

University of Nairobi Postharvest Project

Establishment of Aggregation Centers for Smallholder Horticultural Farmers and Organization
of the All Africa Postharvest Congress and Exhibition

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FINAL NARRATIVE REPORT

Submitted by:

Principal Investigator:

Prof. Jane Ambuko

SIGNED



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Executive Summary

Food waste and loss is recognized globally as a large and increasingly urgent problem and is particularly acute in developing countries where food loss reduces income by at least 15% (FAO) for 470 million smallholder farmers and downstream value chain actors, most of whom are part of the 1.2 billion people who are food insecure. Additionally, one third of the food produced globally—about 1.3 billion tons of food per year—is never consumed at all. This food is wasted or lost at some step of the supply chain between when it leaves a farm and when a consumer would typically eat it. This project contributed to the Rockefeller Foundation's YieldWise initiative which focused on crop food loss in developing countries, which directly affects poor and vulnerable people. The Foundation's YieldWise Initiative in execution sought to reduce food losses by at least 50% in representative value chains and improving millions of rural lives. This goal aligns with other national, regional, and global levels to reduce postharvest losses. Targets have been set to halve the postharvest losses by the year 2025 and 2030 under Malabo Declaration of the African Union and the United Nation's SDG 12.3 respectively.

In Kenya the focus crop for the YieldWise initiative was mango where it is estimated that 40 to 50% of mango fruits produced are lost or wasted along the supply chain. The losses mean lost income for the diverse stakeholders in the mango supply chains but the farmers (producers) pay the highest cost of these losses. These losses impact negatively on the livelihoods of some of the small-scale farmers who depend on mango farming as their main cash crop and source of income. The Yieldwise initiative identified an innovative approach that brings together four components in ways that will reduce food loss. These include 1) Linking smallholder farmers to market demand of both large anchor buyers and local alternative markets 2) Aggregating farmers to train them in postharvest management, promote their adoption of technologies, and aggregate their crops to meet buyer quantity and quality requirements 3) Using innovative finance mechanisms to promote agricultural investments and facilitate distribution and acquisition of technologies, particularly among smallholder farmers 4) Promoting the adoption of appropriate loss-reducing technologies to improve crop handling, storage, and processing. All four components are needed to implement the model; none of them alone is sufficient to optimize a value chain for crop loss reduction.

To contribute to the realization of the YieldWise goal reducing food losses by 50% this project implemented two activities 1) Organization of the 1st and 2nd All Africa Postharvest Congress and Exhibition 2) Establishment of two Smallholder Aggregation and Processing Centers. Under the first activity, the two congresses were held successfully in Kenya and Ethiopia. The congresses served to convene diverse stakeholders in the food supply chains with the aim of raising awareness about the problem of high postharvest losses, showcase applicable technologies, practices and strategies and establish partnerships towards finding sustainable solutions to postharvest loss reduction in the African Context. The two congress released communiques that spelled out the way forward for postharvest loss reduction in the African Context. Under the 2nd activity, two pilot aggregation centers were established for two horticultural farmer groups namely Karurumo Self Help Horticultural Farmers Group (on-grid) and Masii Horticultural Farmers' Cooperative Society (off-grid). The two centers are equipped with low-cost cold storage and small-scale processing technologies. These facilities have enabled the smallholder farmers to aggregate their produce in order to attain the quantities and quality required to access markets. The farmers in the Karurumo group have been trained to process the surplus produce into shelf-stable products thereby reduce postharvest losses and increase their incomes. The centers are currently used to demonstrate and showcase various technologies for postharvest handling and processing of perishable fruits and vegetables and train various stakeholders on the same.

Outputs from this project have provided an illustration of the feasibility of the YieldWise model and generated learnings that can be replicated to future interventions on other value chains. The All Africa Postharvest Congress has now been adopted by the African Union Commission as a continental convening of stakeholders to showcase postharvest technologies and strategies while checking progress made by member countries towards the set goal of halving postharvest losses by the year 2025. On the other hand, the smallholder aggregation centers established under this project are now being replicated in other Counties in Kenya.

I. BACKGROUND

I.1. RATIONALE AND JUSTIFICATION

The main problem that was addressed through this project is postharvest loss in perishable foods including fruits and vegetables. Mango is one of the main fruits produced in Kenya for mainly for the domestic market and to a small extent for the export market. Mango has great potential as a source of income and livelihoods for the many farmers involved in mango production. However, this potential has not been exploited because of various factors including high postharvest losses along the supply chain estimated that 40 -50%.

Smallholder mango farmers in Kenya have been reduced to price takers by middle men who take advantage of their vulnerability. Majority of the farmers of the highly perishable mango fruit produce small volumes of fruit. The small volumes reduce their capacity to transport their produce individually to the city markets where the fruits can fetch good prices. The farmers also lack proper storage at the farm level and investment in cold storage facilities as individuals is not feasible given the small volumes of fruits harvested by individual farmers. In addition processing the perishable fruits into shelf-stable products is not feasible for individual farmers because of the small volumes produces and the associated costs required to install and run such facilities. This scenario predisposes the farmers to exploitation by traders (middle men) who buy the fruits are very low prices. The farmers are forced to accept the prices given by the traders or suffer total loss because the fruits are highly perishable. Fruits that do not meet the traders' standards are often left to rot away on the trees because there are no alternative uses for such fruits at the farm level. The farmers therefore make very little profits (if any) from fruit production.

To address these challenges faced by smallholder farmers, the Yieldwise Initiative identified an innovative approach that brings together four components in ways that will reduce food loss. The four components include 1) Linking smallholder farmers to market demand of both large anchor buyers and local alternative markets 2) Aggregating farmers to train them in postharvest management, promote their adoption of technologies, and aggregate their crops to meet buyer quantity and quality requirements 3) Using innovative finance mechanisms to promote agricultural investments and facilitate distribution and acquisition of technologies, particularly among smallholder farmers 4) Promoting the adoption of appropriate loss-reducing technologies to improve crop handling, storage, and processing. All four components are needed to implement the model because none of them alone is sufficient to optimize a value chain for crop loss reduction.

This project attempted to implement some of the components of the YieldWise strategy to address postharvest losses in the mango value chain. Besides addressing the problem of postharvest losses in mango, the organization of the 1st and 2nd All Africa Postharvest Congress and Exhibitions sought to expand the scope towards finding sustainable solutions to postharvest losses in food supply chains.

1.2. PROJECT OBJECTIVES

Specific objectives of the 1st and 2nd All Africa Postharvest Congress and Exhibition

- To raise awareness on food losses and waste through data and information sharing.
- To document the impact of postharvest food loss and waste on food and nutrition in Africa.
- To identify and disseminate effective and appropriate technologies and practices for FLW reduction in the African context.
- To identify effective multi-stakeholder strategies and policy interventions for FLW reduction.
- To provide a platform for participants to build networks and partnerships for resource mobilization and other activities geared towards FLW reduction.
- To generate a comprehensive action plan for the reduction of food loss and waste for the African continent.

Specific objectives of Smallholder Aggregation Centers

- To enable smallholder farmers to aggregate perishables produce (fruits and vegetables) in order to attain consistent volumes and quality required by buyers.
- To enable smallholder farmers to transform surplus fruits and vegetables into shelf-stable products such as juices, concentrates and dehydrated products with a longer shelf-life with the aim of diversifying product range and reducing postharvest losses.
- To demonstrate practical application on postharvest technologies and best practices to reduce postharvest losses in perishable fruits and vegetables.

2. OUTPUTS OF IMPLEMENTATION OF THE PROJECT ACTIVITIES

2.1. The 1st All Africa Postharvest Congress and Exhibition

The 1st All-Africa Post-harvest Congress and Exhibition was convened by the University of Nairobi and a consortium of partners from 28th to 31st March, 2017 at Safari Park Hotel in Nairobi, Kenya and hosted by the Government of Kenya. The theme of the Congress was **“Reducing Food Losses and Waste: Sustainable Solutions for Africa”**. The Congress provided a platform for stakeholders in the food supply chain and specifically in the Post-harvest space to develop actionable plans that will move Africa’s post-harvest food loss and waste (FLW) management agenda forward in line with the Malabo Declaration.

The Congress aimed to:

- i. Raise awareness on food losses and waste through data and information sharing;
- ii. Document the impact of post-harvest food losses and waste on food and nutrition in Africa;
- iii. Identify and disseminate effective and appropriate technologies and practices for FLW reduction in the African context;
- iv. Identify effective multi-stakeholder strategies and policy interventions for FLW reduction;
- v. Provide a platform for participants to build networks and partnerships for resource mobilization and other activities geared towards FLW reduction; and
- vi. Generate a comprehensive action plan for the reduction of FLW for the African continent.

The congress also featured a post-harvest technology competition/challenge that collated data and showcased emerging technologies in post-harvest as a great resource for stakeholders in Africa's agriculture sector including extension agents, entrepreneurs, investors, donors and researchers.

The Congress brought together over 600 participants from 45 countries (25 from African countries and 20 others from South America, Asia, North America and Europe). The diverse delegates included policy makers, researchers, academia (including students), local and international agribusiness firms, farmers, financial institutions, potential investors, civil society organizations and thought leaders from around the world. The goal was for the delegates to discuss and develop concrete plans for post-harvest food loss and waste reduction in the African context. One of the key focuses of the Congress was the exhibitions that attracted 54 participants from both public and private sectors as well as 10 top innovators from the postharvest technologies challenge.

Recommendations and next steps

On the last day of the congress, **the Nairobi Declaration** on Post-Harvest Loss Reduction in the African context was pronounced. In the declaration, the delegates collectively committed to the following 'call to action' as the next steps: The Six (6) priority action items include:

1. Commitment by all to reduce Post-harvest Losses – the 4Ps:
 - **Prioritization** and commitment by all stakeholders to actionable plans towards reducing FLW
 - Establishment of inclusive **Partnerships** and collaborations to adopt and scale up best practices in FLW reduction and mainstream PH management
 - Enabling **Policy** environment – incentives, regulations, funding from African Governments
 - **Platforms** and frameworks for engagement and knowledge sharing – knowledge repository
2. Take stock, innovate and scale up
 - Take Stock of existing technologies/innovations
 - Innovate what we need or is required – funding research in PH technologies and Innovations
 - Scale up technologies/innovations which have been tested and proven as appropriate in African context
3. Capacity Development at all levels of the value chain
 - Curricula development/review to incorporate FLW issues
 - Development of science around Post-harvest Losses to bridge the gap between Research and Development and field practice (lab to land)
 - Build and institutionalize FLW capacity development programs: Establish centres of excellence in various value chains
 - Mainstream gender to ensure that capacity development initiatives are responsive to women and attractive to the youth along the entire value chain
4. Measurements/Baseline studies to establish the current status of food loss and capacity gaps of prioritized value chains
 - Need to redress the use and reuse of outdated estimates in shaping the data narrative in Africa
 - Multi-disciplinary teams of experts to measure PHL periodically and develop appropriate indicators against which progress/targets will be measured

- Private sector involvement in data measurement
5. Monitoring and Evaluation Framework: This is critical for tracking progress made towards realization of the set goals and targets under the Malabo Declaration (2014) of halving postharvest food losses by 2025
 6. Continuity of the All Africa Postharvest Congress Convening.
 - Need to Establish well-defined structures for future convening of the congress – Set up a Postharvest Congress Secretariat which will organize All Africa Postharvest Congresses as a regular (possibly biennial) event to achieve clearly defined objectives for each congress, prepare reports, policy briefs from the congress and follow up on.

The detailed [communique and other documents from the congress are available on the project portal](#)

2.2. The 2nd All Africa Postharvest Congress and Exhibition

The Second All Africa Postharvest Congress and Exhibition was jointly organized by the African Union Commission and the University of Nairobi in partnership with other institutions including Stellenbosch University, Jomo Kenyatta University of Agriculture and Technology, Eastern Africa Grain Council, Ministry of Agriculture of the Republic of Kenya, World Food Preservation Center, Technical Center for Agricultural and Rural Cooperation, World Resources Institute and the Ethiopian Society of Postharvest Management. The congress was held at the African Union Headquarters in Addis Ababa, Ethiopia, on 17th - 20th September, 2019 under the theme '*Postharvest Loss Reduction and Agro-Processing: Drivers of Agricultural Transformation in Africa*'.

The Congress was attended by over 450 participants from Member States of the African Union including Academia, Research Institutions, International Organizations, Non-Governmental Organizations, Media organizations, Regional Economic Communities, Financial Institutions, Development Partners, Farmers Organizations, Women and Youth Groups, Private Sector and representatives various governments .

Specific objectives

1. Raise awareness on food losses and waste through data and information sharing
2. Showcase effective strategies, technologies, practices, initiatives for postharvest loss reduction
3. Monitor and review progress on postharvest loss reduction initiatives against set targets
4. Build and strengthen linkages and partnerships (including private sector engagement) for resource mobilization and other activities geared towards postharvest loss reduction

Recommendations and Key Messages for Various Thematic Areas

SUB THEME 1: Public Sector Initiatives in Postharvest Loss Reduction and Agro-Processing: Policy, Strategies and Regulations.

- Policies need to be developed and institutions strengthened at the national level in the efforts to address postharvest losses in Africa.

SUB THEME 2: Financing Models or Options for Agro-processing and Postharvest Management. –

- There is need to tailor financing models to de-risk investments including financial risk pooling on Postharvest technologies to enable smallholder farmers acquire and adapt them.

- Innovative financing models should be developed for postharvest technologies to assist farmers and other players in the value chain in adopting them.
- Finances targeting small scale actors (often the riskiest investment) to be promoted through equity funding, hedge funds, matching funds etc.

SUB THEME 3: Science, Technology and Innovation in Postharvest Management and Agro-Processing.

- The need for baseline data on postharvest losses in Africa was stressed as it is critical to monitor progress towards realization of the set target of halving postharvest losses by 2025, under the Malabo Declaration (2014) and by 2030 under the United Nations' SDG 12.3.
- There is need to strengthen African Institutions' capacity for research to fund homegrown solutions (technologies and innovations) to address postharvest losses in the African context. 28. A multi-disciplinary approach and collaboration among researchers and institutions is very key in addressing PH management and in strengthening research institutions.
- Robust Communication strategies on postharvest loss should be developed and Information and Communication Technologies (ICTs) used to raise awareness on postharvest loss and popularize Postharvest Management Solutions to address post-harvest losses in Africa.
- China is willing to collaborate and partner with Africa to transfer technologies in PH management especially with equipment and bulk based warehouse of grains.
- Government Policy has given incentives and support for small holder grain farmers to reduce losses in large scale grain storage as evidenced in China. Policy can be used to address PH losses and implement informed decisions and interventions based on data and technology developed by researchers.

SUB THEME 4: Capacity Development and Outreach Programmes in Postharvest Management and Agro-Processing.

- There are glaring capacity gaps in the food chains that must be addressed in order to have the requisite human and infrastructural capacity to address postharvest loss in Africa. African governments should work with the private sector, global institutions and development partners to address these capacity gaps.
- Training curricula in universities and other tertiary institutions need to be reviewed to strengthen the postharvest management component in order to impart the requisite skills for complex challenges in postharvest management. There is also the need for technical and vocational training for middle level practitioners, training for extension officers or extension service providers.
- Tailor-made training modules targeting small-scale farmers should be made available proposing turn key application methodologies in postharvest management.
- Capacity building and training of experts, especially in postharvest science and management should address postharvest challenges in Africa as a priority. Likewise, research work done at universities and research organization should reach the end user especially those that are accessible and affordable.

SUB THEME 5: Youth and Women Empowerment through Postharvest Management and Agro-Processing,

- African governments should ensure that the youth and women are at the centre of postharvest management in Africa, by ensuring a supportive policy environment and availing adequate youth and women friendly financing models.

- The congress recognized that Youth and Women engaged in agro-processing enterprises require mentorship through incubation centers, innovation hub and other novel models to navigate the difficult business terrain, including those involved in trade.
- More investment should be made to help youth and women in Agro-processing to access finances to help them start-up or scale up innovations and technologies on postharvest management (include tax reliefs for start-ups).
- Youth and women entrepreneurs in postharvest management should explore possibilities of satisfying the local market before progressively partnering with local partners in the countries where you want to export to.

SUB THEME 6: Private Sector Initiatives and Public-Private Partnerships (PPP) in Postharvest Management and Agro-Processing.

- In developing effective postharvest management strategies, all stakeholders should be involved and consultations should be done at all levels.
- It was noted that accessing markets internationally with products can be difficult for traders and agro-processors, as trade tariffs and non-tariff barriers can hinder them from doing so. A way out of this challenge is to partner with local representatives in the country they want to do business in. African governments were also called upon to assist entrepreneurs, especially those that deal in perishable goods or products.

Full Congress Report, Communique and other Congress documents available on the portal

2.3. SMALLHOLDER AGGREGATION CENTERS

2.3.1. 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 centers. The existing groups were screened based on their institutional maturity using the AIMS group analysis tool. After screening more than twelve groups in Embu County, the team identified the Karurumo Horticultural Self Help Group (KSHSG) in Embu as a suitable and ready entry point to pilot the smallholder aggregation and processing model. A similar process was used to select the Masii Horticultural Cooperative in Machakos County. The Karurumo group was selected for additional support in on-grid cold storage and processing because of their on-going processing activities. On the other hand, the Masii group which was initially engaged in smallholder aggregation was selected to demonstrate smallholder off-grid aggregation. Following the selection, the project team held brainstorming meetings with the groups' members and other stakeholders in the regions to identify the group needs. The meetings also sought to establish the best strategy to engage the groups.

2.3.2. Fabrication and installation of facilities and equipment required for smallholder aggregation and processing

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

2.3.2.1. Receiving, presorting, sorting area/shade

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



Sorting surface at the Karurumo Center



Receiving and presorting shade at Masii Center

2.3.2.2. Cold storage technologies: Evaporative Charcoal Cooler (ECC), Zero Energy Brick Cooler (ZEBC) and Coolbot™ Cold Room

The Karurumo center is equipped with three types of cold storage facilities. These include: two evaporative cooling technologies (Evaporative charcoal cooler and Zero energy brick cooler) which do not require electricity and Coolbot™ cold storage technology, which requires electricity. The Masii center which is an off-grid aggregation center only has the two evaporative cooling technologies.

A modular design was used for the ECC which was designed and fabricated by the Environmental and Bio systems Engineering (EBE) Department of the University of Nairobi. The modular design gives flexibility and adaptability in the size 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. This translates into 4-5 tons for mango fruits.



The zero energy brick cooler (ZEBEC) was built onsite from locally available materials including earthen bricks, river bed sand, water tank and water drip lines. Two ZEBECs each measuring 200 X 300 cm and 60 cm high have been built in Karurumo and Masii. Each ZEBEC can hold upto 1 ton of mango fruits.



Zero Energy Brick Cooler (ZEBEC) at Karurumo



Mango fruits in the ZEBEC at Karurumo

A 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. 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. This arrangement translates into 4-5 tons of mangoes.



Coolbot™ Cold Room at Karurumo Center



2.3.2.3. Wet processing plant

The wet processing plant is made up various components including: a blanching unit; 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.



Wet (juice) processing room at Karurumo Center

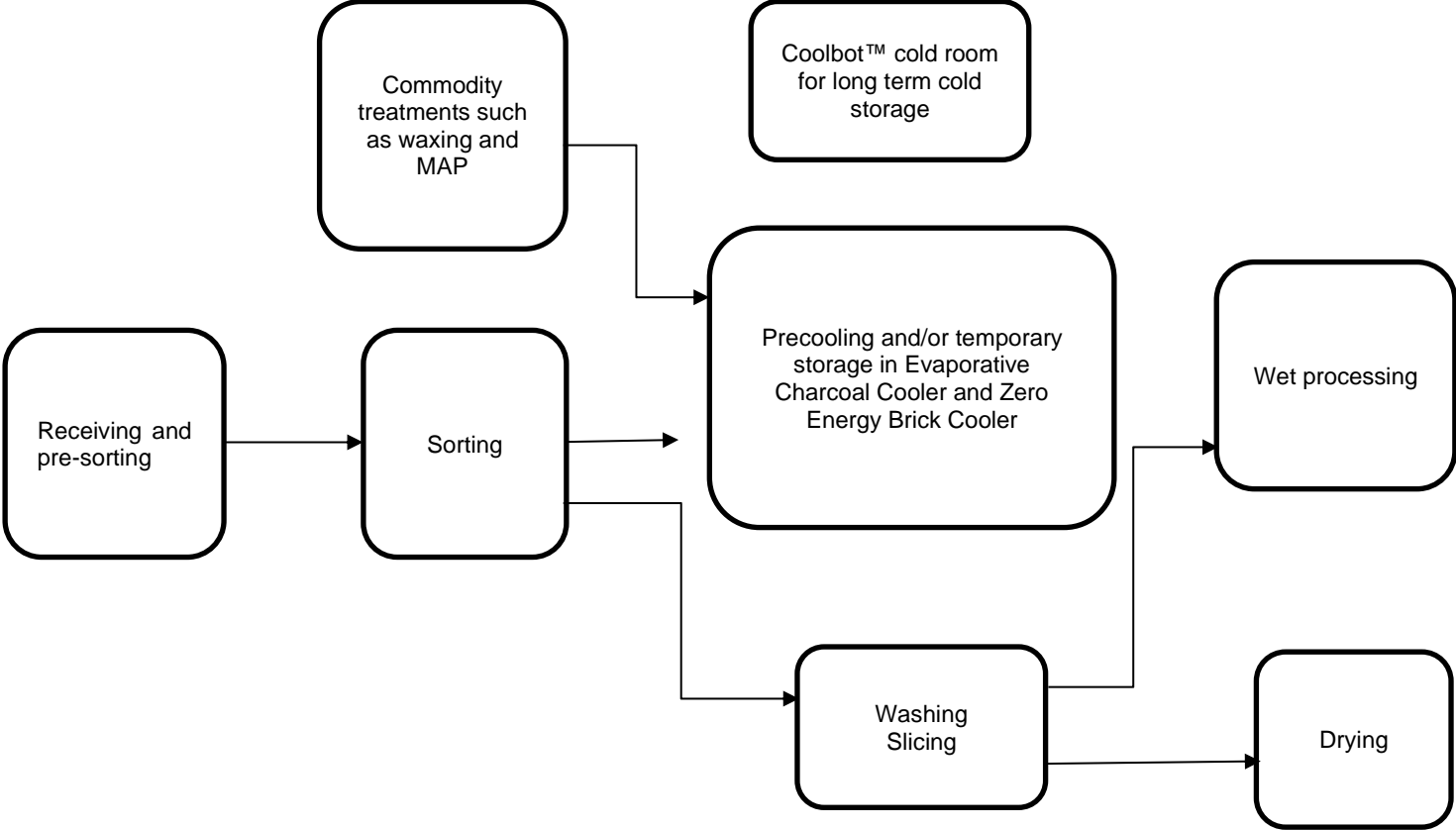
2.3.2.4. Tunnel Solar Dryers

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.

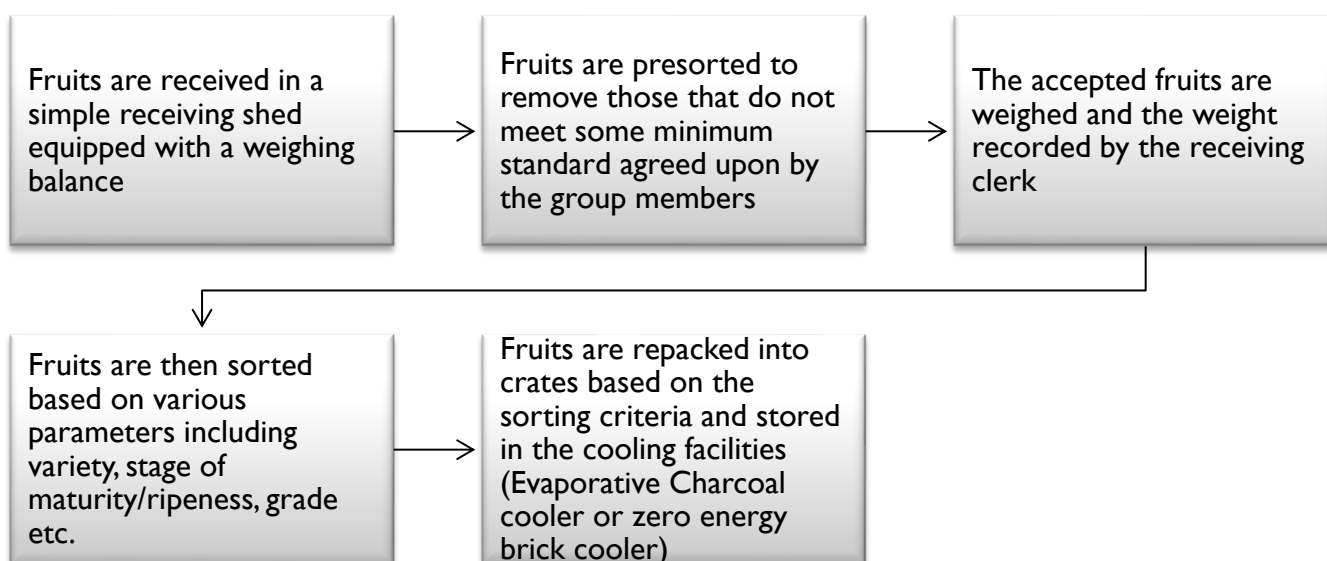


Tunnel Solar Dryers at Karurumo Center

PROCESS FLOW AT THE KARURUMO AGGREGATION AND PROCESSING CENTER



PROCESS FLOW AT THE MASII AGGREGATION CENTER



2.4. ADDITIONAL ACTIVITIES IMPLEMENTED UNDER THIS PROJECT

2.4.1. Training of farmers

To complement the postharvest technologies, 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 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.

2.4.2. Training of graduate students

Student name	Degree Program	Thesis Title	Status
1. Esther Mujuka	PhD Agricultural and Applied Economics	Efficiency of Mango Marketing Channels and Potential Economic Impact of Postharvest Loss Reduction Technologies in Embu and Machakos Counties of Kenya	Research completed, thesis preparation is under way
2. Naphis Bitange	PhD Agronomy	Effect Of Calcium Nutrition On Yield, Postharvest Quality And Jelly Seed Incidence In Mango Fruits	Research completed, thesis preparation is under way

3. Rose Githumbi	Msc Agricultural and Applied Economics	Assessment of post-harvest losses drivers and factors influencing adoption of loss reduction technologies along the mango value chain in Embu and Machakos counties, Kenya	Research is still ongoing
4. Antony Mwirigi	Msc Agricultural and Applied Economics	Analysis Of Adoption Of Pre-harvest Practices and Their Impact on Mango Post-harvest Losses. A Case of Mango Farmers in Embu and Machakos Counties, Kenya	Research completed, thesis preparation is under way
5. Emmanuel Amwoka	Msc Horticulture	Effectiveness of Selected Postharvest Handling Practices and Technologies To Extend Shelf And Preserve Quality Of Mango Fruits	Research completed, thesis preparation is under way
6. Benson Maina	Msc Horticulture	Efficacy Of Waxing Innovations To Extend Shelf Life And Preserve Postharvest Quality Of Mango Fruit	Graduated in 2019 (December)
7. Isaac Nyangena	Msc Food Science and Technology	Effects Of Drying Pre-treatments On The Antioxidant Properties And Shelf Life-stability Of Mango Fruits	Completed and defended thesis, awaiting graduation in June 2020

PUBLICATIONS FROM THE PROJECT

A) Papers Published in Peer-reviewed Journals

1. Esther Mujuka, John Mburu, Ackello Ogutu and Jane Ambuko (2019). Returns to investment in postharvest loss reduction technologies among mango farmers in Embu County, Kenya. Food and Energy Security DOI: 10.1002/fes3.195
2. Benson Maina, Jane Ambuko, Margaret Hutchinson and Willis Owino (2020). The effect of waxing options on shelf life and postharvest quality of 'ngowe' mango fruits under different storage conditions. Advances in Agriculture. Accepted in press
3. Naphis M. Bitange, George N. Chemining'wa, Jane Ambuko and Willis O. Owino. (2020). Jelly

Seed Occurrence and Calcium Distribution in ‘van dyke’ Mango fruit tissues as influenced by Timing and Source of Calcium’. journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), In Press

4. Antony Bundi, John Mburu, Stephen Mbogoh, Jane Ambuko (2020). Factors Influencing the Adoption of Pre-Harvest Practices among Mango Farmers in Embu and Machakos Counties, Kenya. International Journal of Postharvest Technology and Innovation. Accepted, in press
5. Isaac O. Nyangena, Willis O. Owino, Samuel Imathiu , Jane Ambuko. Effect of pretreatments prior to drying on antioxidant properties of dried mango slices, Scientific African (2019), doi: <https://doi.org/10.1016/j.sciaf.2019.e00148>
6. Isaac Nyangena, Willis Owino, Jane Ambuko and Samuel Imathiu (2019). Effect of selected pretreatments prior to drying on physical quality attributes of dried mango chips. Journal of Food Science and Technology. DOI 10.1007/s13197-019-03857-9
7. N. M. Bitange, G. N. Chemining’wa, J. Ambuko and W. O. Owino (2019). Yield and Tissue Calcium Concentration of Mango (*Mangifera indica* L.) Fruit as Influenced by Calcium Source and Time of Application. International Journal of Plant & soil Science, 28(4): 1-12

B) Peer Reviewed Conference Papers

1. Naphis. M. Bitange^{1*}, George. N. Chemining’wa¹, Jane Ambuko¹ and Willis. O. Owino. Effect of Calcium Nutrition on Jelly Seed Occurrence and Calcium Distribution in ‘Van Dyke’ Mango Fruit Tissues. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya
2. Emmanuel Amwoka^{1*}, Jane Ambuko¹, Hutchinson Jesang’¹, and Willis Owino. Evaluation of Low-Cost Cold Storage Options to Preserve Post-Harvest Quality of Mango. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya
3. Jane Ambuko. Processing Fruits and Vegetables to Increase Profitability and Reduce Postharvest Losses in Smallholder Horticulture while Enhancing Access for Consumers. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya
4. Maina Benson^{1*}, Ambuko Jane^{1.}, Hutchinson Margaret¹ and Owino Willis. The Effect of Waxing Technologies on Postharvest Quality of ‘Apple’ Mango Fruit Stored under Different Storage Conditions. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya
5. Ann W. Githaiga^{1*} and Jane Ambuko. Effectiveness of Waxing to Extend the Postharvest Shelf Life of ‘Kent’ Mango Fruit. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya.
6. Antony M. Bundi ^{1*}, John Mburu ¹, Stephen Mbogoh ¹, and Jane Ambuko. Factors Influencing

- the Adoption of Pre-harvest Practices among Mango Farmers in Embu and Machakos. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya
7. Esther Mujuka^{1*}, John Mburu¹, Ackello Ogutu¹, and Jane Ambuko. Returns to Investment in Postharvest Loss Reduction Technologies among Mango Farmers in Embu County, Kenya. Presented at Agro 2019 Conference, 22-24 October, 2019, Nairobi Kenya
 8. **Jane Ambuko**, Emmanuel Amwoka, Isaac Nyangena, Willis Owino, Margaret Hutchinson, Catherine Kunyanga, George, Chemining'wa and John Mburu. Exploiting the Potential of Smallholder Horticulture through Aggregation and Processing Centers: Case Study of Mango in Kenya. Book of Abstracts pg 93. Presented at the 2nd All Africa Postharvest Congress and Exhibition, September 17-20, 2019. Addis Ababa, Ethiopia
 9. Emmanuel Amwoka, **Jane Ambuko**, Hutchinson Jesang' and Willis Owino. Effectiveness of Harvest Practices and Technologies to Maintain Cold-Chain and Extend Shelf Life of Mango Fruit. Book of abstracts Pg 42. Presented at the 2nd All Africa Postharvest Congress and Exhibition, September 17-20, 2019. Addis Ababa, Ethiopia
 10. Isaac Nyangena, Willis Owino, **Jane ambuko** and Samuel Imathiu. Effect of Selected Drying Pretreatments on Physical and Nutritional Quality Characteristics of Dried 'Apple' Mango Chips. Book of Abstracts Pg 41. Presented at the 2nd All Africa Postharvest Congress and Exhibition, September 17-20, 2019. Addis Ababa, Ethiopia
 11. Esther Mujuka, John Mburu, Chris-Ackello Ogutu, **Jane Ambuko**. 'Returns to Investment in Postharvest Loss Reduction Technologies among Mango Farmers in Embu County, Kenya. Tropentag, September 18 - 20, 2019 in Kassel, Germany
 12. **Ambuko Jane**, Esther Karithi, Margaret Hutchinson and Willis Owino. Low-cost Cold Storage Technologies to Preserve Postharvest Quality of Fruits and Vegetables. Presented at the LASER-PULSE Conference, Speke Hotel, Uganda. May 6-8, 2019
 13. **Jane Ambuko**, Emmanuel Amwoka, Margaret Hutchinson, George Chemining'wa, Catherine Kunyanga, John Mburu and Willis Owino. From the Lab to Land: Taking Postharvest Management Solutions to Horticultural Farmers through Aggregation Centers. Presented at the 6th RUFORUM Biennial Conference, 22-26th October, 2018, KICC, Nairobi - Kenya
 14. Benson Maina, **Jane Ambuko**, Margaret Hutchinson and Willis Owino. Effect of Different Waxing Technologies on Shelf Life of Mango Fruits Stored under Different Storage Conditions. Presented at the 6th RUFORUM Biennial Conference, 22-26th October, 2018, KICC, Nairobi - Kenya

15. Emmanuel Amwoka, **Jane Ambuko**, Hutchinson Jesang' and Willis Owino. Effectiveness of Cold Chain Management Practices to Extend Shelf Life of Mango Fruit. Presented at the 6th RUFORUM Biennial Conference, 22-26th October, 2018, KICC, Nairobi - Kenya
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19. **Ambuko Jane**: The 1st All Africa Postharvest Congress and Exhibition – Lessons, Recommendations and Way Forward. Lead Paper Presented at the Ethiopian Society of Postharvest Management. Addis Ababa, Ethiopia. 26-27th January, 2018.
20. **Ambuko, Jane**, Esther Karithi, Hutchinson Margaret, and Owino, Willis. The coolbot™ technology: opportunities and challenges for smallholder horticultural farmers in Africa. Presented at the VI Postharvest Unlimited Conference, October 17-20, 2017, Madrid, Spain
21. **Jane Ambuko**: Strengthening Small Scale Processors to Reduce Postharvest Losses and Improve Profitability of Smallholder Horticulture. Presented at the Fruits, Vegetables and Herbs Conference at Kenya school of Monetary Studies, 25-27th September 2019
22. **Jane Ambuko**. Innovations and Technologies in Food Storage & Postharvest Quality Preservation. The 3rd Annual Agribusiness Investors Summit 2019, Strathmore University Business School, 28-29th March 2019.
23. **Jane Ambuko**. 'Applicable Technologies to Reduce Postharvest Losses – Contributing to Food Security'. Presented at Food Security Workshop, CAVS, Nairobi. 9-10th December 2018
24. **Jane Ambuko**. Postharvest Loss Reduction in Horticultural Food Value Chains: Applicable Solutions from Research. Presented at the Fruits, Vegetables & Herbs Conference and Exhibition. 5th – 7th September, 2018. Kenya School of Monetary Studies

Media Publications

1. **Jane Ambuko:** ‘Exploiting The Value Of Mango Fruit During The Peak Season’ – HortiNews, June-July, 2019 Issue, Page 21-24
2. **Jane Ambuko;** ‘To put more money in mango farmers’ pockets, we must fully embrace value addition’. Seeds of Gold – January 26, 2019
3. **Jane Ambuko.** Need for a Paradigm Shift in Efforts to Address Food Insecurity in Africa – Reduce Postharvest Food Losses. International Affairs Forum (IAF), Food and Water Security, June 2019 Issue, Pg 31 - 34
4. **Jane Ambuko.** Simple techniques to keep your fruits and veges fresh. Seeds of Gold, June 16, 2018.
5. **Jane Ambuko.** Simple Practices and Technologies for Cool/Cold Chain Management in Fresh Fruit and Vegetables. HortNews – June-July 2018
6. **Jane Ambuko.** Smallholder aggregation and agro-processing for better market access and profitability while reducing postharvest losses in horticultural value chains. Published in HortNews – April-May 2018 Issue, Pg 40-42
7. **Jane Ambuko.** Easy way to put money in mango farmers’ pockets. Published in Saturday Nation – Seeds of Gold, March 24, 2018

YouTube (Digital Media)

1. Featured Video, The DrumBeat: Africa Bioscience Trends, ISSUE NO.14. Post Harvest Management: From Lab to Land, Available on YouTube link
<https://www.youtube.com/watch?v=D0u9NBLc60c&feature=youtu.be>
2. Enabling Farmers enjoy maximum turnover of their farm produce – Part 3.
<https://youtu.be/H2GvIadQBwQ>

Exhibitions

1. Jane Ambuko, Emmanuel Amwoka and Suleiman Mutuli. Postharvest Technologies and Innovations for Smallholder farmers. Exhibition at the AGRF Conference in Ghana. Sept 4-7, 2019
2. Jane Ambuko, Emmanuel Amwoka and Suleiman Mutuli. Exhibition at the 2nd All Africa Postharvest Congress and Exhibition, September 17-20, 2019
3. Jane Ambuko, Emmanuel Amwoka and Suleiman Mutuli. Postharvest Technologies and Innovations to Reduce Postharvest Losses in Horticulture. Nairobi Innovation Week 2019. 11-14th June 2019, University of Nairobi Grounds

4. Jane Ambuko, Emmanuel Amwoka, Benson Maina and Justa Gathambi. Taking Postharvest Management Solutions to Horticultural Farmers through Smallholder Aggregation and Processing Centers - at the 6th Higher Education Week and RUFORUM Biennial Conference, 22-26th October, 2018
5. Jane Ambuko. University of Nairobi Postharvest Project Exhibition at the AWARD@10 Celebrations at Trademark Hotel, Nairobi Kenya, 29th November 2018

SPIN-OFFS AND FOLLOW UP RESEARCH & DEVELOPMENT ACTIVITIES BUILDING ON THE GAINS OF THE YIELDWISE PROJECT

1. Establishment of Evaporative Cold Storage Facilities for Small-scale Traders in 3 Markets in Kalobeyei, Turkana County. Partnership with the World Food Program (WFP)
2. Further research to increase efficiency of the evaporative cooling technologies established for smallholder farmers in Karurumo and Masii. Partnership between the University of Nairobi the Postharvest Research team and Massachusetts Institute of Technology (MIT), USA
3. SolCOOL' - Solar Powered Cold Food Chains for Food Waste Reduction and Value Addition
4. Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction – Innovation Platform to Gain Sustainable Efficiencies in the Global Food System
5. Adaptation and upscaling of tested and applicable postharvest technologies for smallholder horticultural farmers to reduce postharvest losses. Partners include: UON, Agricultural and Livestock Research Organization (KALRO), Jomo Kenyatta University of Agriculture and Ministry of Agriculture
6. Strengthening Kenyan Small Scale Processors to Access Market and Reduce Losses. Partners include University of Nairobi (UON), Purdue University, Nelson Mandela Institute of Science & Technology, Farmer Groups and Smallholder Private Sector Processors

3.0. PROJECT ACTIVITIES' CONTRIBUTION TO THE OUTCOMES, LEARNINGS AND IMPACT OF THE YIELDWISE INITIATIVE

3.1. The All Africa Postharvest Congress and Exhibitions

The 1st and 2nd All Africa Postharvest Congress and Exhibitions (AAPHCE) greatly increased the level of awareness about the problem of postharvest losses. Awareness is critical in the efforts to trigger action towards postharvest loss reduction. During the congresses, applicable technologies and practices that can be used to reduce postharvest losses were show-cased through the exhibition. This is expected to contribute significantly to increased awareness and subsequent adoption of postharvest technologies. The congresses provided an excellent platform for researchers, academics, farmers, industry, development agencies, civil society and policy makers to learn, share information, build networks and partnerships with the overall objective of identifying effective strategies and interventions to reduce postharvest losses.

3.2. Smallholder aggregation and processing centers

Mango is one of the major cash crops produced by the smallholder farmers in Embu and Machakos Counties. Therefore it was the key commodity that was targeted when setting up the aggregation centers. The two regions also produce other horticultural crops including bananas, tomatoes, citrus, papaya and a wide range of leafy vegetables all of which are destined for the local market. The mango

season in Embu and Machakos Counties (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 centers 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 past mango seasons, farmers at the Karurumo and Masii centers 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 are even higher as long as the farmer can access the markets for high quality processed products. 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 have 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. At the Masii center, up to 7 6 tons of fruits can be aggregated at any one time. Currently, the traders move from farm to farm to collect small volumes of inconsistent quality from small scale farmers who are spread across the regions. Through aggregation centers, the traders can make orders of fruits of the 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.

3.3. 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 and Masii aggregation centers 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 centers, 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 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; Coolbot cold room. 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 Karurumo 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.

4.0. LESSONS LEARNT

One of the key lessons learnt is that with the right technologies and strategy the goal halving postharvest losses by the year 2025 (Malabo Declaration, 2014) and 2030 (United Nations SDG 12.3) can be achieved. However, any interventions geared towards helping smallholder farmers must take cognizance of their unique situations and circumstances. Interventions must therefore be tailored to the needs of each group and not generalized.

For the aggregation center model to succeed, all actors in the supply chain must work together for the common good. Buyers of the fresh fruits could sabotage the farmers aggregation centers initiative if they are not brought on board. This is because the buyers' activities are driven by profit. However,

shrewd negotiation with the buyers can provide a ready market for the farmers because the buyers have the much-needed market information.

County Governments are key and interested parties in smallholder aggregation as a strategy to support smallholder farmers in their regions. Therefore, partnership between development partners and the County governments can facilitate expansion of the established centers and establishment of new centers.

5.0. CHALLENGES IN ESTABLISHMENT OF SMALLHOLDER AGGREGATION CENTERS

Challenge	How it was addressed
Identification of suitable farmer groups for establishment of the aggregation centers	Thorough vetting of the potential beneficiaries with the help of Technoserve Kenya's field staff
Seasonality of mango fruits – without other commodities that can be aggregated, the aggregation facilities can be underutilized	The farmers in the area have been encouraged to venture into production and aggregation of other horticultural commodities such as banana, tomatoes
Connectivity to 3-phase power supply required to power the pasteurizer in the juice processing line	Engaged the Embu County officials to support the group to get connected to 3-phase power. The Governor has committed facilitate the connection before the start of the next mango season in November.
Lack of business acumen/skills among the beneficiaries	Training on business skills including record keeping
Brokers shunning the aggregated produce because the farmers are seeking better price	More farmers encouraged to join groups and negotiate better prices from brokers – avoid exploitation from brokers when they buy from individual farmers

2.5. RECOMMENDATIONS AND WAY FORWARD

The two aggregation centers installed under this project will serve as pilot aggregation centers. They will serve as learning models which can be improved or modified to suit the needs of other groups that may be interested in smallholder aggregation. Having learnt from these pilot centers, the project team is ready to provide the requisite expertise to any other teams including from public and private sector which are interested in establishing smallholder aggregation center.

In Karurumo, Embu County, the project team has offered to provide technical support to enable establishment of an additional smallholder aggregation and/or processing center targeting a women group. In Masii, the Deputy Governor (Machakos County) is in discussions with the project team and Technoserve in a bid to strengthen the group's activities beyond aggregation. He would like the center to be transformed into a model center for smallholder aggregation and processing. The model, if successful can then be scaled up to other regions in Machakos County.

The groups require extra support to transform the aggregation centers into viable businesses. In this regard, the groups will require training and support in business skills. The centers have great potential to tap into niche markets for processed products (dry and wet). Given the scale of operation, the groups may not be able to compete effectively with companies or SMEs already involved in fruit/vegetable processing which already have established brands. However, through rapid market appraisals, they can identify niche products that resonate with specific market segments and narrow down to such products. The project team will offer the groups technical support to develop such products under the Strengthening Africa Processors to Reduce Postharvest Losses (SAP) Project. The farmers have also ventured into production, aggregation and/or processing of other commodities to ensure full utilization of the installed facilities all year round. This will ensure sustainability of the centers while contributing to increased profits.

The project team is working with County governments and development partners to scale up the concept of aggregation centers. The team will continue to use various forums including conferences, exhibitions, field days and others to popularize the concept of smallholder aggregation and processing centers as a strategy to, reduce postharvest losses, enhance market access and increase profits for small holder farmers.