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Impact of Post-Harvest Technologies on Post-Harvest Losses in Crops in Kenya: A Review

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Abstract **Original Research Article**

A significant portion of the produce often gets lost after harvest, which has dire consequences to food production in Kenya, especially among small-scale farmers. This paper discusses the effectiveness of different technologies in post-harvest to reduce losses on some of the most important crops like maize, mangoes, avocados, and cassava. Some of these technologies include hermetic storage bags, metal silos, mechanical shellers, coolbot™ cold storage, and the controlled atmosphere system. These technologies have remained very effective in cutting down on losses through spoilage while at the same time enhancing the quality of produce and increasing market access. For instance, hermetic storage bags brought down the losses of maize from 25% to under 4% as well as metal silos that allowed 96% protection of the grain. Mechanical shellers made the processing faster and eliminated the problem of broken grain and contamination while Coolbot™ systems increased the shelf life of mangoes from 12 to 40 days. However, the ability to adopt these innovations is grossly hampered by the high costs, infrastructural deficiencies, and low levels of technical know-how. Further, this study reveals that there is a need to support the uptake of these technologies through subsidies and capacity building for farmers as well as the development of infrastructure in rural areas to support the effective use of the technologies to improve food security, increase the income of farmers and improve sustainable agricultural growth in Kenya.

Keywords: Post-Harvest Losses, Small-Scale Farmers, Hermetic Storage Bags, Metal Silos, Mechanical Shellers, Coolbot Cold Storage, Food Security.

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INTRODUCTION

Food loss and waste have become a rife in the world now that most of the food is lost and wasted through harsh climatic conditions and economic vulnerabilities. Post-harvest loss is a key contributor to food losses across the food supply chain. Globally a third of all food produced is lost or wasted every year, making food loss one of the biggest threats to food security (FAO, 2019). is defined as the loss of quantity or quality of food items that occurs as a result of handling, storage, processing, packaging, and distribution after harvesting (FAO, 2011).

Postharvest is one of the most sensitive stages of food loss, particularly in developing countries. These problems could be addressed by post-harvest technologies (PHT), which improve the quality and shelf life of agricultural products while also making them more marketable (Parfitt *et al.*, 2010). In developing countries post-harvest management may be ineffective due to inadequate post-harvest infrastructure and technologies, meaning that post-harvest losses are higher in such countries (Kummu *et al.*, 2012). Pre-harvest losses are higher in low and middle-income countries, accounting for 40% while in low income countries' post-harvest losses stand at 14% and are largely seen in high-income countries at the consumer stage (Kade, 2005).

Post-harvest technologies (PHT) help make food products more valuable, safer, and durable – all of which is especially important for freshly harvested produce that spoils quickly. PHT in particular can lead to a great extent in addressing the threats of food insecurity through decreasing post-harvest loss and may even minimize the effects of food waste on the environment (Kitinoja 2013). In addition, reducing PHL through improvement in PHT could potentially lessen demands on global resource utilities including water, land, and energy globally needed to produce food which would otherwise be channelled towards wastage (Kummu *et al.*, 2012).

PHT has developed over the recent past in a number of areas such as transport, storage, and preservation. According to the FAO (2019), these technologies are valuable when supporting sustainable development goals, specifically SDG 12.3 to reduce, by 2030, per capita food waste in the retail and consumer sectors globally

(Affognon *et al*., 2015).

Post-Harvest Technologies

The term "post-harvest technologies" (PHT) describes a variety of instruments, approaches and processes used to preserve the quality and prolong the shelf life of agricultural products after harvest. These technologies are used during the "post-harvest" phase, which includes all actions from the time the produce is harvested until it gets to the customer, and sometimes even after consumption (Kader, 2004). The fundamental goal of PHT is to prevent quantitative and qualitative losses resulting by physical damage, microbiological decay, physiological deterioration, and biochemical alterations, which all decrease the market value and nutritional quality of agricultural goods (Hodges *et al.*, 2011).

PHT's primary focus areas include cold chain management, transportation, packing, mechanized threshing and shelling, storage, and preservation. Refrigeration, modified atmosphere storage and moisture management all aim to create an environment that will slow the deterioration of the produce. This in turn extends shelf life since it reduces on losses to factors such as mould, pests, and other decay factors (Kitinoja, 2013). Some of the techniques used to preserve food include; drying, canning, and packing. These preservation methods are essential for maintaining food safety and nutritional content. Solar drying and freeze-drying lowers the moisture content in perishable foods to levels that discourage microbial activity to occur, hence slowing the rate of spoilage of the food making it last longer in the market (Parfitt *et al*., 2010). Fruits, vegetables, and cereals preservation through sun drying, solar drying and freeze drying successfully reduces PHL by more than 50%. On the other hand, conventional drying methods are relatively slow and ineffective and lead to product deterioration and loss of nutrients (Hodges *et al*., 2011). With the help of a solar dryer and other improved processing equipment, food spoilage can be cut down by 30% than when using traditional methods (Affonon *et al.*, 2015).

Threshing and shelling are two of the major PHT activities involving the processes of detaching grain or seed from their respective husks or pods through the use of different machines. These approaches help to reduce physical losses on grains apart from helping to reduce post-harvest losses. In addition, mechanized threshers and shellers make processing much quicker and therefore minimize the crops' vulnerability to pests or bad weather that can affect the quality of commodities such as rice, beans, and maize (Affonon *et al.*, 2015).

Packing advancements, such as vacuum packing, eco-friendly packaging, and materials that help cushion an item during transport and storage, ensure that the contents remain safe from contaminants as well as physical harm. Packaging also plays the role of maintaining the freshness of foods especially vegetables and fruits (Affognon *et al*., 2015).

Lastly, transportation and cold chain management which are key in developing countries control the temperature and humidity to ensure the quality and efficiency of perishable produce are protected from spoilage, wastage and improve on access to market (Chegere, 2018). These post-harvest technologies help in preserving, retaining quality and enhancing appearance of food products so as to meet consumer preferences along the value chain from the production point to the end user.

Justification

Kenya experiences major problems in managing post-harvest losses, especially for perishable commodities such as fruits, vegetables and grain. According to the United Nations, by the year 2050, the world population will be at 9.7 billion, meaning that there is an added demand on the needed food necessities and pressure on agricultural assets (FAO, 2019). PHL aggravates these challenges since many crops will be unavailable when combined with post-harvest losses due to wastage. The proper application of post-harvest technologies can significantly reduce food wastage and hence help feed a growing population, reducing the pressure for added production, which generally leads to more environmental degradation (Kummu *et al.*, 2012).

Post-harvest technologies provide interventions that minimize physical damage, spoilage, and contamination at different levels of the post-harvest supply chain, and thus are quite apt to handle both quantitative and qualitative food loss. The use of PHT is not only appropriate but also necessary to enhance food accessibility and enhance the rural populations' living standards in developing countries where PHL maybe 40% due to infrastructural drawbacks (Hodges *et al.*, 2011). Post-harvest technologies assist in preserving the quality of perishable foods and assisting the customer with improving great quality diets.

PHT also helps agricultural producers to generate higher revenues, better market access, and improved production efficiency – key facets that can explain the effect towards economic development and the eradication of poverty (Affognon *et al* . , 2015).

Objective

The objective of this paper is to review case studies on the impact of post-harvest technologies on post-harvest losses in crops in Kenya.

Specific objective

1. To establish the impact of grain storage silos, mechanical shelling, and hermetic storage bags on reducing post-harvest losses in maize.
2. To determine the impact of Coolbot™ technology on reduction of post-harvest losses in mangoes.
3. To establish the impact of post-harvest technologies on reduction of cassava losses in Kenya
4. To determine the impact of post-harvest technologies on improving the shelf life of avocados in Kenya
5. To determine the gains smallholder farmers will make through post-harvest technologies adoption in terms of increased incomes, food security and market access.

METHODOLOGY

Data was collected from scientific articles indexed in peer-reviewed journals, reports and research reports of agricultural research institutions. The criteria for selecting the studies included the findings related to the post-harvest technologies which showed an actual and potential impact on reducing post-harvest losses and barriers to adopting such technologies. Literature reviews of hermetic storage bags, mechanical shellers, Coolbot cold storage, Controlled Atmosphere systems, and other scientific advancements were done to demonstrate how the losses of important crops like maize, cassava, mangoes, and avocados were addressed. Data was analyzed and conclusions were made in order to understand the relationship between post-harvest technology, the results of technology, and the effects of technology on smallholder farmers.

Case study 1

Hermetic Storage Bags for Maize Preservation in Kenya

Kenya is one of the largest maize-producing regions with major losses arising from pest attacks at the storage stage. De Groote *et al.* (2013) worked on a study to establish hermetic storage bags' efficacy in reducing post-harvest losses. The study randomly selected small-scale maize producers who were issued with Purdue Improved Crop Storage (PICS) bags for testing for two consecutive seasons of storage. Three sites, namely Kiboko, Embu, and Homa Bay, were selected based on differences in climatic conditions, the availability of research facilities, and most importantly, confirmation by farmers that weevils and Large Grain Borers (LGBs) are major post-harvest storage pests.

Data from household surveys and direct measurements showed that farmers using the PICS bags reduced their losses of maize from 25% on average due to traditional storage methods, for instance polypropylene bags, to less than 4% when using hermetic bags. Over the six-month storage period, the moisture content, damage by insects and incidence of mould were assessed and it was found that maize stored in PICS bags retained better quality compared to the control samples. Hermetic bags eliminate the requirement of adding chemical protectants, which provides a three-way benefit to farmers, consumers, and the environment through the avoidance of the use of acetylic dust at about 1.1 kg used conventionally to treat one ton of grain for six to eight months' preservation according to (Mutungi *et al.*, 2022). The economic analysis showed that the use of PICS bags would save the average smallholder farmer about 15% of their harvest value, allowing for more food security and market access during the lean season.

Case study 2

Mechanized Shelling for Maize

Maize farming is one of the most popular farming activities carried out in Kenya. However, most farmers suffer losses since shelling this crop manually is not very effective. Shelling is a very crucial step in taking care of maize after harvest. In the Eastern and Southern Africa region (ESA), shelling is mostly done manually. These processes are time-consuming and result in losses and damage. Losses amounting to 6.8% of the maize grain are usually caused by hand threshing and winnowing (Mutungi *et al.*, 2022). On the other hand, the mechanical process of shelling maize increases the speed of the shelling process and also eases the handling of maize after the time of harvesting. According to Mutungi *et al*. (2022) shelling reduced broken grain by 81% and impurities by 38%. This reduced food loss from 68 kg to less than 20 kg per ton which resulted into an additional usable grain in families by 48 kg. The extra usable grain is considered to be worth $10.50 or 1.5 months of food for a household. Mechanical shellers operate with small engines and they can shell a large amount of maize within a short duration of time and the grains are not damaged.

Several earlier researches reveal that the use of mechanical maize shellers help reduces the post-harvest losses and time hence conserve time that the farmers can devote to engage in other productive activities in Meru County as well as in other counties (Njue and Wawire, 2021). Mechanical shellers are efficient but they use fuel and, at certain times, they have to be overhauled; this makes them expensive for smallholder farmers.

Case study 3

Grain Storage Silos in Kenya: Addressing Maize Storage Issues

Maize is an important crop in Kenya, although traditional storage methods have sometimes led to massive losses due to infestation by pests and mould growth emanating from moisture. Community-level metal silos have been an effective solution. These silos play a role in reducing post-harvest losses since the grain is protected from moisture and other destructive bugs. Furthermore, because corn needs to be stored for a long time, farmers can take their grain to the market when the price is high for their households, thus raising their household incomes. The early uptake was slow because the silos were costly and there was limited awareness of their benefits (Tefera et al., 2011). Gitonga et al. (2015) conducted a study in the Nyanza and Eastern provinces of Kenya and concluded that the use of metal silos would significantly cut post-harvest maize losses.

The research, which spanned 18 districts, showed a massive 96% decline in grain losses by households using metal silos. Adopters lost an average of only 3 kg of maize per season, compared with non-adopters who lost 75 kg. In addition, the silo designs were airtight, hence providing very good protection of maize against the larger grain borer and maize weevil, at 98% and 92%, respectively. This facility in storage helped the households to store the maize for longer time as food security for 1.8 extra month and gave the farmers a chance to wait for better market prices to be able to increase their income and stability (Gitonga *et al.*, 2015). The conclusion drawn from this study affirms that metal silos have enhanced change in maize storage and food security in Kenyan households. Thus, with the potential for minimizing post-harvest losses and for optimizing supply to the markets, the technology increases the food supply, as well as increases the financial stability of the smallholder farmers. These guidelines provide a perception of the future of metal silos as a sustainable solution for storage issues as well as the promotion of sustainable agricultural livelihoods.

Case study 4

Impact of Coolbot™ Technology on Post-Harvest Losses of Mangoes in Kenya

Mango is one of the common farming activities practiced especially in the areas of Makueni County. Post-harvest losses in the mango value chain are tremendously high and range between 25-40% due to poor handling methods and limited storage structures. The seasonal nature of mangos combined with their sensitivity to heat and high humidity decreases the time that the fruits can be held in transit or even in storage, thus constraining markets and lowering net farm returns (Karithi, 2016). Smallholder farmer shops cannot afford traditional cold storage solutions that are expensive, therefore, suitable solutions must be sought.

In response to these challenges, the Coolbot™ technology was thus developed. The Coolbot™ is a cold storage innovation that transforms an air conditioning unit to offer low temperatures and hence can be used economically by small-scale farmers. At the same time, it can maintain storage temperatures as low as 10°C which is good for the storage of mangoes and other crops; but does not have the same energy demands as conventional systems of refrigeration.

Research done in Makueni County showed that mangoes kept in coolbot™ technology had lesser decay levels than traditional means. Temperatures in the cold room containing the Coolbot™ were maintained at 10±1°C while outdoor and indoor temperatures varied between 25 and 28 °C. This helped in substantially controlling the ripening process and hence the mangoes remained fresh up to 35 days unlike the contrasting periods of ambient conditions that only allowed the mangoes to be ripe for about 12 days (Karithi, 2016).

Moreover, the use of Coolbot™ storage in combination with modified atmosphere packaging (MAP) preserved the mango even longer. For example, the shelf life of mangoes was extended to 40 days when they were packed in Active bags placed inside Coolbot™ cold room with corresponding preservation in firmness, colour and nutritional quality (Karithi, 2016). The study revealed, however, some challenges particularly on the response of Coolbot™ technology that was efficient in minimizing the post-harvest losses and enhancing mango quality. These were the first costs that one had to incur and even though the costs were considerably lower than those of regular cold storage, they could still be a barrier to income-constrained smallholder farmers. However, for such experiments, there is a need to have a continuous and reliable power supply which sometimes can be hard, especially in rural settings.

Coolbot™ technology was proven cost-effective and recommended for use by smallholder farmers to enhance their earnings from horticultural crops through the mitigation of post-harvest losses. An increase in the use of this technology could greatly improve the sustainability of the mango chain in Kenya.

Case study 5

Post-Harvest Technologies and Their Impact on Reducing Losses in Cassava Processing

Cassava is a widely grown crop in Kenya because of its importance in food security but the crop undergoes many setbacks during post-harvest handling. Cassava tubers are more perishable in their fresh state and last for less than 72 hours; hence, post-harvest losses exceeded 23 percent soon after harvest. Such losses include speedy deterioration, microbial infection, and inadequate handling techniques indicating the need to add value by processing the products (Abong *et al.*, 2016).

A study conducted by Abong *et al.* (2016) between March 2013 and February 2014 across four counties in Kenya: Kilifi and Kwale (Coastal region) and Busia and Migori (Western region) compared the efficiency of different post-harvest technologies used in cassava value chain at different stages in Kenya. These regions were selected because they are among the most active producers of cassava in the country (Abong *et al.*, 2016).

Technologies used include drying, fermenting and milling cassava into dried chips and flour. These methods were useful in minimizing the problem of bulkiness, increasing storage and shelf life, and minimizing the cyanide toxicity of cassava products (Abong *et al.*, 2016).

The Sun-Drying method was widely used, particularly in the western part of Kenya (Busia and Migori) where cassava was prepared into dried chips. The sun drying of cassava chips gave extra days of preservation making it easier to transport and store the chips. In Migori and Busia, dried chips took the largest proportion of the processed cassava products with 43% (Abong *et al*., 2016). The use of the plastics silos and drying techniques led to a reduction in the post-harvest losses level by 50%. The dried cassava was then kept for up to six months without deterioration, giving the farmers the chance to transport their produce to the markets during off-peak seasons when the prices were slightly higher (Abong *et al.*, 2016). Fermentation practice was more common in Busia due to potential high levels of cyanide. This process not only detoxified the cassava but also adds to the process of improving the taste and texture of the food (Abong *et al.*, 2016). Further, it established that eradication of cyanide toxicity occupied an essential place in pointing out the problem restricting fresh cassava market demand. Most milling and processing into flour was reported to be done in the Coastal region particularly in Kilifi and Kwale with 33% of Processors engaging in cassava flour production for products such as ugali and porridge (Abong *et al.*, 2016). Through milling, there was enhanced product quality; transportation and storage were also enhanced. This was also the case with the flour where consumers had a better market reaction since the product had a relatively longer shelf life than the perishable roots.

The constraints experienced by processors; were fluctuations in the supply of raw products, high perishability of the products unavailability of appropriate tools for processing, and lack of adequate training in new and better ways of processing the products (Abong *et al*., 2016).

The study showed that the use of better post-harvest technologies like sun-drying and milling cut down post-harvest cassava losses and further enhanced the quality of cassava products produced which are marketable.

Case study 6

Impact of Post-Harvest Technologies on Reduction of Avocado Losses in Kenya

The effects of post-harvest technologies on controlling post-harvest losses in avocado production are clearly demonstrated by research conducted in various regions of Kenya. The survey in Kenya has shown that most avocados that are harvested, stored, and transported are wasted. Shivachi *et al*. (2023) observed that 40% of avocados that are harvested fail to reach the market due to inadequate post-harvest technologies. These are typically incurred between harvest and consumption and are primarily the result of ineffective storage measures by the majority of smallholder farmers who produce cash crops.

The existing solutions to these problems are; near infrared spectroscopy technique controlled atmosphere storage smart packaging. The paper by Lu et al (2023) describes how to apply near-infrared spectroscopy method to predict the ripening and quality of avocados. In grading, this technology comes in handy in the identification of avocados based on the degree of dry matter content required hence little wastage due to improper categorization. Several large depots in Kenya have been able to decrease avocado rate of damage during hand sorting employ the near infrared spectroscopy technique over time.

The controlled atmosphere storage (CA) is beneficial to avocados. According to Shivachi *et al*. (2023), there are practical ways of controlling the storage environment in relation to oxygen and carbon dioxide concentration in order to slow the rate of ripening. However, the adoption of these technologies is limited by high initial costs and a lack of technical knowhow among Kenyan smallholder farmers. Shivachi *et al.* (2023) highlight that the integration of storage technologies such as controlled atmosphere storage systems with temperature control minimized the transit losses by 30-60% Smart packaging using the RFID technology made monitoring of the products possible to minimize spoilage.

Smart packaging technology utilises Radio Frequency Identification (RFID) systems. Lu *et al.* (2023) findings clearly show that transportation processes have incorporated RFID tags to monitor temperature and humidity. RFID technology used in the management process has helped to reduce losses when avocados are exported to other countries where quality must be maintained in order to compete.

Another factor that has led to solving the problem of post-harvest losses in avocados is the ozone treatment and wax coatings which have natural Pre preservation. These treatments when used in the study by Lu et al. (2023) are of great help in controlling fungal diseases which are a menace to avocados since they cause decay.

While these technologies have served to mitigate on the incidences of post-harvest losses in avocados, there are several impediments to their optimal uptake by small scale farmers in Kenya and they include; high costs and lack of technical know-how.

DISCUSSION

Most of the post-harvest technologies discussed in the case studies have helped to a great extent in lessening post-harvest losses of various crops in Kenya. Hermetic storage bags like the PICS bags have been useful in reducing the loss of maize through pests particularly weevils and larger grain borers. These bags employ an airtight system of containment for the purpose of protecting grain. It cuts the losses of grains that are stored in normal methods, which are normally known to lose twenty-five percent, to less than four percent. This shows how excellent they are in preserving the quality of grains without the application of chemicals. Mechanical shelling of maize enabled a reduction in grain breakage, impurities and lowered post-harvest losses from 68 kg to about 20kg per ton.

Metal silos located in the community reduced losses of maize up to 96% thus protecting the grain from pests as well as moisture. Through this technology, farmer will be able to store their produced maize for some time as they wait for better market prices hence increasing their incomes to help in the fight against food insecurity. Furthermore, this safe storage option ensures the farmers are not compelled to sell at early instances of the harvest time when market prices are always low.

In the case of perishable crops such as mangoes, Coolbot technology has reportedly extended the number of days stored mangoes can last from 12 to 35 by merely cooling them. This eliminates one of the main challenges that the supply chain of mangoes faces due to the fruits ripening and rotting soon after harvesting, by acting as a barrier that can delay this process while promoting better arrival at markets.

Cassava is a crop with high perishability and therefore sun drying, fermentation as well as milling can be considered as efficient ways through which this crop can be preserved for longer periods thus resulting to low waste. These methods not only preserve cassava (keeping it good for up to six months) but also turn the tuber into more saleable products.

In the case of avocado, new methods of handling after harvest have drastically reduced losses during transportation and export. Controlled Atmosphere storage, quality checking by near infrared spectroscopy technique, and smart packaging with inclusions of Radio Frequency Identification (RFID) tags maintain optimal conditions for storage and check real-time data in order to prevent the process of deterioration in long hauls. This enhanced quality and long-lasting avocado has thus improved the competitiveness of Kenya at global platforms.

These technologies are very useful because they assist in decreasing post-harvest losses, enhancing the quality of products, as well as increasing farmers' margins. Nonetheless, small scale farmers make up a larger percentage of farming populations and cannot afford such technologies because they are initially expensive to acquire, require constant maintenance, and access to training is limited. Alleviating some of these challenges may help farmers to maximize on these technologies hence boosting food security in Kenya.

CONCLUSION

Various post-harvest technologies have demonstrated tremendous capability in the mitigation of post-harvest losses and enhancement of crop productivity in Kenya. Innovations including hermetic storage bags, Sheller machines, metal silos, Coolbot™ and controlled atmosphere have gone a long way in improving on storage of staple crops like maize and horticulture produce like mangoes and avocados. Some of these technologies are not only effective in the preservation of perishable produce for the prolonged periods, but also in improving grain quality and reducing chemical preservatives usage. Nonetheless, the small scale farmers who can harness these technologies are constrained by issues surrounding their adoption, such as high initial costs, low technological literacy, and limited credit.

RECOMMENDATION

To overcome post-harvest losses and improve agricultural production in the country the following measures should be taken. First, government and the development partners must extend incentives through subsidies or financial support in an effort to offset the costs of procuring and implementing the use of the advanced technologies among the small holder farmers. Such support would help put these technologies within the reach of the small holder farmers who cannot afford large capital investments. Furthermore, increasing the scale of training activities and extension services related to improving farmers' technical literacy regarding the utilization and care of post-harvest technologies is necessary. These can be accomplished through partnership with agricultural research organizations and non-governmental organizations.

Additionally, there is a need for the development of rural electricity as a key enabler for technologies that rely on a stable power source, like the Coolbot™ cold storage technology. Enhancing cross public and private sector cooperation may also help in promoting affordable storage and processing solutions. Such integrated approaches will help address post-harvest losses while at the same time support food security, earnings, and vulnerability of the agricultural sectors in Kenya.

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