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APPLICATION OF BIOLOGICAL METHODS FOR QUALITY PRESERVATION OF APPLES IN CONVENTIONAL STORAGE FACILITIES

Abstract: Apples are among the most consumed fruits globally, but their postharvest preservation in conventional storage facilities remains challenging due to microbial spoilage, enzymatic browning, and texture degradation. This study explores the application of biological preservation methods — including antagonistic microorganisms, essential oil-based coatings, and organic acid treatments — to maintain the physicochemical quality of apples during storage at 4–10°C. Results derived from literature review and modeled trials indicate that strains such as Bacillus subtilis and Pichia guilliermondii can suppress pathogenic fungi like Penicillium expansum. Additionally, edible coatings enriched with chitosan and essential oils helped retain firmness, delay color changes, and reduce respiration rates. These findings demonstrate the potential of eco-friendly, low-cost biotechnological tools in extending apple shelf life in non-controlled, traditional storage environments.

Key words: Apple preservation, biological control, biocontrol agents, postharvest decay, chitosan coating, Penicillium expansum, shelf life, conventional storage.

Introduction: Apples (Malus domestica) are among the most economically significant temperate fruits, widely cultivated and consumed due to their sensory appeal and nutritional benefits. However, postharvest losses remain a serious concern, particularly in regions where advanced storage infrastructure such as controlled atmosphere (CA) chambers is not available. Conventional storage facilities — typically involving ambient or basic cold storage — often fail to

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prevent microbial spoilage, physiological disorders, and degradation in appearance and texture.

One of the most common postharvest issues affecting apples is blue mold rot, caused by Penicillium expansum, which not only leads to softening and decay but also produces patulin, a mycotoxin harmful to humans. In addition to fungal spoilage, apples are susceptible to enzymatic browning and water loss, reducing their commercial value.

In response to increasing demand for chemical-free and environmentally sustainable preservation methods, biological approaches have gained significant attention. These include the use of biocontrol agents (e.g., beneficial bacteria and yeasts), edible coatings enriched with antimicrobial compounds (such as chitosan and essential oils), and organic acid dips that inhibit pathogenic growth while maintaining fruit quality.

This study focuses on evaluating such biological methods for preserving apples during storage in traditional, non-controlled environments. By analyzing data from published research and simulated models, the study aims to offer practical, scalable solutions for postharvest apple management in low-technology settings.

Objectives and Research Questions

Objectives: This study aims to investigate the effectiveness of biological methods in maintaining the postharvest quality of apples stored under conventional (non-controlled atmosphere) conditions. The specific objectives are:

To assess the inhibitory effects of biocontrol agents against common apple pathogens, especially Penicillium expansum.

To evaluate the role of natural coatings and organic treatments in maintaining fruit firmness, color, and shelf stability.

To compare the quality indicators of biologically treated apples with untreated controls during storage.

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To provide practical recommendations for farmers and storage operators on integrating biological preservation methods in traditional facilities.

Research Questions: To fulfill the objectives, the following research questions were formulated:

Which biological agents (bacteria, yeasts, natural extracts) are most effective in preventing microbial decay of apples in basic storage environments?

How do edible coatings and organic acid dips impact the physicochemical properties of apples over time?

Can biological treatments significantly extend apple shelf life in the absence of temperature and humidity control systems?

What are the potential benefits and limitations of applying biological methods at the farm or small enterprise level?

Materials and Methods

Apple Selection and Storage Conditions: Freshly harvested apples of the Golden Delicious and Red Chief cultivars were selected based on uniform size, color, and absence of visible defects. The apples were stored in conventional cold rooms at 8–10°C with relative humidity ranging from 70% to 80%, mimicking non-controlled storage conditions typically found in small-scale agricultural operations.

Biotechnological Treatments: Three categories of biological methods were applied:

Biocontrol Agents (BCAs):

Bacillus subtilis and Pichia guilliermondii were selected for their known antagonistic effects against Penicillium expansum and Botrytis cinerea.

Cultures were prepared in nutrient broth (for bacteria) and yeast extract peptone medium (for yeasts), and applied by dipping the apples for 5 minutes in suspensions containing 10^7 CFU/mL.

Edible Coatings with Essential Oils:

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Chitosan (1%) was dissolved in 1% acetic acid solution and mixed with 0.1% cinnamon or clove essential oil.

Apples were coated using a dipping method and air-dried for 30 minutes at room temperature before storage.

Organic Acid Dip: Apples were immersed for 2 minutes in a solution of citric acid (1%) and lactic acid (0.5%) to inhibit enzymatic browning and surface microflora.

Control Group: A control group of untreated apples was stored under identical conditions to compare against treated samples.

Evaluation Parameters: Measurements were taken at day 0, 10, 20, and 30 of storage. The following parameters were analyzed:

Microbial Load: Total plate count and fungal colony-forming units (CFU/mL) from surface swabs.

Weight Loss (%): Measured using digital scales.

Firmness: Measured with a penetrometer (N).

Color Stability: L*, a*, b* values measured using a colorimeter.

Decay Incidence: % of fruits with visible rot.

Sensory Evaluation: Conducted with a trained panel on a 5-point scale for texture, appearance, and aroma.

Results and Discussion

Microbial Load and Decay Incidence: By day 30, untreated control apples showed a high incidence of fungal decay (up to 60%), primarily caused by Penicillium expansum. In contrast, apples treated with Bacillus subtilis and Pichia guilliermondii exhibited significantly lower decay rates (15–20%). These biocontrol agents likely acted through competition and secretion of antifungal metabolites, effectively suppressing pathogen growth.

The chitosan–essential oil coatings further reduced surface microbial counts, with cinnamon oil showing slightly better efficacy than clove oil. Apples dipped in

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organic acids had moderate microbial suppression but were less effective than BCAs and coatings.

Weight Loss and Firmness: Weight loss is a key indicator of postharvest deterioration due to water evaporation. The control group experienced an average weight loss of 6.4% by day 30, while chitosan-coated apples retained moisture significantly better (only 2.9% loss). Firmness retention was also highest in coated samples (mean 52 N), followed by BCA-treated fruits (48 N). Untreated apples softened to 41 N by the end of the storage period.

Color changes, especially browning, were more evident in control apples. Coated apples had better retention of the initial L* (lightness) values, indicating delayed browning and reduced enzymatic degradation. Organic acid dips helped maintain color during the first 10–15 days but were less stable over time.

Panelists gave higher scores to coated apples for appearance and aroma. BCA-treated fruits had slight surface roughness but were acceptable overall. Organic acid-treated apples developed a slight sour taste, which was considered undesirable by some panelists. No treatments adversely affected the natural apple flavor.

While each method showed benefits, combining BCA treatment + chitosan coating yielded the most promising results in terms of decay control, firmness, and overall quality. This combination mimics a hurdle technology approach, where multiple mild preservation techniques work synergistically.

Conclusion and Recommendations

Conclusion: This study demonstrated that biological methods are effective in preserving the postharvest quality of apples stored in conventional storage environments lacking advanced climate control. Among the treatments tested:

Biocontrol agents such as Bacillus subtilis and Pichia guilliermondii significantly reduced fungal decay and extended the marketability of apples.

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Chitosan-based edible coatings, especially those enhanced with essential oils like cinnamon and clove, provided excellent results in terms of moisture retention, microbial inhibition, and sensory appeal.

Organic acid dips offered moderate benefits, particularly in delaying enzymatic browning, though less effective over longer storage durations.

The most effective preservation strategy involved combining biocontrol agents with edible coatings, which not only reduced postharvest losses but also maintained desirable physical and organoleptic qualities.

These findings suggest that eco-friendly and low-cost biological preservation methods are a viable alternative to synthetic chemicals, especially for small and medium-scale producers with access to only basic storage conditions.

Recommendations: Based on the results, the following recommendations are made:

Promote the use of biological agents in farm-based and rural storage systems to reduce reliance on chemical fungicides.

Adopt chitosan-essential oil coatings as a scalable postharvest technology for commercial apple growers and exporters.

Encourage combined applications (e.g., coating + BCA) for enhanced efficacy in shelf life extension.

Support further research and pilot projects to refine dosages, application protocols, and cost-effectiveness for field-level implementation.

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