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Advances in Post-Harvest Technologies for Extending Shelf Life of Roots and Tuber Crops

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SUMMARY

Roots and tubers are vital food staples, particularly in tropical and subtropical regions, contributing significantly to global food security. However, they are highly perishable due to their high moisture content, leading to significant post-harvest losses. Extending their shelf life through innovative post-harvest technologies is crucial to improving food availability, reducing waste, and enhancing economic returns for farmers and the supply chain. This review critically examines recent advancements in post-harvest technologies designed to extend the shelf life of root and tuber crops, which include traditional storage methods, modern refrigeration systems and controlled atmosphere storage, which regulate temperature, humidity and gas composition to delay spoilage. Emerging technologies such as enzymatic inhibition, edible coatings and the use of natural biopreservatives are also explored for their potential to reduce physiological deterioration, microbial spoilage and enzymatic browning which are common in tubers.

INTRODUCTION

Roots and tubers, such as yams, cassava, potatoes and taro play a critical role in global food security, particularly in tropical and subtropical regions. These crops are rich in carbohydrates and essential nutrients including carbohydrates, vitamins, and minerals, making them staple foods for millions of people. They serve as staple foods for millions of people, providing essential nutrients (Sanni and Adebowale, 2003). However, these crops are highly perishable due to their high moisture content, which makes them susceptible to microbial spoilage, enzymatic browning, and physiological deterioration (Tolcha, 2013). Post-harvest losses can be significant, often reaching 30–50% of the total yield, especially in developing countries where proper storage and preservation technologies may be lacking (FAO, 2018). Over the past few decades, various post-harvest technologies have been developed and improved to extend the shelf life of roots and tubers, thereby reducing losses and improving food security.

Traditional Storage Methods and their Limitations

Historically, roots and tubers have been stored using traditional methods, such as underground pits, barns, or simple platform structures made of local materials. While these methods are cost-effective, they often fail to provide adequate protection against environmental factors like humidity, temperature fluctuations, and pests. As a result, traditional storage methods are associated with high levels of spoilage and significant losses (Tolcha, 2013). The traditional yam barn is the most popular structure for yam storage and some other tubers. It consist of a framework of vertical poles of farm wood or stakes which are spaced about one meter (Babarinsa, 2004). The yam barn provides adequate ventilation for the stored tubers without excessive moisture loss. Possible sources of losses while using this structure are sprouting, rotting and moisture loss (Babarinsa, 2004). Underground Storage and in-ground storage are methods for storing potatoes and cassava roots. Underground storage involves keeping tubers in a circular pit lined with leaves to protect them from soil temperature changes. In-ground storage, on the other hand, involves leaving roots un-harvested until needed, but can lead to rot, decreased extractable starch content, and increased pest attacks (Aromolaran *et al.*, 2001). The Platform Storage method is used for different roots and tuber crops like yam, cassava, irish potatoes, sweet potatoes and onions. The crops are carefully laid on the constructed platform made of woods and covered with palm leaves. The crops are predisposed to rodent, insect and pest attacks. While the Clamp Storage involves keeping the roots piled up in the field into heaps covered with layers of straw or palm leaves and soil to a thickness which varies according to farmers' experience (Babarinsa, 2004).

Advances in Post-Harvest Technologies: Recent advances in post-harvest technologies have significantly improved the shelf life of roots and tubers. These innovations can be categorized into several key areas such as temperature control methods, post-harvest chemicals, biological control methods and coatings/packaging techniques (FAO, 2017).

Cold storage is one of the most common and effective methods for prolonging the shelf life of roots and tubers. By lowering the storage temperature, metabolic activities, respiration rates, and microbial growth can be slowed down, which helps preserve the quality of the produce (Opara, 2009). Potatoes, for instance, are typically stored at 4°C to 12°C, which can extend their shelf life by several months (Mousa *et al.*, 2017). However, cold storage may lead to chilling injury in certain crops, particularly in tropical species like cassava and yams, which are sensitive to low temperatures. Chilling injury manifests in the form of discoloration, water-soaked appearance, and increased susceptibility to decay (Rees *et al.*, 2012).

Controlled atmosphere (CA) storage is another advanced storage which entails modifying the concentrations of oxygen (O_2), carbon dioxide (CO_2), and nitrogen (N_2) in the storage environment in order to slow down respiration and delay spoiling. Studies have demonstrated that in tubers such as potatoes and yams, lowering O_2 levels and raising CO_2 levels can prevent the growth of spoilage bacteria and delay the onset of sprouting and senescence (Thompson *et al.*, 2015). For instance, a CA environment containing 5% O_2 and 5% CO_2 was found to be effective in prolonging the storage life of sweet potatoes by limiting enzymatic browning and inhibiting microbiological activity (Woolfe, 2019).

Another interesting post-harvest technique is modified atmosphere packaging (MAP), which modifies the atmospheric composition around the product inside the packaging and thereby enhancing shelf life. This can be achieved through vacuum packing or flushing with gases like CO_2 or nitrogen. MAP has shown promising results in extending the shelf life of roots and tubers, such as potatoes and cassava, by minimizing enzymatic browning and microbiological spoilage (Ray *et al.*, 2020) and they may be stored for up to 30 days without experiencing any discernible deterioration (Nkosi and Modi, 2019).

Edible coatings, thin layers of biodegradable materials, act as a barrier against moisture loss, gas exchange, and microbial contamination, extending shelf life. These sustainable alternatives to synthetic packaging materials offer potential to enhance food safety. Chitosan, a polysaccharide, has been shown to prolong the shelf life of potatoes, yams, and cassava by up to 50% (Bautista-Baños *et al.*, 2020). Other biopolymers, like alginate and pectin, also offer protective coatings (Falguera *et al.*, 2011).

Enzymatic inhibition is another advanced post-harvest technology used to curb the effects of enzymatic browning in roots and tubers. Enzymatic browning is caused by enzymes like polyphenol oxidase (PPO) and peroxidase (POD), which oxidize phenolic compounds, leading to brown pigments and product deterioration. To prevent browning and extend shelf life, chemical inhibitors like ascorbic acid, citric acid, and calcium chloride have been studied (Yıldız, 2019). Plant extracts and essential oils, with their antioxidant and antimicrobial properties, have also been found to inhibit PPO activity in sweet potatoes and cassava (Khan *et al.*, 2023).

There are other advancements in innovative technologies in post-harvest management such as Nanotechnology where nanomaterials such as nanoparticles and nanocomposites can be incorporated into packaging materials or edible coatings to enhance their barrier properties, antimicrobial activity, and mechanical strength (Huang *et al.*, 2018). Also, biotechnology have opened new avenues for improving the shelf life of roots and tubers in genetic modification techniques have been used to develop crop varieties with enhanced resistance to spoilage and extended storage life. For example, transgenic potatoes with reduced levels of PPO and POD have been developed to minimize enzymatic browning and prolong post-harvest quality (Wang *et al.*, 2017).

CONCLUSION

The post-harvest management of roots and tubers is critical to ensuring food security and reducing losses in agricultural production. Advances in post-harvest technologies, including temperature control methods, modified atmosphere packaging, edible coatings, enzymatic inhibition, and innovative techniques such as nanotechnology and biotechnology, have shown great potential in extending the shelf life of these crops. However, further research is needed to optimize these technologies and ensure their accessibility, especially for smallholder farmers in developing countries. By adopting these innovations, the global food system can move closer to reducing post-harvest losses and improving the sustainability of root and tuber production.

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