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Research Application Summary

From the lab to land: Taking postharvest management solutions to horticultural farmers through aggregation centers

Ambuko, J.[1], Amwoka, E.[1], Hutchinson, M.[1], Chemining'wa, G.[1], Kunyanga, C.[2], Mburu, J.[3] & Owino, W.[4]

[1]Department of Plant Science and Crop Protection, Faculty of Agriculture, University of Nairobi, P. O. Box 209053-00625, Nairobi, Kenya
[2]Department of Food Science and Technology, Faculty of Agriculture, University of Nairobi, P. O. Box 209053-00625, Nairobi, Kenya
[3]Department of Agricultural Economics, Faculty of Agriculture, University of Nairobi, P. O. Box 209053-00625, Nairobi, Kenya
[4]Department of Food Science and Technology, Jomo Kenya University of Agric & Technology, P. O. Box 62000 – 00200, Nairobi, Kenya

Corresponding author: ambuko@yahoo.com, jane.ambuko@uonbi.ac.ke

Abstract

High postharvest losses (PHL) which is estimated to be 30% of the food produced for human consumption, is one of the current global challenges that requires urgent attention. Over the years there has been substantial research to address PHL. The problem of PHL is very complex in nature and addressing it requires multifaceted interventions. Appropriate technologies and innovations constitute a critical component of the required interventions. Years of research in postharvest management have yielded applicable technologies and innovations to address PHL. However much of the research outputs or solutions have not been applied due to different reasons including lack of awareness, unavailability and inadequate knowledge on how to use the technologies. To address some of these hindrances to postharvest technology adoption, smallholder aggregation and processing center, a scale up approach conceptualized by the Rockefeller Foundation's Yieldwise Initiative was adopted. The smallholder aggregation approach was introduced on pilot scale to Karurumo smallholder Horticultural farmers in Embu County of Kenya. The center is envisioned to be a zero-loss, one stop center where smallholder farmers aggregate high quality fruits and vegetables for fresh market. In addition, the unsold produce are processed into shelf-stable products thereby extending their shelf life and marketing period. To achieve this goal, the center has been equipped with simple postharvest technologies including: zero energy brick cooler (ZEBC) and evaporative charcoal cooler (ECC) for precooling and temporary storage; Coolbot™ cold room for longer term cold storage; a small scale wet processing line and tunnel solar dryers for dried products. All the technologies at the center are simple and low-cost postharvest management technologies and innovations which are products of research. Although some of the technologies have been tested and validated on-station (at the University), there has been no commercial application in Kenya, except for the ECC. This paper describes how smallholder aggregation and processing at the Karurumo center, the first one of its kind in Kenya, can be used as a postharvest technology demonstration and learning center for farmers and other stakeholders in Horticulture. The center is an outreach opportunity for researchers to scale out their research outputs and meaningfully engage the end users – from the lab to land. It is envisioned that the smallholder aggregation and processing centers' approach can be applied in scaling out other research outputs to ensure wide-scale adoption and application by the end users.

Key words: Aggregation, food loss, Kenya, postharvest losses, Yieldwise

Résumé

Les pertes élevées après récolte (PHL), estimées à 30 % de la nourriture produite pour la consommation humaine, constituent l'un des défis mondiaux actuels qui requiert une intervention rapide. Au fil des années, d'importantes recherches ont été menées sur les pertes post-récolte. Le problème des pertes post-récolte est très complexe par nature et sa résolution nécessite des interventions à multiples facettes. Les technologies et les innovations appropriées constituent un élément essentiel des interventions requises. Des années de recherche sur la gestion post-récolte ont permis de mettre au point des technologies et des innovations applicables pour réduire PHL. Cependant, une grande partie des résultats de recherche ou des solutions n'ont pas été appliqués pour différentes raisons, notamment le manque de sensibilisation, l'indisponibilité et les connaissances inadéquates sur la façon d'utiliser les technologies. Pour surmonter certains de ces obstacles à l'adoption des technologies post-récolte, un centre de transformation et de de regroupement des petits exploitants, une approche de mise à l'échelle conceptualisée par l'initiative Yieldwise de la Fondation Rockefeller a été adoptée. L'approche de regroupement des petits exploitants a été introduite à l'échelle pilote pour les petits exploitants horticoles de Karurumo dans le comté d'Embu au Kenya. Le centre se veut être un centre à perte zéro et à guichet unique où les petits exploitants agricoles regroupent des fruits et légumes de haute qualité pour le marché. En outre, les produits non vendus sont transformés en produits de longue conservation, ce qui permet de prolonger la durée de conservation et la période de commercialisation. Pour atteindre cet objectif, le centre a été équipé de technologies post-récolte simples, notamment : un refroidisseur en briques à énergie zéro (ZEBC) et un refroidisseur à évaporation de charbon (ECC) pour le pré-refroidissement et le stockage temporaire ; une chambre froide Coolbot™ pour le stockage à long terme ; une ligne de traitement humide à petite échelle et des séchoirs solaires en tunnel pour les produits séchés. Toutes les technologies du centre sont des technologies de gestion post-récolte simples et peu coûteuses et des innovations qui sont le fruit de la recherche. Bien que certaines des technologies aient été testées et validées sur place (à l'université), il n'y a pas eu d'application commerciale au Kenya, à l'exception du CEC. Ce document décrit comment le regroupement et le traitement des petits exploitants du centre de Karurumo, le premier du genre au Kenya, peut être utilisé comme centre de démonstration et d'apprentissage des technologies post-récolte pour les agriculteurs et acteurs horticoles. Le centre offre aux chercheurs la possibilité de diffuser les résultats de leurs recherches et d'impliquer de manière significative les utilisateurs finaux – du laboratoire à la terre. Il est prévu que l'approche des centres de traitement et de regroupement des petits exploitants puisse être utilisée pour la diffusion à grande échelle d'autres résultats de recherche afin de garantir leur adoption et leur application par les utilisateurs finaux.

Mots clés : Agrégation, pertes de nourriture, Kenya, pertes post-récolte, Yieldwise

Introduction

Horticultural production in Kenya and in many of Sub-Saharan Countries (SSA) is dominated by smallholder farmers with limited resources. Over the years, significant efforts have been made to help the smallholder farmers to enhance yields of high quality fruits and vegetables. As a result, there has been a significant increase in yields of most fruits and vegetables which is attributed to increased acreage and yield/acre (HCD, 2016). Unfortunately, the increased yield has been accompanied by increased postharvest losses. Accurate data on postharvest losses, especially in SSA is scanty. However according to FAO reports (FAO, 2011) postharvest losses in fruits and vegetables is estimated to range between 40-50%. These losses occur at all stages of the supply chain from harvesting, packing, transportation, in wholesale and retail markets, and during delays at different stages of handling (Kitinoja, 2010).

Loss of quality leading to PHL in fresh fruits and vegetables (FFV) is attributed to various biological and environmental factors. Preservation of the postharvest quality of FFV can be achieved through application of appropriate postharvest technologies and practices. Over the last few decades, there have been significant advances in postharvest research globally leading to development of appropriate postharvest technologies. Application of these research outputs has greatly improved the handling and quality of food crops, and contributed significantly to improving nutrition and national development. The improvements in postharvest management and handling of perishable foods such as FFV include harvesting indices, harvesting methods, pre-cooling methods and applications, storage techniques, packing and packaging, quarantine systems, transport systems especially by road and sea, modified and controlled atmospheres, among others (Yahia, 2008).

Despite the many decades of research and available solutions to address PHL, high losses are still reported in FFV. This is because many of the postharvest technological innovations are either not used or used inadequately. The reasons for this scenario are diverse including unavailability of adequate technologies; unfamiliarity with available technologies; inadequate use of or difficulties in the adaptation of available technologies; and the refusal to use available technologies due to different reasons (Yahia, 2008). Strategies to reduce PHL among SHFs in SSA should be cognizant of the scale of operation – the land area dedicated to production (often less than 0.3 ha) and the low volumes of produce harvested and handled on any given day. The small scale of operation for majority of SHF is one of the factors that have contributed to non-adoption of available PH technologies considering the economies of scale. Additionally, although many applicable and appropriate postharvest technologies for use in developing countries have been identified, there is limited or lack of information on cost-benefit-analysis (CBA) which is critical for adoption of the technologies. According to Kitinoja *et al*. (2010), the adaptive research step between on-station research to test effectiveness of the technologies and subsequent extension of the results is missing. The local costs of the technologies are not considered when investigating the technology. The issues described above other hindrances to technology adoption must be addressed to ensure that postharvest technologies and innovations developed through research are adopted by the end users and have the desired impact on PHL reduction. This paper describes some of the on-going efforts to reduce post-harvest losses in Kenya.

Approach

On-station testing of selected postharvest technologies. Over the years, researchers from the University of Nairobi and their partners have engaged in on-station studies to adapt and test low-cost cold storage technologies that can be used by smallholder farmers in Kenya and other developing countries. These technologies are briefly described as follows:

Evaporative cooling facilities: evaporative charcoal cooler (ECC) and zero energy brick cooler (ZEBC). Evaporative cooling is premised on the evaporative heat exchange which takes advantage of the principles of the latent heat of evaporation, as tremendous heat is exchanged when water evaporates. Evaporative cooling is a natural and physical phenomenon whereby cooling occurs by evaporative heat exchange. Evaporative coolers in the various forms provide a cooling effect by forcing hot dry air over a wetted medium. When water evaporates from the medium, it takes energy from the surrounding thereby providing a cooling effect while at the same time increasing the relative humidity. Evaporative cooling in various forms has been demonstrated as an efficient and economical means for reducing the temperature and increasing the relative humidity and consequently preserving the quality of fruits and vegetables (Ambuko *et al*., 2017). Among the many forms of evaporative cooling, the Karurumo Centre has adopted the evaporative charcoal cooler (ECC) and the zero energy brick cooler (ZEBC) which is also referred to as the zero energy cool chamber (ZECC). The modular ECC was designed and fabricated by the Environmental and Bio systems Engineering (EBE) Department of the University of Nairobi. The modular design was used to ensure that the size of the ECC can be modified to suit various user needs. The ECC designed for Karurumo was 4 M X 4 M with a capacity to hold 200 – 250 standard bread crates arranged in rows to allow proper air circulation in the chamber as required for effective evaporative cooling. Thereafter it was transported to Karurumo, finalized, installed and tested on site to ensure onsite functionality and effectiveness. The zero energy brick cooler (ZEBC) was built onsite from locally available materials including earthen bricks, river bed sand, water tank and water drip lines. The bricks were arranged to make a double wall measuring 200 X 300 cm and 60 cm high. Wet river bed sand was sandwiched in between the two walls. A top cover for the ZEBC was made from locally available absorptive materials. Water drip lines were fitted to the ECC and ZEBC and connected to an overhead tank to ensure continuous water supply required to keep the medium (charcoal and sand respectively) wet. A temperature difference of 6 – 12^{0}C between the evaporative cooling chambers and the ambient room was achieved. In addition, significantly high relative humidity (80-98%) was achieved in comparison to an average of 60% RH for the ambient room.

Low-cost cold room - the Coolbot™ cold room. The Coolbot™ cold room is made up of three components: an insulated room/shell; an electronic gadget called Coolbot™; and an air conditioner that is compatible with the Coolbot. The insulated shell can be made from various materials with good insulation capacity. In pilot studies to test effectiveness of the Coolbot technology, the insulated shell was built from 200 mm thick structural insulated panels made from polystyrene (Ambuko *et al*., 2015). The room was fitted with an air conditioner (LG brand of 24,000 BTU) and Coolbot™ which was sourced from Store It Cold LLC (USA). At the Karurumo center, the cold room walls were made using sandwich panels of expanded polystyrene and colored steel sheets of 0.4 mm thickness. A 24,000 BTU/HR split unit air conditioner with R-404A refrigerant was used. The 4 M X 4 M Coolbot cold room can hold up to 250 bread crates arranged in rows to allow air movement required for forced air cooling.

Scaling out postharvest handling and processing technologies through the aggregation center model.

The research team sought to scale out the above on-station tested technologies and other simple postharvest technologies to the end users through the aggregation centers. An aggregation center was envisaged to be a one-stop shop where postharvest technologies can be demonstrated while being applied practically by the end users. In this case the targeted end users was a group of smallholder horticultural farmers. The goal is to enable smallholder farmers to aggregate high quality fruits and vegetables for the fresh market and transform the surplus into shelf-stable products through wet and dry processing.

Selection of the aggregation center location and farmer group. The research team from University of Nairobi in collaboration with Technoserve Kenya Ltd (the implementing partner of the Rockefeller Foundation) and with support from extension officers from Embu County government conducted a reconnaissance survey to identify the most suitable farmers groups and location of the aggregation center. The existing groups were screened based on their institutional maturity using the AIMS group analysis tool. After screening more that twelve groups in Embu County, the team identified the Karurumo Horticultural Self Help Group (KHSHG) in Embu as a suitable and ready entry point to pilot the smallholder aggregation and processing model. Following the selection, the project team held brainstorming meetings with the group members and other stakeholders in the region to identify the group needs. The meetings also sought to establish the best strategy to engage the group.

Installation of small scale aggregation and processing facilities. Based on the group needs, the project team identified various postharvest handling and small scale processing technologies that would suit the group. Besides the technologies, other supportive facilities and services were provided to the group. The installed technologies, facilities and services provided are briefly describe below:

Receiving, presorting, sorting shade. The simple shade equipped with a smooth tiled working surface serves as the receiving area for fruits and vegetables brought to the aggregation center. The delivered produce is first presorted to ensure that only high quality fruits are received by the receiving clerk at the center. The fruits are then weighed and sorted based on variety, stage of maturity, size and other criteria depending on the intended use.

Cold storage technologies. The cooling and cold storage technologies (evaporative charcoal cooler, zero energy brick cooler, Coolbot™ cold room) described earlier were installed at the aggregation center. Each of the storage facilities was equipped with plastic crates and plastic pellets for stacking the crates as part of good postharvest handling and storage practice. The pellets ensure that the produce packed in the crates does not have direct contact with the floor and also better air circulation from the top to bottom of the cold room.

Wet processing plant. The wet processing plant is made up various components including: a blancher which can be used to blanch peeled fruits before pulping to voluminize the pulp; pulping machine fitted with different sieves suitable for pulping different fruits; a pasteurizing machine; a water purifying unit; mixing tank and filling tank. The various components were fabricated and fitted by a local food processing equipment company – DK Engineering.

Tunnel solar dryer. The tunnel solar dryer, a German innovation was built onsite by the project team using locally sourced materials. Two tunnel solar dryers each measuring 18 M long and 2 M wide were fabricated and their drying capacity for various fruits and vegetables tested onsite. Each of the two tunnel dryers can dry one metric ton of sliced mango fruits per loading. On a good sunny day, up to two loadings can be realized per day. On-site studies showed that drying of cut leafy vegetables take a shorter time and hence 3 – 4 loadings (100 Kg each) can be achieved every day.

Training on postharvest handling and small scale processing

To complement the postharvest technologies, two training sessions were organized for the group members and other value chain actors in the region. The first training session focused on postharvest handling of fruits. The objective of the training was to enhance the horticultural value chain actors' knowledge, understanding and skills in postharvest handling of horticultural produce and also expose them to simple postharvest technologies. The second training session focused on small scale dry processing of fruits and vegetables. The objective of this training session was to equip the trainees with practical skills for small scale processing of fruits and vegetables.

Findings and discussion points

Handling of mango fruits and other fresh fruits and vegetables delivered to the aggregation center. The process flow for fresh produce received at the aggregation center is depicted in Figure 1. When the mango fruits (the focus commodity) are received at the center they go through the following steps/processes: 1) Receiving and pre-sorting to remove fruits that are not fit for use including pest infested, rotting or overripe fruits 2) Sorting based on various parameters such as variety, stage of maturity, quality 3) Washing in sanitized water for commodities that require washing 4) Precooling in the evaporative charcoal cooler (or zero energy brick cooler) to remove the field heat 5) Cold storage in the Coolbot™ cold room 6) Wet processing into various products including pulp, ready to drink juice or concentrate 7) Drying in the tunnel solar dryers. The nature of the fruit (variety, stage of maturity, grade) determines its end use at the center.

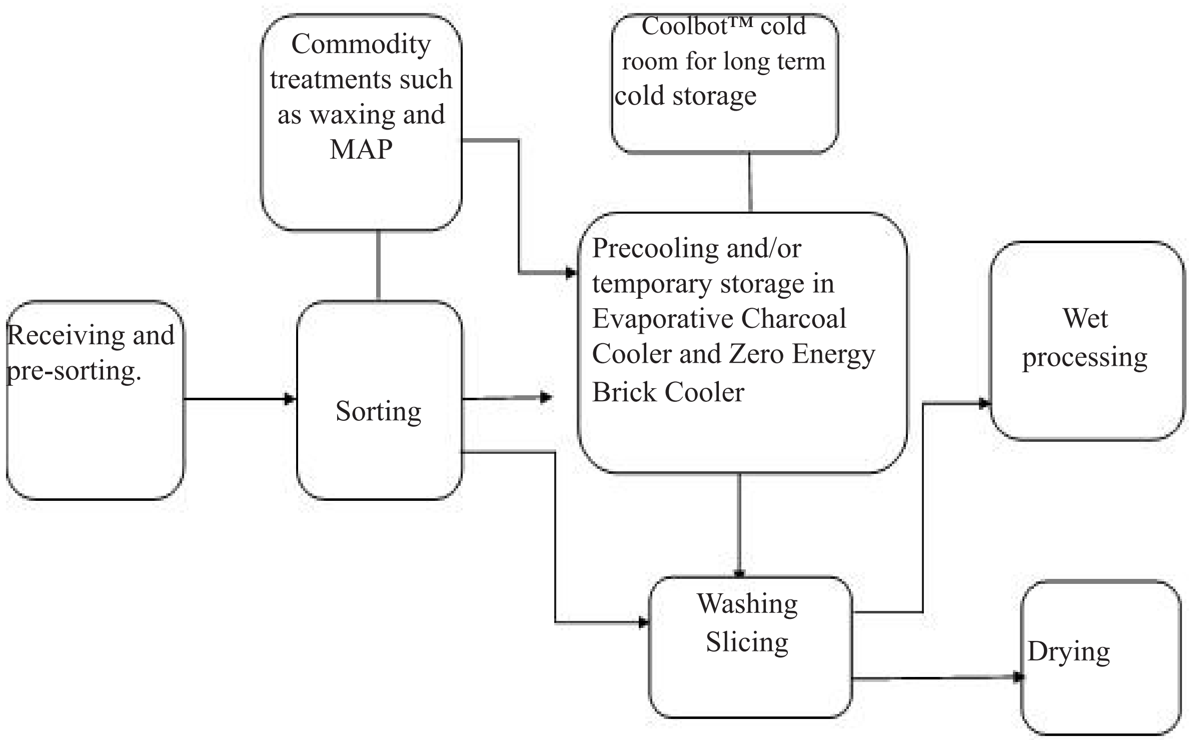

Figure 1. A schematic depiction of the process flow for fruits and vegetables delivered to the Karurumo Smallholder Aggregation and Processing Center

Benefits of small scale aggregation and processing to smallholder farmers and other actors

Mango is one of the major cash crops produced by the smallholder farmers in Embu County. Therefore it was the key commodity that was targeted when setting up the aggregation center. Embu region also produces other horticultural crops including bananas, tomatoes, and a wide range of leafy vegetables all of which are destined for the local market. The mango season in Embu County and most of the mango producing counties in Kenya, is November to March. During this period, there is an oversupply of mangoes in the domestic market since export market is limited. During the peak season, the farm-gate price for one mango fruit ranges between KSH 1 – 5 (1 – 5 US Cents) with an average price estimated at KSH 3. The retail price per piece in the urban cities such as Nairobi ranges from KSH 20 – 60, with an average of KSH 30, which is 10 times the farm gate price. Perishability of mango fruits and lack of appropriate storage facilities have reduced the mango farmers to 'price takers', a situation that has been exploited by middlemen. The aim of the aggregation center was to empower the smallholder farmers who already belong to groups. Farmers have over the years been encouraged to form groups in order to benefit from services such as training, bulk purchase of agro-inputs among others. However such groups have not been exploited substantially to benefit the farmers after production to ensure better market access and prices for their produce.

The smallholder aggregation and processing centers if well organized and managed have the capacity to be a game-changer benefiting both the farmers, traders and consumers alike. The farmers will not be forced to sell their perishable produce at sub-optimal prices. With the cold storage facilities, farmers can delay the sale of their produce as they negotiate for better prices. It is anticipated that if the traders cannot buy the fruits at a good price, farmers can either keep the fruits in the cold room or process them into diverse products (wet and dried products). Transformation of the fruits into shelf-stable products such as pulp, juices and dried chips has multiple benefits to the farmers. Besides extending the marketing period, processed products fetch better value for the farmers. Unpublished data shows that while fresh mangoes will fetch USD 284/MT, dried mangoes can fetch upwards of USD 4,400/MT in the export market (Kibaara, 2017). Farmers belonging to the aggregation centre are bound by the group regulations which stipulate that they should not sell their produce directly to traders but through the aggregation centres. This regulation is to ensure that the traders do not exploit the individual farmers. Although group marketing is the ideal option, some farmers often go against the group regulations and sell their produce directly to traders, who take advantage of the farmers' poverty and dire need for cash.

During the last mango season, farmers at the Karurumo center were able to negotiate for a price of KSH 7- 10 per piece of mango during the peak season and KSH 12 towards the end of the season. This translates into a more than double the price usually paid for mangoes during the peak season. The profit margins for the processed products including pulp, ready to drink juice, juice concentrate, dried chips have not been established but preliminary operations indicate better returns and profitability compared to sales of fresh fruits. Given the seasonality of mango, the group members have received training on aggregation and processing of other commodities such as banana, leafy vegetables, tomatoes and other horticultural produce from the area. This is to ensure continuous operation of the center throughout the year.

The traders can also benefit substantially from aggregation because they can consistently access large quantities of high quality fruits and vegetables at one stop. The aggregation facilities at the Karurumo centre can hold up to 10 tons of mango fruits at any one time in temporary storage (evaporative coolers) and long-term storage in the Coolbot™ cold room. Currently, the traders move from farm to farm to collect small volumes of inconsistent quality from small scale farmers who are spread across the region. Through aggregation centers, the traders can make orders of fruits of an agreed quality, quantity and price. This not only saves them time but operational costs which is expected to reflect in the prices negotiated with the farmers. These benefits should also positively affect the consumer who otherwise pays more for fruits and vegetables due to the inefficiency in the supply chain.

Opportunity to scale out research outputs from research institutions

The aggregation centers have provided an opportunity for researchers to scale out research outputs and promote adoption of other postharvest practices and technologies. At the Karurumo aggregation center there are several technologies whose application and practical use has been demonstrated. The handling technologies include crates, ordinary bread crates and space-saving nestable crates. Use of crates instead of sacks or baskets to package mangoes (and other fruits or vegetables) has been promoted as a best practice to reduce mechanical damage during transportation. Nestable crate is a new product in the market but the adoption is slow because farmers and traders have not appreciated the real benefit for the extra cost – compared to an ordinary crate. Through training and practical demonstration at the center, the space-saving benefits of the nestable crates have been demonstrated to farmers and traders.

The use of applicable commodity treatments such as chlorine based (sodium hypochlorite) and non-chlorine based (acetic acid and sodium bicarbonate) sanitizers aimed at disinfecting produce before storage have been demonstrated. The effectiveness of these sanitizers have been tested and validated through on-station research on sweet pepper (Amwoka and Ambuko, 2016) and tomatoes. In addition, application of waxing formulations that can extend the shelf-life of mango fruits have been demonstrated. Although waxing is not a common practice among smallholder farmers, the potential benefits to extend the shelf life under cold storage by more than 3 weeks have been demonstrated at the Karurumo center. Cold chain management is critical in postharvest handling of perishable fruits and vegetables. Proper cold chain management slows down deterioration thereby extending the shelf life and consequently the marketing period of perishable commodities. However the high cost of conventional cold rooms has contributed to poor cold chain management in perishable commodities and consequently the high postharvest losses (40 – 50%) reported. Over the years there have been substantive efforts to find low-cost alternatives for smallholder farmers. The efforts have included on-station research to adapt and test applicable technologies. These include evaporative cooling technologies (Ambuko *et al*., 2017; Ambuko *et al*., 2018); Coolbot cold room (Ambuko *et al*., 2017; Ambuko *et al*., 2018). In addition to the low-cost cold storage technologies, farmers have been trained on importance of other cold chain management practices to preserve postharvest quality of perishable commodities.

The processing technologies installed at the center including the wet processing facilities and the tunnel solar dryer complement the storage and shelf life extension technologies. The processing technologies provide the researchers an opportunity to work with farmers and buyers of the processed products to delve into new products development. These could be specialty products targeting certain niche markets that have not been explored. This will also avoid competition with established brands in the mass market.

Challenges and recommendations

Although smallholder aggregation and processing has potential to be a game-changing intervention, group dynamics can affect the impact. There is therefore need for capacity building to inculcate principles and processes that the group members must abide with to ensure cohesiveness. The cost and benefit analysis for various scenarios require further research so as to make the business case for the aggregation center model for various users. Although the center has been established to benefit a group of farmers and other actors in the region, they require an entrepreneurial acumen to make profits out of the center. Once the business case and profitability of this model is demonstrated through the pilot, it is expected to scale out of Karurumo into other parts of Embu County, other Counties in Kenya and eventually to other countries in Africa and beyond.

Conclusion

The center is a learning and outreach center for various actors interested in postharvest management. Postharvest researchers will continue to equip the center with technologies and innovations from research so as to ensure that their research benefits the targeted end users – 'lab to land'. If proven successful in scaling out postharvest technologies, the approach can be adopted to scale out other agricultural research outputs and enhance researchers' interaction with the end users of their research.

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