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Review on Biochemical Technological Solution to Reduce Post-Harvest Losses in Agriculture

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Abstract

Post-harvest losses are increasingly becoming a significant challenge, causing substantial economic losses for farmers and countries worldwide. Efforts have been made to minimize these losses as much as possible. Crop production is vital for food security, making post-harvest losses undesirable as they endanger lives and diminish farmers' incomes. This study focuses on reviewing post-harvest losses, particularly in developing countries, where they are most prevalent. Understanding post-harvest losses is crucial due to their potential threat to food security, especially in developing nations where significant losses occur during storage of vegetables, fruits, and cereals. Various measures and technologies to reduce post-harvest losses have been explored. However, many developing countries still struggle to implement these measures due to a lack of modern techniques, technologies, and approaches, perpetuating food insecurity. Implementing smart farming techniques such as the Internet of Things (IoT), extension trainings, and utilizing advanced storage structures have been identified as effective strategies for reducing post-harvest losses. Adoption of these measures is expected to significantly decrease post-harvest losses, leading to broader benefits.

Keywords: Post-harvest loss; agriculture; biochemical methods

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Introduction

Post-harvest losses occur throughout the farm-to-market process, encompassing harvesting, handling, storage, and distribution of food. These losses span the food supply chain from crop harvest to consumption (Aulakh *et al*., 2013). They primarily result from physical damage due to rough handling, unsuitable environmental conditions, inadequate containers for transport and storage, improper temperature management post-harvest, and lack of access to cooling facilities, food processing, or storage equipment (Kitinoja, 2016). These losses contribute to global hunger by reducing food supply and farmers' purchasing power, thereby diminishing financial gains from crops (Kitinoja, 2016). Food security is defined as ensuring that all individuals have consistent access to sufficient, safe, and nutritious food to meet their dietary needs and preferences for an active and healthy life (FAO, 2011). Approximately one-third of food crops are lost annually worldwide, and with the projected population increase to 9.1 billion by 2050, a 70% increase in food production will be necessary (FAO, 2009). Thus, addressing post-harvest losses is critical given the escalating food demand from a growing global population.

The impact of the COVID-19 pandemic on the agricultural sector in many developing countries has led to decreased production (Adebisi *et al*., 2021). Therefore, protecting the reduced quantity of food produced from post-harvest losses is imperative for achieving food security. The availability of sufficient food is intricately linked to the agricultural system's capacity to meet food demand (Dharmathilake *et al*., 2020). The current practice of producing nearly double the amount of food needed for consumption annually and discarding half of it is detrimental to human survival. When food is wasted, so are the resources—land, seeds, agricultural inputs, water, energy, and labor—that were invested in its production (Kitinoja, 2016). Food security necessitates not only increasing production and total food supply but also preserving the quality and quantity of available food for human consumption. Undoubtedly, reducing post-harvest losses is a crucial strategy for improving farmers' livelihoods, as minimizing waste leads to

higher income. Post-harvest losses affect the supply chain, leading to elevated food prices in the market and consequently impacting food security (Sisay, 2022). In developing countries, despite citizens' efforts to utilize produced food efficiently, a significant amount is lost in post-harvest operations due to limited knowledge, inadequate technology, and poor storage infrastructure. Conversely, in developed countries, losses in the middle stages of the supply chain are relatively low due to advanced technologies and efficient crop handling and storage systems. However, a substantial portion of food is wasted at the end of the supply chain, known as food waste, either through discarding or intentional non-use due to spoilage or expiration (FAO, 2014).

Extensive Review

Overview of crop production and post-harvest losses

The deterioration in crop quality and quantity post-harvest is a widespread issue affecting both developed and developing nations. Quantity losses, uncommon in developed countries, are prevalent in developing nations (Alavi *et al*., 2012). On the other hand, quality loss encompasses the reduction in calorie content, nutritional composition, acceptability, and digestibility of food products (Abass *et al*., 2014). Post-harvest losses, including quality, nutritional value deterioration, loss of viability, and commercial losses, are recognized as significant challenges (FAO, 2017). These losses comprise direct physical damage and quality deterioration, diminishing the economic worth of crops and rendering them unsuitable for consumption. In severe cases, these losses can amount to as much as 80% of total production (Fox, 2013). Post-harvest losses account for 10-15% of primary horticultural crops in developing nations and up to 20-40% in underdeveloped countries (Nita and Aradhita, 2022). In Africa, these losses range from 20% to 40%, a substantial figure considering the continent's low agricultural productivity in many regions (Abass *et al*., 2014). According to a World Bank report, sub-Saharan Africa (SSA) alone loses food grains worth approximately USD 4 billion annually (Zorya *et al*., 2011).

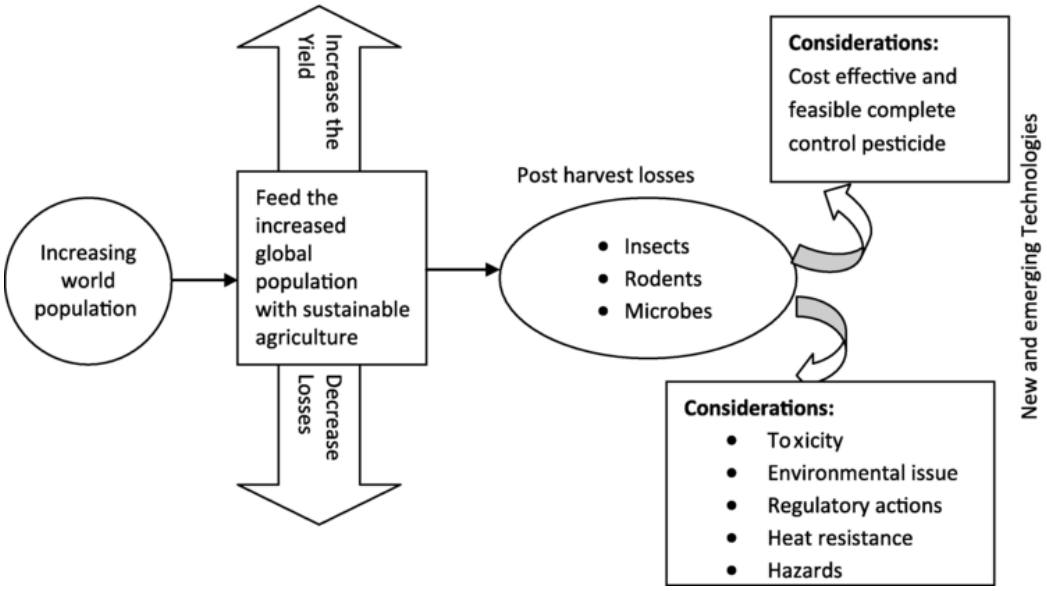

Figure 1 Considerations for postharvest preservation technologies

Post-harvest loss in cereals

Wheat, rice, and maize, along with other grain cereals, are globally recognized as essential food crops and form the cornerstone of staple diets in many developing nations. Mitigating post-harvest losses of these cereals holds significant promise for enhancing food security, combating hunger sustainably, reducing agricultural inputs, fostering rural development, and uplifting farmers' livelihoods. The deterioration of grains primarily occurs due to aerobic respiration of fungi, which metabolize carbohydrates in the kernels, releasing CO_2, H_2O, and heat. Some storage molds also produce mycotoxins, including Deoxynivalenol, Ochratoxin, Aflatoxin, Zearalenone, and Fumonisin, posing risks to human and animal health (Ileleji, 2010). Insect pests are recognized as a major source of grain losses during storage in sub-Saharan African countries such as Uganda, Tanzania, and Malawi, with on-farm losses estimated at 1.4 to 5.9 percent (Kaminski and Christiaensen, 2014). In Ghana, insect infestations have been reported to cause over 50% loss of maize (Boxall, 2002), while in Vietnam, rodents and fungal diseases during storage are the primary causes of post-harvest losses in maize (Alavi *et al*., 2012). Annually, India experiences food grain losses

equivalent to one-third of its population's demand, amounting to 12-16 million metric tonnes (Nagpal and Kumar, 2012). In Nigeria, the estimated loss of rice during the food supply chain amounts to 56.7 billion Nigerian naira, while rice losses range from 8 to 26 percent in China.

(FAO, 2017a; Majumder *et al*., 2016). To address these challenges, various hermetic storage options such as Purdue Improved Cowpea Storage, Super Grain Bags, and metallic silos have gained popularity in recent years as cost-effective storage technologies, widely promoted and adopted in several countries.

Post harvest loss in fruits and vegetables

Improper handling, storage, and preservation techniques, along with microorganism spoilage, contribute significantly to postharvest losses in fruits and vegetables, with estimates reaching up to 40% (Singh *et al*., 2014). The high water activity in fruits and vegetables renders them highly perishable, resulting in approximately 33% of the total produce spoiling from harvesting to marketing (Kader, 2005). Within the same period, an estimated 30-40% of fruits and vegetables are wasted (Salami *et al*., 2010).

Market demand dictates the harvesting time for vegetables among rural farmers, often leading to harvesting based on market demand due to inadequate storage facilities (Ogedengbe and Akanji, 2022). In both developed and developing countries, fruit and vegetable losses range from 5-30% and 20-50%, respectively (Kader, 2002). While developed countries have managed to reduce losses to some extent with modern techniques, developing countries continue to face significant challenges (Hodges *et al*., 2011; Nayak *et al*., 2018).

The extent of postharvest loss varies depending on factors such as marketing channels, including delays in marketing and damage during transport (Sreenivasa *et al*., 2009). Highly perishable items like tomatoes and fresh radishes are sold quickly, while more durable items like cabbage and cauliflower can be transported to distant markets (Kitinoja, 2016).

Despite advancements, reported losses for fruits and vegetables have remained relatively stable since the 1970s (Kitinoja, 2016). Analysis in Table 1 indicates higher post-harvest losses for vegetable crops compared to fruit crops. Tomatoes experience the highest physical loss on farms, while cabbages suffer more mechanical damage (54%) than other produce. Amaranths incur significantly high losses at wholesale markets, likely due to inadequate storage facilities, leading to reduced profitability for wholesalers. In Ghana, tomatoes exhibit higher post-harvest losses compared to Benin, Rwanda, and India, potentially attributed to agricultural practices, inadequate post-harvest handling, or lack of proper storage facilities. Wholesale markets experience the highest levels of post-harvest losses, followed by retailers, suggesting that farmers may harvest fruits prematurely, passing on losses to wholesalers.

Other losses from post-harvest losses

Economic Loss

Approximately one-third of the world's food, equating to around 1.4 billion tons and valued at roughly USD 1 trillion, is lost annually during post-harvest operations and treatments (FAO, 2016). This loss not only results in wasted expenses but also reduces farmers' profits. Environmental consequences accompany these losses. The resources-land, water, and energy-utilized in producing the lost food are squandered. Additionally, the unutilized food contributes to increased CO2 emissions, impacting the environment negatively. According to a report by the Food and Agriculture Organization of the United Nations (FAO), an estimated 3.3 gigatonnes of CO2 equivalent emissions result from produced but uneaten food, without considering land use change (FAO, 2013). The blue water footprint, representing water use throughout the food's life cycle, for wasted food globally is estimated to be about 250 cubic kilometers (Fox, 2013). Similarly, the land allocated to grow this food becomes a wasted resource. For instance, a study on rice post-harvest losses in Nigeria found that lost paddy accounted for 19% of the total cultivated area (Gesellschaft, 2014). On a global scale, in 2007 alone, approximately 1.4 billion hectares of land were wasted in growing unconsumed food, an area larger than both Canada and China combined (FAO, 2013).

The need for proper storage facility

Farmers encounter losses in terms of calorie, quantity, and quality due to inadequate storage facilities post-harvest. Nonetheless, employing proper storage techniques can mitigate these losses by 1-2% (Obiedzińska, 2017). Advanced technology has led to lower middle-stage supply chain losses in developed countries compared to developing ones (Gill and Sharma, 2021).

Technology for post-harvest loss reduction

Efficient storage technology, updated infrastructure, and good storage practices play crucial roles in reducing post-harvest losses of plant produce. Enhanced storage technology can significantly decrease losses associated with storing plant raw materials (Jagjeet and Surabhi, 2021). Collaborative efforts between the World Food Programme (WFP), governments, and non-governmental organizations (NGOs) in Uganda and Burkina Faso demonstrated that improved post-harvest management practices and the application of new storage technologies can substantially reduce crop losses after harvest (Costa, 2014). Implementation of improved practices and new technologies resulted in a reduction of food loss by approximately 98%, irrespective of cultivation or storage duration (Abedin *et al*., 2012).

Innovations such as a patented technology developed by the University of Guelph, Canada, utilizing a safe, plant-derived chemical compound (hexanal), have been shown to effectively reduce post-harvest losses. Similarly, researchers in Israel have introduced an edible coating that can extend the shelf life of fresh produce at ambient temperature, protecting against water loss and decay for up to one month (Kitinoja, 2016). Additionally, Tamil Nadu Agricultural University in India has devised a nano-film to prolong the shelf life of fruits and vegetables, while the Industrial Technology Institute in Sri Lanka has developed a bio-wax formulation to mitigate post-harvest damage (Kitinoja, 2016).

Production practices before harvest significantly influence post-harvest quality and quantity, potentially leading to rejection or downgrading of produce at the time of sale.
Bad effects can be caused by;

1. Excessive rain or irrigation can make leafy vegetables brittle and prone to damage, increasing the risk of decay.
2. Insufficient rain or irrigation can result in citrus fruits having low juice content and thick skin.
3. Periods of dryness followed by sudden rain or irrigation can cause growth cracks or secondary growth in potatoes, as well as growth cracks in tomatoes.

Soil fertility and fertilizer application

Insufficient levels of plant nutrients in the soil can significantly impact the quality of fresh produce at harvest, while excessive fertilizer application can also detrimentally affect crop development and post-harvest condition. Some effects include:

- Nitrogen deficiency may lead to stunted growth or yellowish discoloration of leaves in green vegetables like cabbage.
- Potash deficiency can result in poor fruit development and abnormal ripening.
- Imbalances in calcium moisture can cause blossom end rot in tomatoes and bitter pit in apples.
- Boron deficiency may lead to imperfections in papaya, hollow stem in cabbage and cauliflower, and outer skin cracking in beets.

Cultivation practices play a crucial role in achieving optimal yields and quality of fresh produce. Key aspects include:

- Weed control: Weeds serve as common hosts for crop diseases and pests and compete with crops for nutrients and soil moisture, thus diminishing produce quality.
- Crop hygiene: Decaying plant residues, dead wood, and decaying plants act as reservoirs for infections, underscoring the importance of maintaining crop hygiene.

Conclusion and Recommendation

In conclusion, this study has thoroughly examined the multifaceted causes of post-harvest losses and proposed potential remedies to address this critical issue. Post-harvest losses not only affect the economic viability of farmers but also have profound implications for global food security. By implementing the recommended measures discussed in this study, significant strides can be made in mitigating post-harvest losses, thereby enhancing food security and ensuring ample food availability for all.

It is imperative that farmers and relevant stakeholders receive comprehensive training on adopting new technologies aimed at reducing post-harvest losses. This training should encompass not only the technical aspects of

implementing these technologies but also provide insights into the economic and social benefits of their adoption. Additionally, extension services should be strengthened to facilitate the dissemination of information and knowledge about best practices in post-harvest management.

Furthermore, there is a pressing need for further research to identify simpler methods for accessing and utilizing these technologies, particularly for rural farmers who may face challenges in adopting sophisticated solutions. Research efforts should focus on developing cost-effective and scalable interventions that can be easily implemented in diverse agricultural contexts.

In conclusion, addressing post-harvest losses requires a concerted effort from policymakers, researchers, extension workers, and farmers alike. By investing in innovative solutions, enhancing knowledge dissemination, and fostering collaboration across various stakeholders, we can effectively curb post-harvest losses and build a more resilient and sustainable food system for the future.

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