

Communication

Extension of Small-Scale Postharvest Horticulture Technologies—A Model Training and Services Center

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Abstract: A pilot Postharvest Training and Services Center (PTSC) was launched in October 2012 in Arusha, Tanzania as part of a United States Agency for International Development (USAID) funded project. The five key components of the PTSC are (1) training of postharvest trainers, (2) postharvest training and demonstrations for local small-scale clientele, (3) adaptive research, (4) postharvest services, and (5) retail sales of postharvest tools and supplies. During the years of 2011–2012, a one year e-learning program was provided to 36 young horticultural professionals from seven Sub-Saharan African countries. These postharvest specialists went on to train more than 13,000 local farmers, extension workers, food processors, and marketers in their home countries in the year following completion of their course. Evaluators found that these specialists had trained an additional 9300 people by November 2014. When asked about adoption by their local trainees, 79% reported examples of their trainees using improved postharvest practices. From 2012–2013, the project supported 30 multi-day training programs, and the evaluation found that many of the improved practices being promoted were adopted by the trainees and led to increased earnings. Three PTSC components still require attention. Research activities initiated during the project are incomplete, and successful sales of postharvest goods and services will require commitment and improved partnering.

Keywords: postharvest technologies; e-learning; small-scale; impact evaluation; Sub-Saharan Africa

1. Introduction

A USAID-funded project in East Africa of a new model for extension of postharvest technologies was piloted during 2010–2014 under the Horticulture CRSP (Collaborative Research Support Program, now known as the Horticulture Innovation Lab, Davis, CA, USA) at the University of California (UC) at Davis. Project partners included the Department of Food Science and Technology at UC Davis, the International Programs office at the World Food Logistics Organization (WFLO, Alexandria, VA, USA), the University of Georgia, and the Asian Vegetable Research Development Center (AVRDC)—The World Vegetable Center (Arusha, Tanzania), and additional financial support and in-kind technical support was provided by postharvest specialists from The Postharvest Education Foundation (PEF), in which the authors are founding board members.

The pilot Postharvest Training and Services Center (PTSC) was launched in October 2012 on the campus of AVRDC—The World Vegetable Center in Arusha, Tanzania. The project operated as planned in Northern Tanzania (2012–2014), training young horticultural professionals from seven countries (Benin, Ethiopia, Ghana, Kenya, Rwanda, Tanzania, and Uganda) as “Postharvest Specialists” and was followed six months later by USAID Save the Children/Technical and Operational Performance Support (TOPS)-funded evaluation studies (October 2014–May 2015). Simultaneously, during 2012–2015, three years of mentoring were being provided by PEF for more than a dozen Tanzanian extension workers and postharvest trainers who are currently working within the local community in and near Arusha to improve postharvest handling practices and reduce losses in horticultural crops.

1.1. Background Information

Less than 5% of funding for horticultural research and extension (R&E) has been allocated to postharvest issues over the past 25 years [1,2] as the historical focus has been on increasing production. In the 1990s, the focus in the horticultural research sector moved to the field of marketing and more recently it has focused upon value chain development. Internet database searches show that less than one in 2000 agricultural projects undertaken globally have focused on fresh produce handling and marketing, according to advanced searches undertaken in five major online databases during 2010 (AidData [3]; USAID Documents [4]; World Bank [5]; United Nations Food and Agricultural Organization (UN FAO) Information Network for Postharvest Operations (INPho) [6]; Devex [7]). While thousands of development projects have been launched in developing countries between 1990 and the present time by dozens of donor agencies and governmental bodies, few have focused on agriculture (less than 6% according to the AiDA database [3]; 25% according to the World Bank [5]), very few have focused on horticulture (approximately 1% of the agricultural projects), and only one-third of this 1% of horticultural projects included any kind of postharvest component [8].

Of the 1.3 billion tons of food losses and waste reported by the UN FAO [9], an external analysis shows that 44% is made up of fruits and vegetable crops, and 20% is roots and tuber crops [10]. In terms

of the percent of kilocalories (kcal) lost or wasted for each type of food commodity, roots and tubers experience the greatest amount of loss and waste (63% on a caloric basis) while the rate of kcal losses for fruits and vegetables is 42%. In comparison, about 25% of the kcal of cereals and of seafood produced are lost or wasted.

A UN FAO–commissioned report published in 2011 advocated for “strengthening the supply chain through training and support for farmers, making investments in infrastructure and transportation, as well as investments in an expansion of the food processing and packaging industries”, which experts believe could help to reduce the amount of food loss and waste [9]. In most countries where high levels of fresh produce wastage is occurring, the local farmers, traders, small-scale processors, and marketers of fruits and vegetable crops have little or no access to postharvest training, technical information, guidance on use of new technologies, or local access to the tools and supplies needed to utilize new technical knowledge or improved postharvest handling practices.

In developing countries, food losses and food waste occur mainly at earlier stages of the value chain and can be traced back to financial, managerial, and technical constraints in harvesting techniques and postharvest handling as well as a lack of storage and cooling facilities. While postharvest losses for fruits and vegetable crops are reported to be 44% of the total global production by weight [10], these losses have been measured in Sub-Saharan Africa (SSA) for many crops to be even higher levels of 40% to 80% [11].

1.2. Description of the Model

The five key components of the postharvest extension model known as the PTSC are (1) training of postharvest trainers, (2) postharvest training demonstrations for local clientele, (3) adaptive research, (4) postharvest services, and (5) retail sales of tools and postharvest supplies. The concept of the PTSC was developed during 2007–2008 by the lead author while she was serving as an independent consultant for a Millennium Challenge Corporation (MCC) project in Cape Verde. Several PTSCs were constructed in Cape Verde during 2008–2010, but the designs were “enhanced” by the local authorities to include beautiful architectural features, millipede inspection stations, and/or large-scale cold storage facilities, so by the time all the modifications were made, the costs were very high and the design was not promoted beyond the MCC project for the Cape Verde islands. The original concept and model were further developed as part of a research project for the Bill and Melinda Gates Foundation which the lead author developed and led for WFLO during 2009–2010 on the investigation of appropriate postharvest technologies that could be disseminated in a sustainable manner in SSA and South Asia.

Postharvest advocacy needs in developing countries are many and include enhanced funding for R&E, updating laws governing markets, access to micro-credit, reduced interest rates, support for associations, extension programs for women, hiring and training more women as horticultural extension agents, and access to high quality planting materials/seeds, simple postharvest tools, supplies (especially improved packages), equipment, and market information [8]. Training of trainers, building local postharvest extension capacity, and training local populations in the specialized skills needed for reducing food losses have been advocated and proposed for many years, but very few studies have been funded or implemented. This pilot project was the first attempt to bring all the needed components together in one

location and provide potential users with a complete package of postharvest training, supplies, services, and support activities.

The PTSC was designed to serve as:

- a site for extension workers and local postharvest trainers to meet with growers and others working along the value chains to provide training to improve local capacity and knowledge on improved produce handling, harvesting, sorting/grading, packing, cooling, storage, food safety, processing, and marketing practices
- a training venue with permanent demonstrations for observing improved, cost-effective small-scale postharvest handling practices, facilities, and equipment
- a site where local private companies can demonstrate and explain the benefits of their goods and services related to improved postharvest handling, processing, or storage
- a retail shop with postharvest tools and supplies, packages, plastic crates, and other goods that can be purchased locally at reasonable prices
- a place where people can come to ask questions or get advice on how to use improved postharvest practices, learn about costs and benefits and marketing options
- a place where growers or traders can pay a small fee for services such as having their produce packed in improved containers, cooled and/or stored for a few days before marketing, leasing of a small insulated transport vehicle, using a solar dryer to produce dried fruits or vegetable snack products, *etc.*

2. The Evaluation Plan and Objectives

The final project report for the Horticulture CRSP project was submitted by WFLO in May 2014. The evaluation team reviewed the final report, and the objectives for an *ex post facto* evaluation of a completed postharvest extension project were set in cooperation with USAID/TOPS, and the data collection and analysis methods were planned during the proposal phase of the project.

2.1. Data Collection Methods

Data collection instruments (written surveys and structured interview schedules) were developed and field-tested in SSA by WFLO's local evaluation team, and data was collected over a six-month period via email surveys, phone, and face-to-face interviews to characterize the implementation, outcomes, and impacts of the five project components of the PTSC pilot project. Written surveys and questionnaires were developed using traditional evaluation methods, in collaboration with stakeholders, the local evaluation team, and clientele in order to ensure the questions were suitable and easy to understand, and that responses would be reliable [12]. Table 1 provides a summary of the data collection plan, target groups, sources of data, and response rate.

2.2. Objectives of the Ex Post Facto Evaluation

The evaluation project had three major objectives.

Objective 1: To determine the major capacity building outcomes and impact of the Postharvest Training and Services Center (PTSC) and Training the Trainers (ToT) program

Objective 2: To identify best practices in the management of the PTSC and its extension services
 Objective 3: To identify problems, concerns, and obstacles to making the PTSC a sustainable and replicable model

Data was collected using a variety of methods (surveys, face-to-face or phone interviews, site visits) as shown in Table 1, where x indicates which method(s) were used for which target groups.

Table 1. Data collection plan and implementation.

Target Groups	Size of Target Group	Email Surveys	Face-to-Face Interviews	Phone Interviews	Site Visits for Observations	Response Rate
Training of trainers (ToT) participants	36 in total	x				92%
Local trainees (farmers and food processors)	50 people, random cluster sample selected from a population of 500 trainees		x		x	100%
Postharvest trainers	14 in total	x		x		100%
PTSC administrators and managers	7 in total		x		x	100%

3. Results and Discussion

Data analyses undertaken for the *ex post facto* evaluation project included simple counts and percentages for quantitative data and descriptive information (categories, lists, case studies) for qualitative data. This communication draws on both the final project report for Hort CRSP and preliminary evaluation reports for USAID/TOPS, none of which have been published. Project leaders at WFLO plan to formally present the results of the TOPS-funded postharvest extension project evaluation once the project has been completed.

3.1. Training of Postharvest Trainers

One of the major objectives of the Hort CRSP-funded project was to educate 30 trainers as postharvest specialists and provide them with the knowledge, tools, and motivation to train 5000 local clientele in their own home locations by the end of the project. The project outcomes exceeded these targets, as 36 young horticultural professionals from seven countries in SSA were provided with 18 months of e-learning-based training during 2011–2012. All 36 completed the postharvest e-learning program and were given certificates as postharvest specialists. Topics included postharvest loss assessment, commodity systems assessment, technical information on small-scale practices, designing postharvest demonstrations (on harvesting, handling, sorting/grading, improved packages, cooling practices, storage, food processing methods, and more), planning extension programs, and designing their own PTSCs for their home countries.

From October 2012 through October 2013, without any project-provided funding but with access to mentoring and technical support, these 36 trainers planned and implemented postharvest horticultural training programs for more than 13,000 local farmers, extension workers, food processors, and marketers in their home countries. The TOPS evaluation reached 33 of these trainers, and their reports revealed that from November 2013 to November 2014, an additional 9300 people were trained by 28 of the trainers. The five persons who did not report providing any postharvest training for local populations were either actively pursuing graduate studies (in Germany, South Africa, and the USA) or had taken new jobs outside the agricultural sector (in Ghana and in Tanzania).

When asked about adoption of postharvest practices by their local trainees, 79% of the respondents reported on examples of trainees who are now using improved postharvest practices. Among those practices were improved harvesting, packing practices, and postharvest handling practices, Zero Energy Cool Chamber (ZECC) storage, solar drying, use of a cool room (via second-hand reefer container), postharvest loss assessment, and use of a postharvest tool kit and materials. However, solar drying and improved packaging practices were the most commonly used practices. Some farmers and traders of fresh horticultural crops started to dry and package their surplus produce or products which are not sold at the daily market with improved (vented) plastic bags, in order to avoid postharvest losses. These simple practices provide value in addition to the commodity and allow trainees to increase their incomes.

3.2. Postharvest Training and Demonstrations for Local Farmers in Tanzania

During 2012–2013, 14 instructors provided more than 30 postharvest training programs in Tanzania for local farmers, food processors, and marketers. Nine of the 14 postharvest instructors were women (from the USA, Lebanon, New Zealand, and Tanzania), and five were men (from Uganda, the USA, Zimbabwe, and Tanzania). Most of the instructors were independent consultants working with local organizations in Tanzania. Four of the instructors (two men and two women) were recent graduate “Postharvest Specialists” of the Hort CRSP ToT program. All 14 instructors were evaluated during the TOPS project. They were each contacted via email by one of WFLO’s local consultants, and she then followed up via phone calls to probe for details and any missing information and to ensure that each written survey was fully completed.

A few of the training programs were open to the public (“open house days” where local people were welcome to attend), but most were designed for a specific audience, based on requests or locally assessed training needs. Most of the training programs were offered over a period of several days, and all of the programs covered three or more postharvest topics. The sites for training included the PTSC at AVRDC, the Ministry of Agriculture, Food Security and Cooperatives (MAFC) Njiro training venue, and the OIKOS Mkuru Training Camp. Individuals or groups were invited by telephone or a group would make inquiries at AVRDC or the Selian Agricultural Research Institute (SARI) in Arusha about having a postharvest training program developed for them. According to these 14 instructors, the topics that women asked about most often were the use of shade, gentle handling, home storage, food processing, and marketing. The topics asked about most often by men were cooling, cold storage, transport, Good Agricultural Practices (GAPs), food safety, food processing, and marketing.

Two WFLO consultants, based locally in Arusha, conducted face-to-face interviews with 50 participants from the training programs. This sample was comprised of five persons who had been randomly selected

from 10 randomly selected participant groups via cluster sampling. The survey results included responses from 42 women and eight men who had participated in PTSC training programs, with an average age of 46 years. The topics of the training programs were improved postharvest handling of fresh produce, ZECC storage, food processing methods (jam making, solar drying), cooling/cold storage, or marketing of horticultural crops. Most of the respondents identified themselves as farmers or food processors, and many were also marketers of their own fresh produce or processed products. Two of the respondents were also working as extension workers.

A wide range of demonstrations were mounted during the Hort CRSP project and have continued since the project ended. Specifications for demonstrations were based on published research and review articles [11,13–15].

These include:

- Use of shade
- Hand-washing/hygiene practices
- Improved containers (plastic crates, half-size wooden crates)
- Zero energy cool chamber (for storage of fresh fruits and vegetables)
- Solar drying
- Cold room equipped with CoolBot

Several new demonstrations have been added during 2014–2015 by the postharvest staff at AVRDC. These include:

- A simple hydro-cooler with recirculation system
- Improved wooden crates (smaller, smooth on the inside)
- Liners for use in traditional containers
- Wakati (a high relative humidity % storage container; under study with Arne Pauwels of Belgium)

Because the trainings took place at the PTSC sites where these demonstrations have been established, the 50 respondents reported having seen many of the following demonstrations (see Table 2 for a count of the number indicating they had seen each of the demonstrations). In addition, when they were asked to rate the usefulness (as most or least useful), most of the respondents did not select one demonstration as was anticipated, but each rated many of the demonstrations they had seen as “most useful”.

Only three of the 50 respondents reported that they had not used one or more of the practices that they had first seen in a postharvest demonstration. Many reported using maturity indices (25), shade (27), sorting/grading (40), and/or improved containers (34) to help reduce fresh produce wastage.

The demonstrations designated as “least useful” were those with a high perceived cost (a cold room equipped with the CoolBot™, at a cost of approximately \$2000 for specialized equipment and materials for self-construction, had not been adopted by any of the respondents, and the equipment required for jam-making was deemed too expensive by one respondent). Of the practices rated as “most useful”, the least-cited was hand-washing and hygiene, which is already being practiced by those doing food processing.

All of the 50 persons interviewed for the evaluation indicated that they had adopted new postharvest handling practices or technologies for reducing losses and increasing the value of their crops after receiving training via the PTSC, and 42 people were able to provide details on local costs and benefits.

Table 2. Training participant ratings of postharvest demonstrations.

Demonstrations	No. that have seen it	Rated the demo as most useful	Rated the demo as least useful	No. that have been using the new or improved practice
Shade	44	31		27
Gentle handling	33	24		17
Maturity indices	33	24		25
Improved containers	45	32		34
Sorting/grading	47	36		40
Hand-washing/hygiene	45	10		35
ZECC	45	33		20
CoolBot™	37	3	24	0
Solar drying	44	34		29
Jam making	43	32	1	17

3.3. Adaptive Research

Adaptive research was planned on pest control, low-cost cool chambers, improved solar dryers, cool transport in insulated containers, food safety and/or other topics, but the research studies were not successfully carried out by AVRDC. Several meetings were held on the planning process during 2012 and 2013, and visits were made to Africa by the Principal Investigators and the Hort Innovation Lab management entity team in order to kick-start the process. In June 2013, a no-cost extension was granted to AVRDC in order to allow them more time to carry out some of these research studies.

In February 2014, AVRDC hired independent consultants to complete as much of the work as possible. Research studies were conducted on improved traditional containers (liners in wooden crates, use of plastic crates), consumer packages (recyclable clamshells and very thin plastic produce bags), insulated pallet covers for use during shipping (in order to measure effects on temperature change), and solar dryer modifications for enhancing drying during overcast weather (adding a black plastic wrap around the legs at the bottom of the dryer). AVRDC managed the work and provided the needed funds. A few of the studies have since been completed, and the results of a study on the use of low-cost insulated pallet covers and consumer packages for reducing losses of amaranth has been submitted to a major journal.

3.4. Postharvest Services at the PTSC in Arusha

Advisory services for those who are interested in adopting new practices and technologies were one of the only services being provided by the PTSC since the close of the project in 2014. The TOPS evaluation project revealed that since the end of the Hort CRSP pilot project, several local communities and training groups near Arusha have been receiving advice on constructing ZECCs for storing fresh foods on their farms or for food service. The ToT participants and AVRDC postharvest staff in Tanzania are actively making advisory field visits, meeting interested groups, and providing consulting for local clientele. Several local non-governmental organizations (NGOs) (Istituto OIKOS, The Mesula Project, ECHO-Impact Center, Arusha, Tanzania) have requested assistance and received postharvest training and advice on setting up their own demonstrations and training programs. None of the other planned

“fee for services” activities (sorting/grading, packing, pre-cooling, cold storage, *etc.*) were being provided by the PTSC for local clientele.

The model included a variety of these postharvest services which were intended to serve as a ready source of income, generating funds to pay for utilities, management, and maintenance staff for the facilities. Without these sources of revenue, the PTSC will remain dependent upon the host organization for funding its management and training programs.

3.5. Retail Sales of Tools, Packages, and Postharvest Supplies

The evaluation revealed that the retail shop for the PTSC was never fully implemented, and much of the original inventory of tools and supplies provided by the Hort CRSP project is still on the shelves. The PTSC shop mainly functions for one week per year during the August “Nane-Nane” agricultural show at Njiro, Tanzania, when the shop is restocked with the most desired products and opened for business during a period of eight days so people can visit to make their purchases.

Both customers and the administrators of the PTSC project considered the retail shop to be one of the services provided for the local population, and expected the prices of goods and supplies to be kept lower than those at any competing vendor. The PTSC shop managers, on the other hand, did not have any wholesale buying expertise, and did not have the budget to be able to buy items in large enough quantities to make bulk purchases for the shop at lower wholesale prices.

When the 50 training program participants were queried regarding where they would obtain tools, supplies, and training if the PTSC did not exist, more than 50% said “nowhere” or said they “didn’t know” or “were not sure” (Table 3).

Table 3. Respondent ($n = 50$) answers to queries on where to obtain postharvest tools, supplies, and training.

If the PTSC did not exist:	Where would you go for postharvest training?	Where would you go for postharvest demos/advice?	Where would you buy postharvest goods and services?
Nowhere	20	8	0
I don’t know	7	15	3
Not sure	0	8	2
Other sources/charity organizations	21	16	16

The other sources listed by respondents included several local NGOs, churches, and international charities, but these sources were thought to be unreliable since they seldom offered training and did not always have the needed supplies. For example, OIKOS was included as a possible source for glass jars, but the evaluators learned that OIKOS buys its jars from the PTSC. The evaluation results make it clear that the PTSC shop has an important role to play in local postharvest loss reduction and small business development in Northern Tanzania, if it could be set up, stocked, operated, and marketed with a more business-like approach.

4. Timelines and Budgets

The PTSC set-up process began in early 2012 on the AVRDC campus in Arusha, Tanzania. AVRDC hired a postharvest specialist in June 2012, and assigned one of their campus staff as the PTSC manager in July. The PTSC designs, demonstration protocols, procurement lists, and equipment/supplies specifications were all provided by the project leaders. Renovations and procurements went over budget, but AVRDC paid the additional costs since they intended to use the PTSC for their own projects and programs as well as for Hort CRSP-funded project activities.

The total budget for the Hort CRSP project was \$500,000, with approximately \$100,000 for implementing the ToT program, and approximately \$100,000 used for the PTSC renovations, set-up, and one year of locally offered postharvest training programs by guest instructors. A variety of adaptive research studies were funded but not completed as planned.

The postharvest demonstrations were of relatively low cost, and many could be used over and over again for training on site. When the 14 instructors were asked to estimate the costs for the postharvest demonstrations they had utilized during their training programs, they provided the following information:

- Use of shade—low cost (\$50 to \$100 for materials and labor), could use any type of local materials to make thatch or a woven roofing/poles structure
- Gentle handling—very low cost, mostly show and tell, \$30 for a commercially purchased harvesting bag, much less (\$5 to \$6) to make one locally
- Use of maturity indices (color charts, sizes)—very low cost (for making color copies, lamination, strong wire to make sizing rings)
- Improved containers (liners, cushions, crates, *etc.*)—very low cost (a few cents for a paper liner, \$5 to \$7 for a plastic crate)
- ZECC—\$400 to \$500 for bricks, sand, shade covering, labor, and water tank to construct a new Zero Energy Cool Chamber
- Solar drying practices—\$300 to \$400 for materials and labor to construct a new direct-style solar drier with six large trays

5. Conclusions and Recommendations

5.1. Description of Outcomes and Benefits of PTSC Extension/Outreach Results

Local capacity building in postharvest knowledge, skills, and training expertise in seven countries in SSA was one of the positive outcomes of the project. The follow-on training activities reported on by the 36 ToT participants were able to reach a wide range of local clientele in their home countries, who gained enough knowledge to make changes in their postharvest practices. In Tanzania, the random cluster sampling of 50 farmers, food processors, and marketers who had participated in more than one dozen local training programs offered by the PTSC reported having many positive outcomes. 100% of those surveyed reported that they reduced produce wastage, and 42 of the 50 persons were able to provide details on the costs and positive financial benefits of their changes in postharvest practices. Table 4 provides four examples, and many more examples will be fully documented and published upon completion of the project evaluation for USAID/TOPS.

Table 4. Examples of relative costs and financial benefits of improved postharvest practices for fresh produce as reported in Tanzania.

Interviewee No., Sex, Age, Job Type, Site	Crop and Quantity, Traditional vs. New Practices	Relative Cost, % Losses, Market Value Using Traditional Practice	Relative Cost, % Losses, Market Value Using New Practice	Changes in Income per Load	ROI
#12, male, 52, farmer/processor, Nshupu	Tomatoes, 7600 kg. Selling without grading vs. sorting/grading before selling	0 Tsh, 40% 2,850,000 Tsh	160,000 Tsh 10% 3,600,000 Tsh	+590,000 Tsh (US \$327) per 7600 kg	Immediate
#20, male, 54, farmer/marketer, Kindi	Cucumbers, 150 kg. Selling without sorting/grading vs. gentle harvest, sorting and grading before selling	0 Tsh 20% 16,000 Tsh	3000 Tsh 5% 30,000 Tsh	+11,000 Tsh (US\$ 6.11) per 150 kg	Immediate
#48, female, 31, farmer/processor/marketer, Poli-Ndatu	Chinese cabbage, 100 kg. Selling without grading vs. grading before selling	0 Tsh 20% 20,000 Tsh	2000 Tsh 5% 35,000 Tsh	+13,000 Tsh (US\$ 7.22) per 100 kg	Immediate
#49, female, 45, farmer/processor, Nshupu	African nightshade, 10 kg. Harvesting under full sun vs. harvesting in morning when temperature is lower	0 Tsh (did not consider her labor to be a cost) 50% 10,000 Tsh	No added cost (her labor only) 5% 20,000 Tsh	+10,000 Tsh (US\$ 5.56) per 10 kg	Immediate

Each of the cost-benefit examples in Table 4 were individual case studies based upon recall information on key aspects of the specific technologies being adopted (*i.e.*, on cost of materials and supplies, market prices, percentage of postharvest losses). This detailed information was provided verbally to the interviewers during site visits undertaken for the project evaluation, and the PI performed the calculations based upon the information provided, in order to determine whether there was any relative gain in earnings. A simplified cost-benefit analyses method, developed for the Bill and Melinda Gates Foundation's Appropriate Postharvest Technologies Planning Project, which focuses on measuring relative changes in costs and relative benefits such as changes in percentage of losses and market value per kg was used to make the calculations [13]. All the examples provided by the 42 respondents showed a positive and relatively rapid or immediate return on investment (ROI), since the increase in their earnings using the improved postharvest practice was higher than their initial monetary investment. The change in percentage of losses shown in Table 4 is the key reason for these positive results, as losses using traditional practices ranged from 20% to 50%, and losses using the new practices were reported to be 5% to 10%.

The eight males who were interviewed tended to be involved with handling relatively larger quantities of produce (40 to 7600 kg) and in marketing fresh produce. The 42 females who were interviewed for this evaluation study tended to be involved in food processing of fruits and vegetables, which were sometimes purchased in the wholesale market, and in the handling, processing, and marketing of relatively smaller quantities of produce (5 to 150 kg).

The PTSC model has been observed by many international visitors to the AVRDC site, and was included as a case study on reducing postharvest food losses in Africa in a recent publication by the Global Knowledge Initiative (Rockefeller Fdn/GKI, 2014 [16]). Modified versions of these postharvest training programs are currently being implemented in rural India [17].

5.2. Identification of Constraints and Implementation Issues/Concerns

Key administrators and PTSC managers were interviewed by a WFLO consultant, who met them in their offices and spent a few hours with each person in Arusha during 23–27 February 2015. Seven people were interviewed using a written questionnaire as a guide, followed by probing for specifics and details.

Each person provided information on the constraints they had encountered during the initial PTSC set-up, the implementation of training programs and planned services, and in general management. Most of the constraints had to do with the lack of a budget for operating the PTSC once the Hort CRSP project funding ended in 2013. Several constraints had to do with the limited scope of the mission and operating rules for both AVRDC (which, as a registered NGO, is not allowed to sell goods in Tanzania) and the Ministry of Agriculture, Food Security and Cooperatives (MAFC) (which can offer services and goods for sale at cost, but is generally not allowed to price goods and services in order to make a profit).

In general, the administrators and managers believe the PTSC project to be a success, since they believe that having the PTSC enabled them to increase awareness (among farmers, food processors, marketers, visiting scientists, extension workers, and policy makers) of the role of postharvest technology in reducing food losses. Several people mentioned that the model PTSC was already being copied by other organizations, and that the SARI Agriculture Technology Transfer Centre site in Njiro had

been selected as one of the sites for a “value addition/postharvest training center” under the Market Infrastructure, Value Addition and Rural Finance (MIVARF) project where the retail shop could be managed by a private firm and upgraded to better serve its intended role.

Feedback from participants and formal evaluation results provide guidance on general best practices for management, overcoming difficulties, and making improvements for future postharvest training and services centers.

The PTSC model is already being emulated by several Tanzanian organizations, and a variety of “Value addition centers”, “Farmer services centers”, “Postharvest training centers”, and “Packinghouses/ postharvest training venues” are currently being developed in 16 districts under programs being implemented by MAFC and the Prime Minister’s Office. These include:

- a packinghouse for 3500 members of a vegetable cooperative in Lushoto named LUKOVEG (MAFC and the local governmental authority)
- a large citrus/mango packinghouse/training center near Dar es Salaam for a farmers’ association of 2000 members (MAFC)
- the Prime Minister’s Office/African Development Bank’s Market Infrastructure, Value Addition and Rural Finance (MIVARF) project with postharvest training and value addition centers in 12 districts in 2013–2014, with many more planned for 2014–2015, and
- MAFC/Tanzania Horticultural Association (TAHA) Farmer Services Centers (FSCs) under construction in four districts in southern Tanzania and Zanzibar, plus a plan for a large packinghouse to be located near the coast north of Dar es Salaam.

The MIVARF project followed a similar design plan as the Hort CRSP PTSC pilot project, starting with local needs assessments and commodity systems assessments, then working with stakeholders to select key crops and design-appropriate training programs, select and procure equipment, and provide local training for farmers, food processors, and marketers. The MIVARF project has already provided one year of capacity building via ToT programs, and identified local “service providers” in each district who will serve as private sector partners. These established partners are better able to operate the needed postharvest retail shops, provide maintenance, marketing support, and other postharvest services that will help to add value, reduce produce wastage, improve incomes, and create new local businesses and new local jobs. The MIVARF project’s postharvest training and services centers will therefore include all five of the key components of the PTSC model.

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Author Contributions

Lisa Kitinoja conceived and designed the Hort CRSP pilot PTSC project; Diane M. Barrett and Lisa Kitinoja implemented the project as co-PIs; Kitinoja designed the evaluation project for WFLO and

Save the Children/TOPS, implemented the evaluation project, and analyzed the data; both Kitinoja and Barrett wrote the paper.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Kader, A.A.; Rolle, R.S. *The Role of Post-Harvest Management in Assuring the Quality and Safety of Horticultural Crops*; FAO Agricultural Services Bulletin No.152; Food and Agriculture Organization of the United Nations: Rome, Italy, 2004.
2. Weinberger, K.; Lumpkin, A.T. Diversification into horticulture and poverty reduction: A research agenda. *World Dev.* **2007**, *35*, 1464–1480.
3. AiDA. AidData. Available online: <http://aida.developmentgateway.org/aida/Search.do> (accessed on 15 January 2010).
4. USAID Documents. Available online: <http://dec.usaid.gov/index.cfm?p=search.sqlSearch&CFID=9413138&CFTOKEN=51188616> (accessed on 10 January 2010).
5. World Bank, Projects and Operations. Available online: <http://web.worldbank.org/> (accessed on 4 January 2010).
6. UN FAO. INPhO. Available online: <http://www.fao.org/inpho/isma?i=INPhO&p=index.jsp&lang=en> (accessed on 10 January 2010).
7. DEVEX. Available online: <http://www.devex.com/> (accessed on 15 January 2010).
8. Kitinoja, L.; Saran, S.; Roy, S.K.; Kader, A.A. Postharvest technology for developing countries: Challenges and opportunities in research, outreach and advocacy. *J. Sci. Food Agric.* **2011**, *91*, 597–603.
9. Gustavsson, J.; Cederberg, C.; Sonesson, U.; van Otterdijk, R. *Global Food Loss and Food Waste—Extent, Causes and Prevention*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011.
10. Lipinski, B.; Hanson, C.; Lomax, J.; Kitinoja, L.; Waite, R.; Searchinger, T. *Creating a Sustainable Food Future—Reducing Food Loss and Waste*; WRI Working Paper 39p; World Resources Institute: Washington, DC, USA, 2013.
11. Kitinoja, L.; AlHassan, H.A. Identification of appropriate postharvest technologies for improving market access and incomes for small horticultural farmers in Sub-Saharan Africa and South Asia. Part 1: Postharvest losses and quality assessments. *Acta Hortic.* **2012**, *934*, 31–40.
12. Diem, K.G. Using Research Methods to Evaluate Your Extension Program. Available online: <http://www.joe.org/joe/2002december/index.php> (accessed on 15 August 2014).
13. Saran, S.; Roy, S.K.; Kitinoja, L. Appropriate postharvest technologies for improving market access and incomes for small horticultural farmers in Sub-Saharan Africa and South Asia. Part 2: Field trial results and identification of research needs for selected crops. *Acta Hortic.* **2012**, *934*, 41–52.
14. Kitinoja, L.; Thompson, J.F. Pre-cooling systems for small-scale producers. *Stewart Postharvest Rev.* **2010**, *6*, 1–14.

15. Winrock International. *Empowering Agriculture, Energy Options for Horticulture*; United States Agency for International Development: Washington, DC, USA, 2009; p. 79. Available online: http://pdf.usaid.gov/pdf_docs/PNADO634.pdf (accessed on 15 March 2015).
16. Rockefeller Foundation Global Knowledge Initiative. *Reducing Food Waste and Spoilage: Assessing Resources Needed and Available to Reduce Post Harvest Food Loss in Africa*, 2014. Available online: http://postharvest.org/Rockefeller%20Foundation%20Food%20Waste%20and%20Spoilage%20initiative%20Resource%20Assessment_GKI.pdf (accessed on 2 April 2015).
17. Raman, N.L.M.; Dubey, N. Panchayat and economic empowerment of rural women by hands on training. *Am. Int. J. Res. Humanity Arts Soc. Sci.* **2014**, *5*, 249–252.

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