the efficiency and sustainability of post-harvest systems. These advancements not only reduce spoilage and losses but also ensure the safety and quality of horticultural produce, meeting the demands of a growing population.

Applications of Nanotechnology in Post-Harvest Preservation

1. Nano-Packaging: Nanoparticles are incorporated into packaging materials to improve:Antimicrobial properties (against bacteria and fungi),Barrier properties (oxygen, moisture, ethylene),Mechanical strength ,temperature resistance.

Common nanomaterial used for packaging

1. Silver nanoparticles (AgNPs) – strong antimicrobial effec
2. Titanium dioxide (TiO_2) – antimicrobial, UV protection.
3. Zinc oxide (ZnO) – antimicrobial.
4. Chitosan nanoparticles – natural, antibacterial, biodegradable.

Example -Nano-silver packaging extends shelf life of tomatoes, strawberries.

2. Nano-Coatings / Edible Nano-Films

Very thin edible coatings made using nanomaterials create a protective layer on fruits/vegetables.

Function

- Reduce moisture loss.
- Slow respiration rate.
- Delay ripening.
- Control microbial spoilage

Material used

- Nano-chitosan.
- Nano-cellulos.
- Nano-lipid films.
- Starch-based nano-coatings.

Example

- Nano-chitosan coating extends shelf life of bananas and papaya.
- Nano-aloe vera coatings used on citrus fruits.

3. Nano-Sensors for Smart Packaging

Nano-sensors detect real-time changes in food quality.

They can detect:

- Spoilage indicators (pH, gases, temperature).
- Pathogens (E. coli, Salmonella.
- Ethylene level (fruit ripening).
- Freshness indicators (colour-change labels).

Example

- Nano-sensors detecting ethylene to monitor banana and mango ripening.
- RFID + nano-sensors used for tracking fruit quality.

4. Nano-Encapsulation

Nanoparticles are used to encapsulate bioactive compounds to protect and release them slowly.

Function

- Slow release of antimicrobials
- Controlled release of antioxidants
- Protection of vitamins from oxidation

Material used

- Nano-emulsions
- Lipid nanoparticles
- Polymer nanoparticles

Example –

Nano-encapsulated essential oils (clove, cinnamon, oregano) used as natural preservatives.

Advantage of Nano -technology in Post harvest preservation

- Extends Shelf Life

- Improves Food Safety
- Smart / Intelligent Packaging
- Better Quality Retention
- Controlled Release of Preservatives
- Reduces Post-Harvest Losses
- Eco-friendly Packaging
- Improved Barrier Properties.

Conclusion

Nanotechnology in post-harvest preservation helps extend the shelf life of fruits and vegetables by using nano-coatings, nano-packaging, and nano-sensors that reduce microbial spoilage, maintain quality, and improve food safety. It provides better barrier protection, controlled release of preservatives, and real-time freshness monitoring, resulting in lower post-harvest losses and improved product quality.

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