Reducing Postharvest Losses in Sub-Saharan Africa: Training for extension workers, technical specialists and field practitioners

PEF Manual 1

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The Postharvest Education Foundation (PEF)

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Reducing Postharvest Losses in Sub-Saharan Africa: Training for extension workers, technical specialists and field practitioners

PEF Manual 1

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Introduction

This training manual has been developed for extension workers, technical specialists and field practitioners in Sub-Saharan Africa (SSA). The manual provides a range of options for food loss (FL) reduction, to be selected and applied in SSA based upon the causes of losses that have been identified along the food supply chains, and the costs and potential benefits of the potential solutions for different beneficiary groups.

Target group:

Technology specialists, field practitioners and implementers of postharvest management and food loss reduction activities will need to understand practical applications, costs & benefits, implementation and management details. Examples include field staff and trainers working with international projects or NGO's, freelance consultants, technologists, technical advisors and food engineers.

Manual 1

Module 1.1 Overview: Sub-Saharan Africa - Reducing Postharvest Losses

Module 1.2 Reducing Postharvest Losses in SSA: Cereals and Pulses

Module 1.3 Reducing Postharvest Losses in SSA: Roots and Tubers

Module 1.4 Reducing Postharvest Losses in SSA: Fruits and Vegetables

Manual 2

It is a similar package suitable for practitioners in Asia and the Pacific region

Module 2.1 Overview: Asia and the Pacific - Reducing Postharvest Losses

Module 2.2 Reducing Postharvest Losses in Asia/Pacific: Cereals and Pulses

Module 2.3 Reducing Postharvest Losses in Asia/Pacific: Roots and Tubers

Module 2.4 Reducing Postharvest Losses in Asia/Pacific: Fruits and Vegetables

Each package of training materials is focused on 3 food groups, 5 segments of the food supply chain and 5 beneficiary groups. A set of illustrated PowerPoint slides has been developed to complement each module in the manuals. The manuals and modules are supported by illustrations, case studies, and resources for those who wish to use the manual and supporting materials to provide postharvest training programs for others on these topics.

Learning objectives:

- Practitioners will understand the importance of postharvest food losses (in volume, market value, nutrition, calories) in their region
- Practitioners will be made aware of the key causes and sources of losses along the supply chain for the major foods in the 3 food groups in their region
- Practitioners will gain an understanding of the many options available for addressing the causes of food losses identified in food loss assessments.
- Practitioners will be introduced to key postharvest technologies, improved handling practices and management skills that can help the 5 beneficiary groups reduce postharvest food losses
- Practitioners will be able to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology
- Practitioners will be made aware of topics or areas of training/extension and advocacy that are needed to solve postharvest problems for a variety of crops/food products in the 3 food groups

Many thanks to our postharvest colleagues, supporters and PEF e-learning graduates all around the world for sharing their photos and experiences in the field. Photo credits are provided in the text and/or slides. References to books, articles, manuals and websites are provided throughout the manual and citations for written documents in the reference list provided at the end of the manual.

Thank you to Dr. Aditya Parmar (NRI, UK), Mekbib Seife (Ethiopia), Joseph Mpagalile (FAO) and Malidra Ranga (Uganda) for sharing their wonderful photos and stories. A special thank you to Dr. Majeed Mohammed and Dr. Deirdre Holcroft of the Board of Directors of The Postharvest Education Foundation, and to the food loss reduction experts Joseph Mpagalile, Dr. Mireille Totobesola and Dr. Hala Chahine-Tsouvalakis for their reviews of early versions of the manuscripts.

Dr. Lisa Kitinoja
The Postharvest Education Foundation
February 2023

Module 1.1 Overview: Sub-Saharan Africa - Reducing Postharvest Losses

Slides of coordinating Module 1.1 PowerPoint presentation (14 illustrated slides)

Slide 1

Learning objectives

- Practitioners will be made aware of topics or areas of training/extension and advocacy that are needed to solve postharvest problems for a variety of crops/food products in the 3 food groups
- Practitioners will gain an understanding of the many options available for addressing the causes of food losses identified in food loss assessments.

Slide 2

<u>Key foods that are important for the Sub-Saharan African region</u>

Cereals & Pulses	Roots & Tubers	Fruits & Vegetables	
Maize Sorghum Millet Rice Cowpeas Dry beans	Cassava Sweet potato Yam Cocoyam	Banana Plantain Mango Papaya	Tomato Hot peppers Onions Leafy greens Green beans
Oilseeds	Meats & eggs	Milk & dairy products	Fish & Seafood
Groundnuts Oil Palm Sesame	Poultry Goat Beef Eggs	Cow milk Goat milk	Fresh capture Aquaculture

Slide 3

Each type of food and food group has characteristics that allow practitioners to predict the types of handling practices and improved technologies that can reduce food losses.

<u>Summary of key factors for reducing food losses for the 7 food groups</u>

	Proper maturity	More gentle handling	Proper drying	Pest management	Improved containers/ packaging	Temperature management	Improved storage	Reduced marketing delays
Cereals & pulses	X		X	X	X	X	X	
Roots & tubers	X	X		X		X	X	X
Fruits & vegetables	X	X			X	X	X	X
Oilseeds	X		X	X	X	X	X	
Meats & eggs	X	X			X	X		X
Milk & dairy					X	X	X	X
Fish & seafood	X	X			X	X		X

Slide 4

General overview of postharvest loss reduction practices

- Proper maturity at harvest
- More gentle handling of perishable crops to reduce damage
- Proper drying of cereals and pulses before storage
- Postharvest pest management
- Improved containers or packaging
- Temperature management/cooling and cold storage for perishable foods
- Improved storage for cereals and pulses
- Market access
- Supply chain efficiency as a goal

For further information and examples:

Teutsch, B. and Kitinoja, L. 2019. 100 under $100: Tools for reducing postharvest losses. The Postharvest Education Foundation 310 pages. http://postharvest.org/100_under_100.aspx

Slide 5

Proper maturity at harvest

In order to optimize shelf life (storage life), quality and nutritional value of food crops, it is important to pay attention to the stage of maturity in order to plan the harvest.

Some crops can be harvested multiple times over the course of a season (e.g. as tree fruits begin to ripen or as vegetables grow enough to reach the desired size) while others should be harvested all at once as soon as the crop reaches a certain age or moisture content (e.g. for grains such as maize).

Harvesting too early:

- If fruits are harvested too early they will lack flavor, and may not be able to ripen.

Harvesting too late:

- If root crops are left in the field too long, they can become fibrous or pithy (with poor eating quality)
- If cereals are left on the plant too long after full maturity, some of the grains can drop off and be lost during the harvest (shatter).

Slide 6

More gentle handling of perishables to reduce damage

Rough handling occurs during all segments of the food supply chain:

- Digging damage to R&T crops
- Harvest wounds for F&V crops
- Bruises from dropping, throwing, tall heaps
- Compression damage from use of poor quality containers
- Stepping on produce during loading/unloading

Slide 7

Proper drying of cereals and pulses before storage

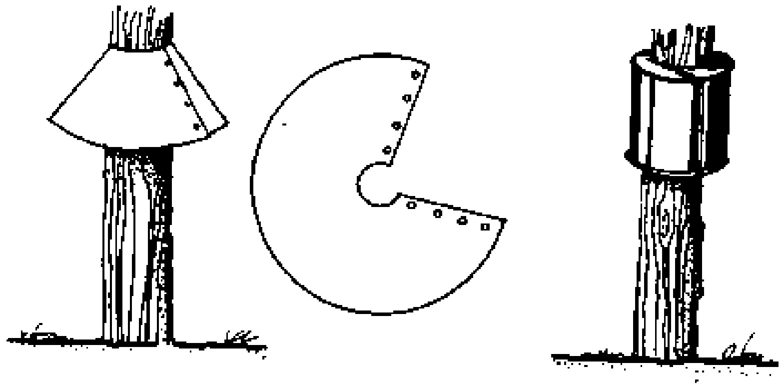
Cereals and pulses that are put into storage at higher than recommended moisture content will be more susceptible to fungal attack and mold damage.

Slide 8

Postharvest pest management includes:

- Insect control
- Decay control
- Rodent control

Using IPM style postharvest pest management, including scouting, sampling and regular inspection, can reduce losses and reduce the cost for pest management.



Rat guards fashioned from metal sheeting or empty cans. Source: FAO. 1985.

Slide 9

Improved containers or packaging

Protecting food crops from damage is one of the key purposes of a package or container.

Handling foods in bundles, sacks or baskets leads to damage, spillage and deterioration.

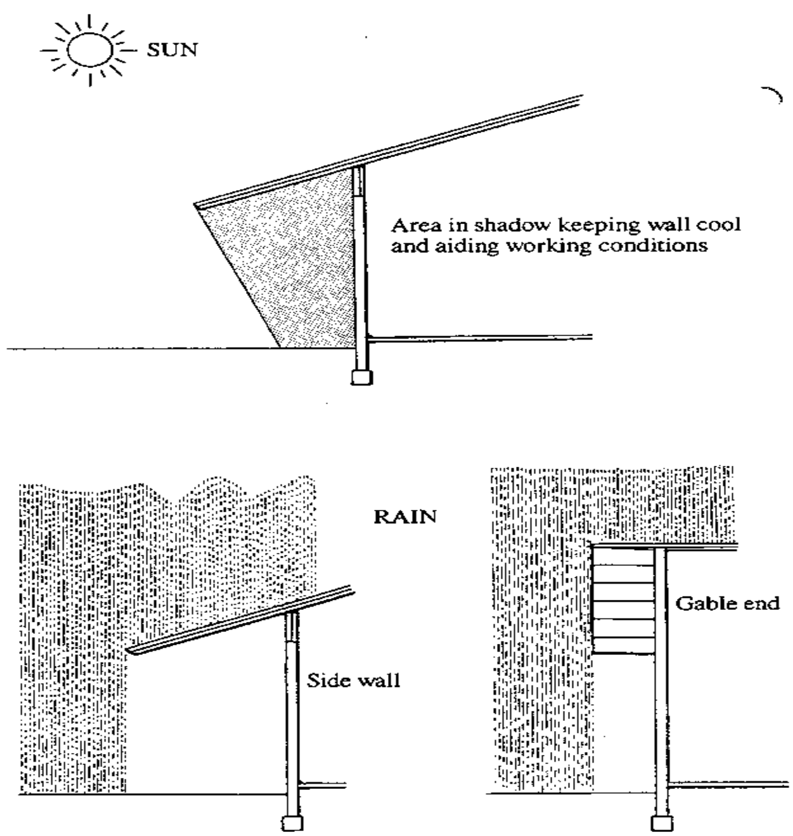
Green beans shipped in baskets from Benin to Ghana (Photo credit: Lisa Kitinoja); Leafy greens in sacks in Rwanda (Photo credit: S K Roy).

Slide 10

Temperature management for cereals and pulses

The postharvest storage potential for harvested grains and pulses (cowpeas, dry beans, lentils) is longer when the crops are stored at lower temperatures. The allowable storage time for grains is reduced by approximately one-half for each 6°C increase in grain temperature.

Overhanging roof extensions on storage structures are very helpful in shading the walls and ventilation openings from the sun's rays, and in providing protection from rain. An overhang of at least 1 meter is recommended.



Overhanging roof extensions protect stored foods. Source: Walker, D.J. 1992.

Slide 11

Cooling and cold storage for perishable foods

During the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining fresh produce quality. Fruits and vegetables are living, breathing tissues separated from their parent plant. Keeping F&V crops at their lowest safe temperature (0-2°C for temperate crops or 12-15°C for chilling sensitive crops) will increase storage life by lowering respiration rate, decreasing sensitivity to ethylene gas and reducing water loss.

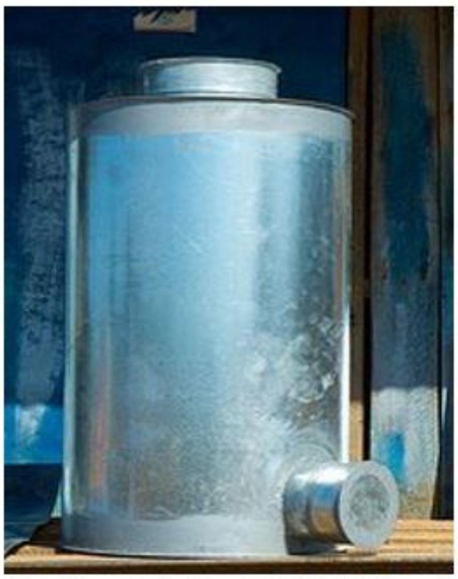
Using cold storage rooms for storage of perishables can assist in reducing postharvest losses if the cold room is not overloaded, and/or packed with all types of incompatible produce.

Overloaded crates and mixed loads in cold storage in Cape Verde (Photo credits: Lisa Kitinoja)

Slide 12

Improved storage for cereals and pulses

There are many options for improved storage technologies for C&P crops, from simple on-farm containers and storage structures to dedicated commercial warehouses. Investments in improved structures and storage management practices will keep the crops clean, dry and protected from pests.




Small metal silo (FAO, Malawi); Large scale storage for cereals and pulses (FAO, Tanzania)

Slide 13

Market access and supply chain efficiency

Reducing marketing delays for perishable crops and improving market information systems for all food crops can help to reduce postharvest losses.

Small-holder farmers are often dependent upon traders to visit the farm and pick up harvested produce to transport it to market. If the produce is perishable, a delay can result in lower quality and a long delay can result in a complete loss.

For crops that can be stored for long periods of time, knowing the cost of storage, the cost of transport and the market prices in a range of local and regional markets can help farmers, traders and wholesalers determine when and where to sell the crops.

For more information:

FAO 2015. Inclusive Business Models: Guidelines for improving linkages between producer groups and buyers of agricultural produce. http://www.fao.org/3/a-i5068e.pdf

Slide 14

The next three Modules in Manual 1 provide details and examples of improved postharvest handling practices and cost-effective postharvest technologies for reducing losses in cereals & pulses, roots and tuber crops, and fruits and vegetables.

Practitioners will learn how to select from the range of potential options for reducing food losses and consider each of the following:

- Technical fit (scale of the technology, suitability for the crop)
- Costs and expected benefits
- Potential environmental impacts (energy use, pollution, etc.)
- Related social issues (gender issues/roles, ethnicity, youth access, etc.)
- Policy framework (does it fit into the existing system? Does it have any support? Are there any incentives for investments or adoption?)
- Food safety issues.

Module 1.2 Reducing Postharvest Losses in SSA: Cereals and Pulses

Slides of coordinating Module 1.2 PowerPoint presentation (63 illustrated slides)

Slide 1

Learning objectives

- Practitioners will gain an understanding of the many options available for addressing the causes of food losses identified in food loss assessments (FLA) for cereals and pulses.
- Practitioners will be introduced to key postharvest technologies, improved handling practices and management skills that can help the 5 beneficiary groups reduce postharvest food losses for cereals and pulses
- Practitioners will be able to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology
- Practitioners will be made aware of topics or areas of training/extension and advocacy that are needed to solve postharvest problems for a variety of cereals and pulses

Slide 2

Key crops for SSA

- Maize
- Sorghum
- Millet
- Rice
- Cowpeas
- Dry Beans

Slide 3

This module covers 5 segments of cereals & pulses (C&P) supply chains

1. harvesting & postharvest handling (on-farm)
2. storage
3. transportation
4. agro-processing
5. wholesale and retail.

The majority of the total of 18.5 million tonnes per year of losses for cereals in SSA occur during production/harvesting (4.6 million tonnes), during postharvest handling and storage (6.1 million tonnes) and during processing/packaging (6.2 million tonnes). Source: Gustavsson et al., 2013.

Slide 4

Reducing food losses during (1) harvesting & postharvest handling on-farm

Making improvements in the following six on-farm activities will have a positive impact on postharvest losses of C&P crops.

- Harvest indices
- Cutting
- Threshing/Shelling
- Cleaning
- Field drying
- Bagging or bulking

Slide 5

Harvest indices and Cutting

Knowing when to harvest is critical for producers of C&P crops. For example, for rice, grain moisture content ideally is between 20 and 25% (wet basis). Grains should be firm but not brittle when squeezed between the teeth, and 80–85% of the grains have turned yellow-colored (like dried straw). Harvesting should be done when there is minimal surface moisture (e.g. from previous rainfall or early morning dew).

Harvesting rice too early results in a larger percentage of unfilled or immature grains, which lowers yield and causes higher grain breakage during milling. Harvesting too late leads to excessive losses and increased breakage in rice during threshing and milling.

Slide 6

Moisture content at harvest

For maize, moisture content at harvest is a critical factor. Mature grain has a harvest index of 30% moisture. If cereal crops are harvested at the proper moisture content, there will be less missing grain after cutting/harvesting. Losses will tend to increase as moisture content decreases if the mature maize cobs are left on the plant. At 20% moisture at harvest, losses from missing grain has been measured at 4 to 5%, and losses from damaged grain can reach 10-13%. Moisture content should be measured during the harvest if at all possible.

<u>Percent postharvest losses when maize is harvested at various stages beyond full maturity</u>

	% moisture at harvest			
	30	25	20	15
Type of losses				
Missing grain	1.4%	2.6%	4.7%	8.7%
Damaged grain	5.5%	8.5%	12.9%	19.7%

Source: Odogola and Henriksson, 1991.

Slide 7

Threshing or shelling

Maize should be husked before shelling, and any decayed cobs should be sorted out and removed from the load.

In Ethiopia, Mercy Corps is promoting a variety of different types of maize shelling technologies for different type of target groups, each with different needs and resources.

<u>Different types of maize shelling technologies</u>

Sheller type	Cost (birr)	Capacity	Grain damage
Handheld	20	20 kg/hour	Very low
Manually powered mechanized	5,600 (used)	4 quintal/hour	Low
Bicycle powered mechanized	6,500 (used)	6 quintal/hour	Low to moderate
Motorized - high speed	28,500	16 quintal/hour	Moderate to high

20 birr = $1 USA; 1 quintal = 100 kg

Slide 8

Reducing damage caused by traditional threshing practices

Beating C&P crops with sticks, trampling them with animals, or rolling heavy objects over the crops are traditional methods used for threshing. In Ethiopia, 75% of rice grains are damaged via on-farm threshing practices. Any threshing method that is more gentle than traditional threshing will help to reduce postharvest losses for C&P crops.

Traditional threshing practices (Photo credit: FAO) versus Pedal powered thresher (Photo credit: Sasakawa Africa Association).

Slide 9

Par-boiling rice

A simple innovation that can further reduce these losses is par-boiling and drying the grains before threshing, which has been shown to reduce losses to less than 2% in Ethiopia (Hailegebrile, unpublished). The traditional parboiling process involves soaking rough rice overnight or longer in water at ambient temperature, followed by boiling or steaming the steeped rice at 100°C to gelatinize the starch, while the grain expands until the hull's lemma and palea start to separate (Gariboldi, 1984; Bhattacharya, 1985; Pillaiyar, 1988). The parboiled rice is then cooled and sun-dried before storage or milling.

Par-boiling is popular in West Africa, and is a relatively new practice in East Africa. The aspects of local acceptance and palatability is an issue to be considered.

Slide 10

Cleaning and field drying

Cleaning the threshed grains properly and drying the grains immediately after threshing will help to reduce postharvest losses. Any decayed grains (discolored, moldy) should be sorted out and removed, and the crop should be properly dried before further handling. This will prevent decay organisms from spreading to the rest of the crop.

Slide 11

Aflatoxin management

Aflatoxins can be a problem in C&P crops if they are not properly dried and protected from moisture during storage and marketing. A highly toxic metabolite produced by the ubiquitous *Aspergillus flavus* fungus is a major public health issue in Africa. IITA studies measured contamination in 30 to 65% of stored maize (also a problem in sorghum, rice, millet, groundnuts, and dried R&T crops).

The fungus infects crops in the field and produces the toxin in the field and in stores, then the fungus is carried from field to store. Contamination is possible without visible signs of the fungus, and very low levels are toxic (maximum allowable levels = 20 ppb US; 10 ppb WFP; 4 ppb EU).

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Some predisposing factors for aflatoxin contamination:

- pre-harvest high night-time temperatures and drought stress
- wet conditions or high humidity at harvest and post-harvest periods
- insect or bird damage
- rain on the mature crop increases contamination.
- improper crop storage or transportation.

Source: PACA and IITA   http://www.aflatoxinpartnership.org/

Slide 13

Bagging or bulking

Spillage is a source of postharvest losses during the transport of C&P crops from the field to the storage structure or the market. Careful bagging practices (slow, steady) and taking care not to tear the bags when handling them can help to reduce losses. Using a ground cloth under heaps and inside a vehicle bed can help reduce losses when carrying bulk loads. Covering the loads if they are on open trucks can reduce spillage and protect from rain and contamination from dust, insects and birds.

Slide 14

Reducing postharvest losses during (2) storage

- Mechanical drying
- Temperature and relative humidity control
- On-farm storage structures and storage management
- Hermetic storage
- Mobile storage
- Commercial storage / warehouse management
- Insect control
- Sanitation and inspection

Slide 15

Mechanical drying

Solar radiation is usually used to dry cereals and pulses, particularly in the dry season. Drying capacity is limited in the wet season. Flash dryers are ideal for the first drying of harvested rough rice, to decrease the moisture content to 18 to 20% (Juliano, 1993).

Adding heat to the load of cereals or pulses during drying can speed the process and result in a more uniformly dried product. If the crops are harvested during the rainy season, heat assisted drying can be particularly important to prevent postharvest losses in storage. Heat can be generated by a wide range of sources, including wood or charcoal fire, electric or diesel-powered heaters, or solar power. However, electricity, diesel and solar power are rarely used by small holder farmers in Africa due to relatively high initial capital and running costs.

Drying recommendations

Crop	Moisture content
Maize	14-16%
Sorghum	14-16%
Rice	18-20%

Source: Juliano (1993)

Slide 16

Types of dryers

There are many types of mechanical driers for C&P crops.

- natural air = no heat added, perforated floor (1 cm^2/30 cm^2), electric fan pushes outside air under the floor and through the grain, exhaust opening at top of bin
- low level heat = small amount of added heat to reduce RH% of air, same as above specifications, usually with a gas-powered heater, electric fan
- batch-in-bin = 1 meter layer of grain in a bin with a perforated floor, requires adding heat, fan for air flow, and stirring the grain during drying
- high temperature = added heat, works best with continuous flow type dryers

Energy use based on type of dryer (operational cost depends upon local cost of fuel or power)

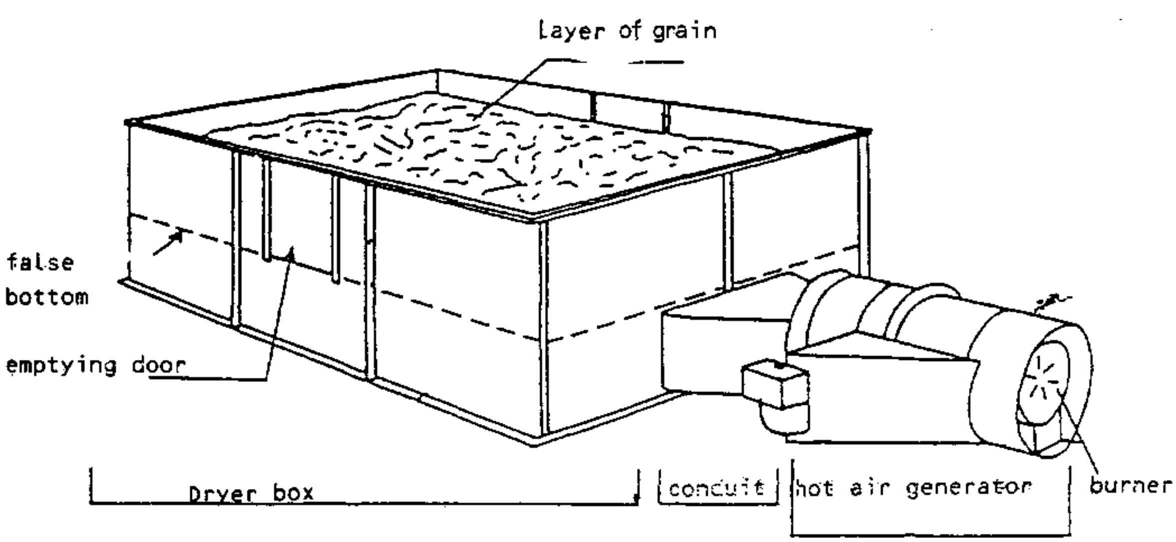
Type of dryer	BTUs per kg of water removed
Natural air	2200-2600
Low heat	2600-3300
Batch-in-bin	3300-4400
High temperature - air recirculating	4000-4400
High temperature without air recirculating	4400-7200

Source: Hellevang, 2013.

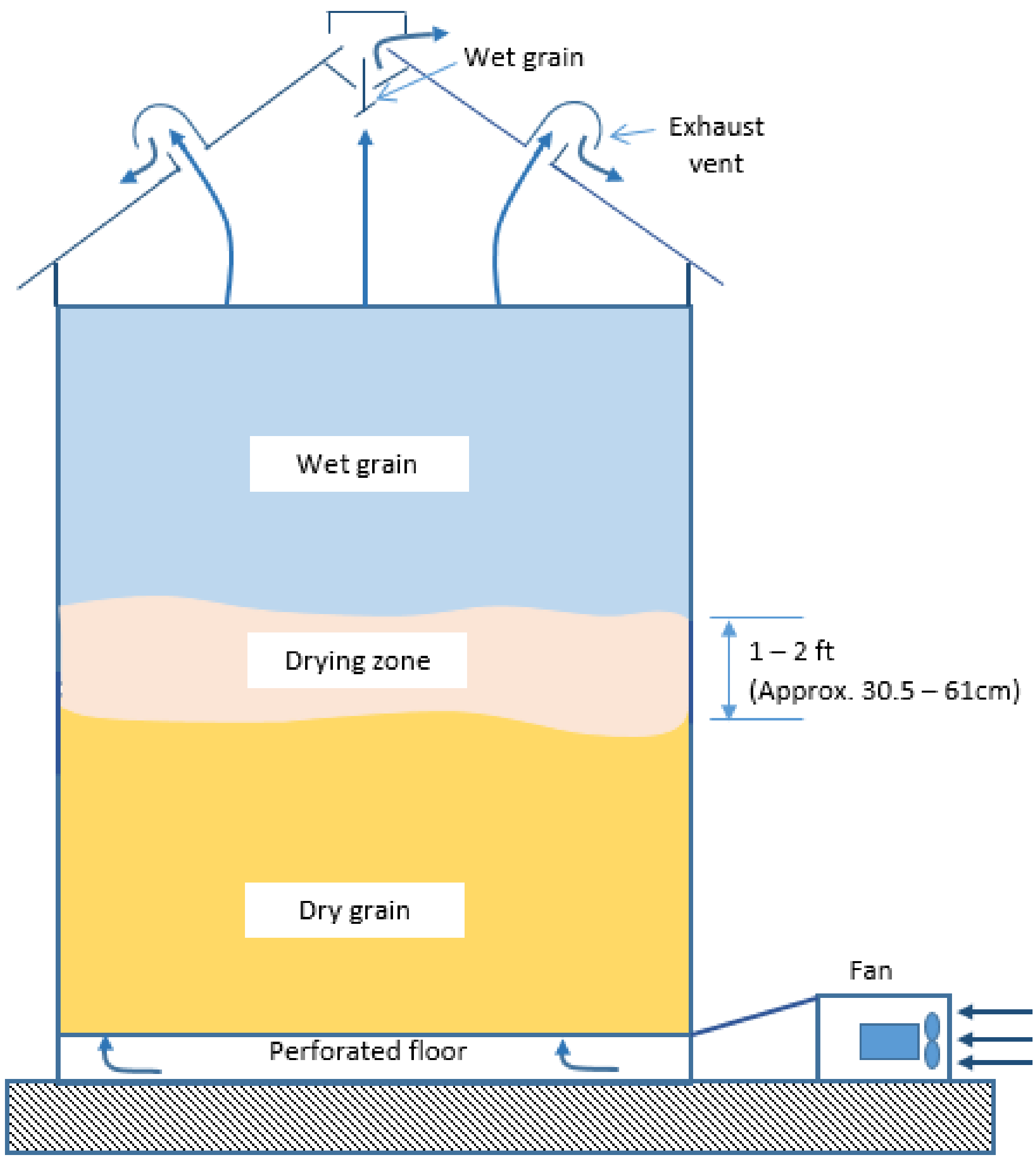
Airflow rate, air temperature and air relative humidity influence drying speed. In general, higher airflow rates, higher air temperatures and lower relative humidities increase drying speed. In general, airflow rates must increase substantially when grain is of higher initial moisture percentage.

Slide 17

A few examples of driers for C&P crops



Heat assisted dryer with false bottom and perforated floor (Source: FAO 1994)



Natural air drying in a 3 m deep bin, where the drying zone is 30 to 60cm in depth near the center of the load. (Source: www.extension.umn.edu)

You can deliver the same airflow per bushel with smaller fans in large, shallow bins compared to narrow, deep bins. Although large, shallow bins are initially more expensive than narrow, deep bins, energy savings make up the difference over the life of the bin. Quality is usually better for slower, lower-temperature systems. Do not over-dry grain! (Wilcke, 2015).

Slide 18

Measuring moisture content

Using a moisture meter: A hand-held Grain Moisture Tester is just one example of a low-cost resistance type moisture meter (costs less than USD 160). It is designed to test many different crops including maize, flax, oats, sunflower, wheat, canola, soybeans and sorghum with an accuracy of ± 0.5% in normal moisture range.

Grain Moisture Testers

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Temperature and relative humidity control

Keeping the C&P crops cool and dry will help to increase storage life and reduce postharvest losses. The allowable storage time for grains is reduced by approximately one-half for each 6°C increase in grain temperature. For example, the allowable storage time (AST) of 13% moisture maize is about nine months at 15°C, five months at 21°C and only three months at 27°C.

Slide 20

On-farm storage structures and storage management

The traditional storage practices for maize in Kenya observed during the SAVE FOOD (FAO 2014) FLA were examples of the type of practices that can be improved by proper management.

On-farm storage of maize in open bags in Kenya (Left) (Source: FAO 2014) and a traditional maize storage crib in Southern Ethiopia (Photo: Joseph Mpagalile, FAO)

Recommendations for improvements include the use of pallets, closed bags, adequate ventilation and rodent control.

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"Gorongosa silos" can be more affordable than metal silos, and are based on locally developed technology. Made mainly of mud and clay bricks, with a supporting structure of cement and iron rods, these silos can last for up to 20 years with good maintenance. FAO trained artisans have constructed these silos for maize storage on family farms in 15 districts of Mozambique to date. The typical maize losses of 30% experienced in the country can be decreased to less than 5%, and the maize can be stored for up to 10 months.

Gorongosa silo for maize storage.

Source: http://www.fao.org/in-action/improved-post-harvest-handling-raises-incomes-for-mozambique-farmers/en/

Slide 22

Underground pit storage

The combination of underground (cool) and plastic container (dry) is being used for improved maize storage in Ethiopia. The pit is lined with heavyweight plastic tarpaulins, sealed and covered to prevent damage from insects, rodents, fire and moisture. Postharvest losses were reduced to less than 1% after 6 months of storage.

Underground pit storage for maize. (Photo credits: Mekbib Seife Hailegebrile)

However, it should be noted that underground storage is very risky and difficult to monitor and is not recommended as a household level storage solution.

Slide 23

Hermetic storage

Storage of dried cereals and pulses can be extended by excluding oxygen and moisture. Hermetic storage bags or structures do this by sealing out light, air, water and pests.

PICS bags are an example of a small-scale application (for 50 to 100kg of product). Purdue Improved Crop Storage (PICS) bags were originally designed for cowpea storage, but they are now being used for maize and other cereals and pulses. They are composed of a triple layer of plastic bags that can be tied to tightly close the bags. Other types of hermetic bags such as the Zero fly are being promoted in countries such as Kenya and Ethiopia.

Sasakawa Africa Association is promoting the use of PICS bags, metal and plastic silos for maize and cowpea storage.

Successful storage duration with no live insects found upon opening the containers

Country	Crop	Storage system	Storage duration
Ethiopia	Maize	Metal silos	12 months
Mali	Cowpea	PICS bags in/or plastic tanks	6 months
Nigeria	Cowpea	PICS bags	6 months
Uganda	Maize	Plastic tanks	12 months

SAA (2014).

PICS bags being demonstrated in Nigeria (Left). [Photo credit: Sasakawa Africa Association] and a Zerofly bag (Right) being promoted during an event in Ethiopia (FAO) [Photo credit: Joseph Mpagalile, FAO]

Slide 24

“Cocoons” are used for hermetic storage of larger quantities of C&P crops. The crops are in sacks and stacked inside the water-proof and airtight cocoon for long term storage. A unit can store from five to 300 tonnes of cereals or pulses for up to one year with minimal postharvest losses – typically, less than 1% (GrainPro.com).

GrainPro® Cocoon with shade cover and Grain Safe. Photo credits: GrainPro.com

Slide 25

Silos made of plastic, metal or cement can be designed for the bulk storage of any desired volume of C&P crops. Sasakawa Africa Association has done field testing on a wide range of sizes of plastic water barrels and water storage tanks. They completely seal the containers to make them air and watertight, and successfully store cereals and pulses for more than one year with minimal losses. In Uganda, a heavyweight blue water barrel costs only about US$20 and can be sealed and used to store maize, with no insect damage, for 18 months (SAA 2014). It is very important to ensure that the barrel is completed sealed to ensure hermetic environment during storage.

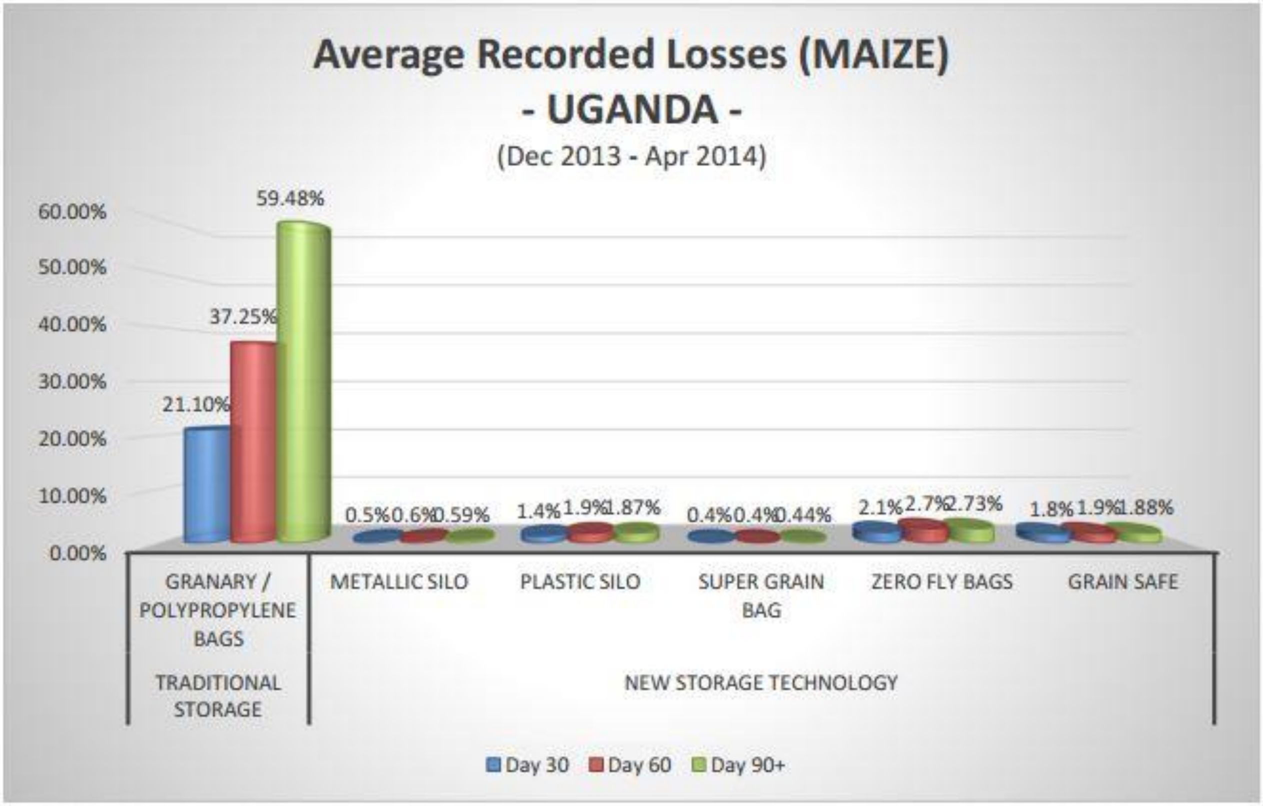
Metal silo promoted by FAO in Malawi (left) and a silo made from a plastic water barrel in Uganda (right; Photo credit: Sasakawa Africa Association).

Storage of rice

An FAO report on the International Year of Rice (2004) summarized how to reduce postharvest rice losses, since most of the rice losses were a result of inadequate storage and drying operations. FAO recommended the use of small metal silos as means for reducing small and medium scale rice losses.

Slide 26

Any of the improved technologies that have been described for on-farm storage will help to reduce losses when compared to traditional storage practices. WFP studies have documented that losses of maize in Uganda can be reduced to as low as 1 to 2% by using silos or improved storage bags.



Postharvest losses using new storage technologies for maize in Uganda. Source: WFP (2014)

Slide 27

Mobile storage

Storage silos can be constructed on wheels, to enable the users to move them to where they are needed. In Nigeria is it possible to rent a mobile storage unit and have it delivered to the farm or marketplace.

Mobile storage units for cereals being moved in Nigeria in 2015 (Photo credits: W.T. Lanier)

The empty silos are lightweight enough to be moved manually, but moving the silos could be a challenge, especially in areas where the road network is not good or when it is the rainy season.

Slide 28

Commercial storage / warehouse management

Large scale storage of C&P crops in SSA is commonly found in large cities, where sacks of cereals or pulses are kept in government owned or commercially managed warehouses.

Common problems that lead to postharvest losses include:

- Failure to enforce quality standards at intake
- Poor temperature management
- Poor sanitation
- Poor pest management practices
- Lack of inspection and removal of damaged/decayed product
- Poor inventory management

Slide 29

Insect control

Postharvest pest management requires knowledge of what type of pests are causing problems and what types of control measures are available to control them. Sampling for insect pests and setting traps can provide useful information and lead to improved pest control.

Probe trap (left) and Pitfall trap (right): Stored grain insect traps developed by S. Mohan (TNAU, Coimbatore). Photo credits: S. Mohan

Slide 30

Sanitation and inspection

A simple broom is the most useful piece of pest control equipment in a warehouse that is used for food grains and processed foods. The prompt removal of spillage prevents insect populations developing in cracks and crevices from where they can infest the stored foods (Walker and Farrell 2003).

Cleaning the storage room (Source: FAO 1985)

Slide 31

Reducing postharvest losses during (3) transportation

- Loading/unloading
- Covers for bulk loads
- Use of strong and durable sacks/bags

Traders are generally in charge of postharvest handling during transportation. As a rule, traders are rarely included in postharvest extension/training programs, and they can be a difficult clientele group to reach, since they are usually on the move from farm to farm and market to market, and rarely have time to attend long meetings or classroom style educational programs. Postharvest demonstrations in the marketplace may be a practical way to reach these FSC actors. For C&P crops, gentle loading/unloading of sacks and covering open loads can help reduce loses by avoiding spillage.

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Loading/unloading:

Taking care not to damage the sacks or spill bulk C&P crops during loading and unloading of vehicles will help to reduce postharvest losses.

Covers for bulk loads:

Using a cover over bulk loads can help reduce spillage and protect the crops from rain, pests, dust and sun damage.

Small and large loads should be covered during transport. (Photos taken in Morogoro, Tanzania. Photo credits: Joseph Mpagalile FAO)

Slide 33

Use of strong and durable sacks/bags

Using good quality sacks or bags and making sure the bags are not hooked (punctured with a hook), thrown or dropped can help to reduce losses during transport.

Slide 34

Reducing postharvest losses during (4) agro-processing

- Improved equipment
- Improved processed food products
- Improved packaging materials
- Improved storage containers
- Sanitation practices

According to International Rice Research Institute (IRRI), most rice varieties are composed of roughly 20% rice hull or husk, 11% bran layers, and 69% starchy endosperm, also referred to as the total milled rice. Milling will typically result in 65-70% total milled rice. The husks and bran are not considered to be postharvest losses, but rather are the by-products of the milling process. Broken grains and fine brokens (tiny pieces of the starchy endosperm) are usually sold at lower market price than whole grains. They can be sifted out and sold as brewer's rice or milled into flour.

For the best results, cereals should be:

- Cleaned before milling
- Milled when at proper moisture content
- Not mixed with other grain types/varieties during milling
- Milled using appropriate milling machine

Slide 35

Improved equipment

IRRI has published training manuals on rice processing, including a range of equipment and practices for husking, milling, separating and polishing. They recommend using rubber rollers rather than steel rollers in order to reduce breakage during husking.

http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling

Using improved milling technologies will result in reduced breakage as compared to manual milling (using a mortar and pestle).

http://www.knowledgebank.irri.org/images/docs/rice-milling-presentation.pdf

A typical hammer mill used for maize milling in rural areas of Tanzania (Photo credit: Joseph Mpagalile, FAO)

A new maize flour processing plant in Uganda (Photo credits: Malidra Ranga, 2015)

Slide 36

Improved milling equipment for Cereal & Pulses crops

Sorghum milling in Ethiopia (Photo credit: Sasakawa Africa Association)

Improved agro-processing equipment often requires access to electricity or diesel fuel.

A few international companies are developing solar powered equipment that can be used off-grid. The initial investment is higher in cost, but there is no cost for power during the life of the equipment. One example is Solar Milling: (video link) https://www.youtube.com/watch?v=a10bMcyDODU

Slide 37

Improved processed food products

Manufacturing processed foods is a way to add value to raw crops. Typically, the processed products will sell for much higher prices than do the raw materials, and if packaged properly will have a much longer shelf life. In 2014, the price of a kilogram of unprocessed grade one maize in Kampala, Uganda was between USh550 and 600 and a 50 kg sack of maize flour cost USh60,000 (about US$24) at the wholesale market. Processing costs range from USh50 to 100 per kg, depending on the location. Yield of flour ranges from 60 to 75%, depending on the types of milling. The yield of coarse ground meal is much higher (up to 98%) but the shelf life is much shorter.

Raw crop market value vs value/kg of processed products in Uganda and Kenya

Maize at 13% M.C. Shelf life 3 months at 27°C Relative market value	Processed product at 11.5% M.C. Shelf life 6 months at 27°C Relative market value
Shelled maize: Uganda US$0.24/kg; Yield: 50 kg	Flour : Uganda US$0.48/kg; Yield 30 to 38 kg
Shelled maize: Kenya US$0.35/kg; Yield: 50 kg	Meal (coarse ground for ugali or posho) Kenya; US$0.42/kg Yield 49 kg
	Flour (finely ground for baridii) Kenya; US$0.64/kg Yield 30 to 38 kg

Sources: MAIZE: Post-harvest Operations Manual; http://www.bettagrains.com; Market Atlas Forum 2014.

Slide 38

Improved packaging materials

Storage containers that can be sealed and protect the dried products from light, water, insects and rodents will greatly increase their storage life. Metal foil packages are low cost and can protect dried C&P crops and other food products for up to one year.

Polyethylene terephthalate (PET or PETE) and foil laminate pouches are exceptional food containers (USU, 2013). The polyethylene (PET) layer is food-grade plastic with no known toxicities (Castle, 1989). The foil layer dramatically reduces the transmission of oxygen and moisture through the film. One trade name is Mylar® and it is often used as a generic name.

Metal foil packages (Source: uline.com)

Tanzania grain mill and improved sacks (Source: FAO; photo credit: Joseph Mpagalile)

Slide 39

Improved containers for storage of dried C&P products

Plastic buckets can be cleaned and reused many times. Typically, the plastic lids will break after a few uses. A new type of lid for plastic buckets of several sizes, known as a gamma-seal, can be permanently attached to a bucket, and then the center portion can be screwed on and off whenever needed without damaging the container or the lid.

Three types of plastic buckets and a gamma-seal screw-on style lid.

Slide 40

Sanitation practices

Regular sweeping of the floors is a required practice for buildings used for handling food grains and processed foods. The prompt removal of spillage prevents insect populations developing in cracks and crevices from where they can infest the foods.

Slide 41

Reducing postharvest losses during (5) wholesale and retail marketing

- Inventory management
- Sanitation practices
- Strong packages and containers

Marketers of C&P crops can hold the products for a fairly long time before sales, if they are protected from pests, heat, rain and dust contamination. Sanitation practices include cleaning the storage areas and displays, and inspecting the product for any damage or decay. Broken packages can be sorted out and sold in bulk form.

Cereals and pulses for sale in Kigali, Rwanda (Photo credits: Dan McLean)

Slide 42

For more information

APHLIS and Hodges & Stathers (2012) provide a detailed illustrated guide to reducing postharvest losses for C&P crops. Many documents can be accessed via https://postharvest.nri.org/losses-information/scientific-publications

Slide 43

Working with and training the 5 target groups of beneficiaries on reducing postharvest losses

1. small-holder farmers
2. village and community storage operators
3. micro, small and medium enterprises

4. small stores
5. market and street vendors (excluding supermarkets)

The majority of postharvest losses for cereals and pulses in SSA will be experienced by small-holder producers, traders, village/community level storage operators and small-scale agro-processors. Relatively lower levels of losses occur during transport and marketing.

Bringing representatives of these target groups together and offering comprehensive training programs on reducing postharvest losses along the entire food supply chain (FSC) can assist the community to develop a more market-oriented approach to reducing postharvest food losses. Handling practices and technologies used by an actor early in the chain may affect the type and amount of losses experienced by those later on in the FSC.

Providing access to improved postharvest technologies is not by itself sufficient to reduce food losses. Any new technologies or recommended handling, storage or processing practices have to be supported by training of the potential users, and by local capacity building for extension agents, marketing officers and other key food supply chain actors.

Any food loss reduction solutions promoted need to be available, cost effective and accessible in the intervention areas. There must be support for changes in practices or adoption of new technologies, via the existence of suppliers, manufacturers/fabricants, distributors and repair services.

Slide 44

Improved postharvest handling practices for (1) small-holder farmers

Smallholder farmers of C&P crops can reduce postharvest losses by focusing on a few key practices.

- Maturity and harvest indices
- On-farm practices (harvesting, threshing, cleaning, drying, storage)
- Market access

Maturity/harvest indices and on-farm practices for C&P crops were introduced and described in detail earlier in this module. For further information, you can refer to the following manuals:

Postharvest Compendium (INPhO)

http://www.fao.org/in-action/inpho/crop-compendium/cereals-grains/en/

http://www.fao.org/in-action/inpho/crop-compendium/legumes/en/

http://documents.wfp.org/stellent/groups/public/documents/reports/wfp250916.pdf

Slide 45

Market access

Smallholder farmers often have limited knowledge regarding market prices and consumer demand or preferences. Advocating and promoting the formation of farmer's groups as formal or informal associations, cooperatives or small businesses is one approach to improving access to markets (WFLO 2010, Ferris et al, 2014). Promoting a market-driven approach not only helps to improve access but ensures there is sufficient market demand for the products, and that any solutions being promoted are available and accessible in the intervention areas (including the existence of suppliers, fabricants and distributors). A market-oriented approach can demonstrate economic and technical feasibility, hence a higher adoption rate and improved sustainability.

Statistically, 50% of smallholders will not be able to link to a commercial market. Therefore, it is important to keep in mind that the challenge is not merely of creating linkages to markets, but also of adequately assessing smallholder conditions, including their market options and methods of optimizing their market performance—all while ensuring that that these options are manageable for the smallholders (Ferris et al 2014).

For more information:

FAO 2015. Inclusive Business Models: Guidelines for improving linkages between producer groups and buyers of agricultural produce. http://www.fao.org/3/a-i5068e.pdf

Slide 46

Learning by doing

Smallholder farmers and farm workers may not be able to read well, so using hands-on teaching methods and demonstrations can be a practical way of reaching this target group.

"Learning by doing" and providing results demonstrations that compare two or more practices or simple technologies side by side, where farmers can make their own observations are often the most effective extension methods.

Examples of results demonstrations for food loss reduction for C&P crops

- Drying methods: compare the drying rate and cleanliness of cereals being dried directly on the ground/soil versus spread out on a clean tarpaulin
- Drying methods: compare grain quality using traditional drying practices versus a low temperature, heat assisted "bulk-in-bin" drying system
- Storage technologies: compare storage life and quality of a small volume of dried pulses stored in a woven sack versus stored in a sealed plastic container such as a used oil jug or a bucket with a tight-fitting lid.

- Processing methods, demonstrate the yield of maize milled to flour using 3 methods: a traditional village scale stone mill versus a well maintained, mechanical mill operated at a fast speed and operated at a slower speed.

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Improved postharvest handling practices for (2) village and community storage operators

- Improved storage structures
- Hermetic storage
- Improved storage management practices
- Temperature and relative humidity (RH) management

Postharvest training for storage operators typically focuses upon introducing the key features of improved storage structures (for adequate protection from weather and pests), and on improved storage management (sanitation, inventory management, temperature and RH). Storage operators are in business to make money, so they will be interested in the costs and benefits of any recommended practice or technology.

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Improved postharvest handling practices for (3) micro, small and medium enterprises

- Commercial drying
- Milling
- Processing facilities for making flour, grits, meal, etc.
- Improved packaging

Micro, small and medium scale enterprises are in business to make money, so they will be interested in the costs and benefits of any recommended practice or technology. The volume of crops that requires handling or processing will often determine which technologies make the most sense economically. There are sometimes tradeoffs to be made between fast processing or use of inexpensive technologies, and decisions to make regarding labor for manual practices versus capital costs for machinery.

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Improved postharvest handling practices for (4) small stores

and for (5) market and street vendors

- Sanitation
- Packaging and displays
- Temporary storage

Food stores and food vendors are in business to make money, so they will be interested in the costs and benefits of any recommended practice or technology.

Slide 50

Improved practices and technologies to reduce postharvest losses for key C&P crops

- Maize
- Sorghum
- Millet
- Rice
- Cowpeas
- Beans

Slide 51

Improved postharvest handling, storage and marketing of Maize

Harvest index: The period between planting and harvesting for maize depends upon the variety. Generally harvesting occurs 7 to 8 weeks after flowering; kernel with 35 – 40% moisture.

The physiological maturity in maize is recognized by the following characteristics:

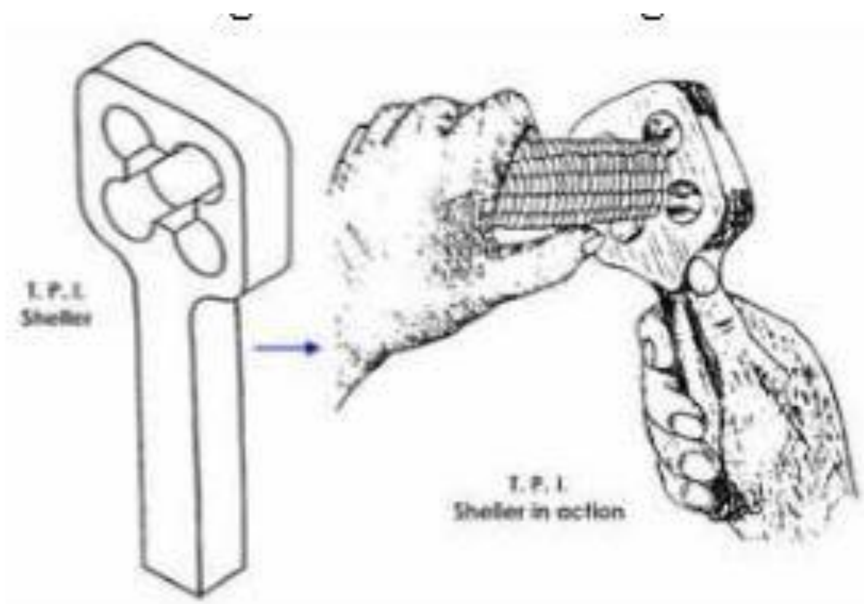
- Yellowing of most of the leaves
- Some of the leaves start drying up
- Yellowing and drying up of the husks
- Husks turning papery
- Maize grains acquire a glossy surface
- Some maize cobs begin to droop (hanging downward) on the stalk. This is in response to the plant shut-off of the supply of nutrients to the shoot system that occurs at physiological maturity.

Source: MAIZE: Post-harvest Operations, page 39 via INPhO Postharvest Compendium. http://www.fao.org/3/a-av007e.pdf

Harvesting: Cut stalks, stack and allow to dry in the field (stooking) or remove and collect cobs

On-farm handling: Dry cobs in ventilated maize crib or on cement pads or tarpaulins to 13% moisture. Shell manually or via mechanical aids. The practice of drying maize cobs on the ground as shown below should be discouraged.

Maize heap left on the ground to dry (The tarpaulin is used to cover the heap in case of an unexpected rain. (Photo credit: Joseph Mpagalile FAO)



Hand-held maize sheller (Source AGROTEC/UNDP/OPS, 1991)

Shelling maize by hand is a difficult task, but uptake of this simple technology in SSA has not been encouraging.

On-farm storage: Store in ventilated maize crib, or in hermetic bags, tanks or silos.

Long term commercial storage: Store maize in shaded, cool, dry conditions, using proper sanitation and pest management practices

Processing and marketing: Package processed products carefully, label with product name, manufacturing date. Protect processed products from heat, moisture and pests during storage.

Slide 52

Improved postharvest handling, storage and marketing of Sorghum

Harvest index: Grain sorghum plants are considered mature when the moisture in the grain drops to about 30%; however, the seed are usually too soft for harvesting when moisture content exceeds 25%. Attempts to harvest above 25% moisture will usually produce either unthreshed heads or cracked grain. The optimum harvest moisture, about 20%, minimizes harvest losses and drying expense.

Harvesting: Cut and collect only the grain heads. Because field drying is difficult and leads to excessive field losses from birds, other wildlife and lodging, harvest when moisture content is 25% and dry the sorghum mechanically to maintain quality and minimize harvest losses.

On-farm handling: Dry grain on cement pads or tarpaulins to 11% moisture, thresh and clean manually or via mechanical aids.

Sorghum heap left to dry outside a household in JImma, Ethiopia (Soure: Joseph Mpagalile, FAO)

On-farm storage: Store in hermetic bags, tanks or silos.

Long term commercial storage: Store sorghum in shaded, cool, dry conditions, using proper sanitation and pest management practices.

Processing and marketing: Package processed products carefully, label with product name, manufacturing date. Protect processed products from heat, moisture and pests during storage.

For more information:

https://extension.uga.edu/publications/detail.html?number=C1017&%20Drying%20and%20Storing

Slide 53

Improved postharvest handling, storage and marketing of Millet

Harvest index: Harvest grain as early as 40 days after flowering. Begin harvesting when seed moisture content drops below 15%.

Harvesting: Cut and collect the seed heads.

On-farm handling: Dry grain on cement pads or tarpaulins to 8% moisture, thresh and clean manually or via mechanical aids. Heat assisted drying is typically required to reach 8 to 10% moisture in order to prevent storage molds. Bulk bins should be lined with fine-mesh screens and warm air should be blown up through the grain (stacked no deeper than one meter).

On-farm storage: Store in hermetic bags, tanks or silos.

Long term commercial storage: Store millet in shaded, cool, dry conditions, using proper sanitation and pest management practices.

Processing and marketing: Package processed products carefully, label with product name, manufacturing date. Protect processed products from heat, moisture and pests during storage.

For more information:

http://extension.uga.edu/publications/files/pdf/B%201216_3.PDF

Slide 54

Improved postharvest handling, storage and marketing of Rice

Harvest index: Grain moisture content ideally is between 20 and 25% (wet basis). Grains should be firm but not brittle when squeezed between the teeth, and 80–85% of the grains have turned yellow-colored (like dried straw).

Harvesting: Harvesting should be done when there is minimal surface moisture (e.g. from previous rainfall or early morning dew). Full stalks can be cut, bundled and collected if handled carefully to avoid shattering. Alternatively grains can be cut from the stalks and collected manually or via mechanical aids (small combine harvesting machines).

On-farm handling: Dry grain on cement pads or tarpaulins to 18-20% moisture, thresh and clean manually or via mechanical aids

On-farm storage: Store rice in hermetic bags, tanks or silos. Stored rice should be 14% moisture content or lower.

Long term commercial storage: Store rice in shaded, cool, dry conditions, using proper sanitation and pest management practices

Processing and marketing: Package processed products carefully, label with product name, manufacturing date. Protect processed products from heat, moisture and pests during storage.

A small-scale rice dehuller (Left) and medium-scale rice milling machine capable of cleaning, dehulling and grading (Right) being used in Tanzania (Source: Joseph Mpagalile, FAO)

For more information: Rice Postharvest Operations via INPhO Postharvest Compendium http://www.fao.org/3/a-ax442e.pdf

Slide 55

Improved postharvest handling, storage and marketing of Cowpeas

Harvest index: At maturity, leaves will dry down but may not drop off completely. Cowpeas should be harvested when seed moisture content is 14 to 18%, depending on the consumer's requirement.

Harvesting: Manual or combine harvest. Dry pods can remain about a week awaiting harvesting without spoilage. However, to avoid field weathering or shattering, dry pods should not be left in the field longer than 2 weeks after full pod maturity.

On-farm handling: Dry cowpeas on cement pads or tarpaulins to 12% moisture, thresh and clean manually or via mechanical aids. Sort out any cracked or broken grains.

On-farm storage: Store in hermetic bags, tanks or silos. Only short-term storage is possible at around 12 % moisture, with much lower (8 to 9%) moisture recommended for long-term storage.

Long term commercial storage: Store cowpeas in shaded, cool, dry conditions, using proper sanitation and pest management practices.

Processing and marketing: Package processed products carefully, label with product name, manufacturing date. Protect processed products from heat, moisture and pests during storage.

Source: Department of Agriculture, South Africa.

http://www.arc.agric.za/arc-gci/Fact%20Sheets%20Library/Cowpea%20-%20Production%20guidelines%20for%20cowpea.pdf

Slide 56

Improved postharvest handling, storage and marketing of dry beans

Harvest index: Maturity is indicated by well filled pods and less than 15% moisture content.

Harvesting: In developing countries, harvesting is mostly manual. Determinate plants are pulled up and placed in rows or piles, very early in the morning to avoid pods opening. Indeterminate plants have to be harvested pod by pod as they mature and climb upwards. Bean pods are collected in baskets or buckets.

On-farm handling: Dry beans on cement pads or tarpaulins to 13-14% moisture, thresh and clean manually or via mechanical aids. Drying to less than 13% moisture will increase the likelihood of cracking. Sort out any cracked or broken beans.

On-farm storage: Store in hermetic bags, tanks or silos.

Long term commercial storage: Store dry beans in shaded, cool, dry conditions, using proper sanitation and pest management practices.

Processing and marketing: Package processed products carefully, label with product name, manufacturing date. Protect processed products from heat, moisture and pests during storage.

For more information:

Phaseolus Beans: Postharvest Operations via INPhO Postharvest Compendium. http://www.fao.org/3/a-av015e.pdf

Slide 57

Costs and benefits

It is simple to learn how to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology. Only the differences are calculated, for a simplified, partial economic analysis, making it easy to do as a training exercise with farmers or traders. Using 100kg or 1000kg of produce to make the calculations allows the user to perform easy mathematics, then multiply the results by whatever volume will actually be harvested/handled and sold.

Postharvest costs & benefits worksheet: assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:		
COSTS		
Relative costs		
EXPECTED BENEFITS		
% postharvest losses		
Amount for sale		
Value/kg		
Total market value		
Total market value (BENEFITS) minus relative costs		

Slide 58

Cost/Benefit examples

Having the option for safe, longer-term storage can provide multiple benefits including reduced postharvest losses and improved market prices for C&P crops. In Tanzania, maize stored in PICS bags until the low season sold for 20,000 Tsh per 100 kg, as compared to less than 8,000 Tsh per 100 kg when sold at the time of harvest (Jones et al 2011).

Example 1) Cereals: Improved maize crib storage

Maize stored in ventilated cribs, and protected from rodents and insects in Uganda experience much lower losses and can be sold at higher market prices.

Example 2) Pulses: Storage of cowpeas in hermetically sealed PICS bags

Cowpeas dried to the proper low moisture (12%) and stored in PICS bags for 6 months will have less than 1% postharvest losses.

Slide 59

Calculating Costs and Benefits

Example 1: Improved maize crib storage

Postharvest costs & benefits worksheet: assume harvest 1000 kg

	Current /traditional practice	New /improved practice
Describe:	Storage of cobs in sacks and baskets	Dry maize cobs using electric fans, then store in an improved ventilated maize crib
COSTS (US$)		

Labor for cutting	2	2
Drying	0	10
Maize crib	0	200
Relative costs	2	212
EXPECTED BENEFITS		
% postharvest losses in 3 months	15%	2%
Amount for sale	850 kg	980 kg
Value/kg	US$ 0.40 33% penalty for insect and rodent attack	US$ 0.60
Total market value	340	588
Total market value (BENEFITS) minus relative costs for 1st load	$338	$376
Relative profits 1st load (fully pays for the cost of the crib)		+ $38
Total market value (BENEFITS) minus relative costs for 2nd load	$338	$576
Relative profits 2nd load and subsequent loads		+ $238

If the actual volume harvested per load is 500 kg, then 0.5 x $238 = US$ 119 increased relative profits for each load. 2000 kg, then 2 x $238 = US$ 476 increased relative profits for each load.

Slide 60

Calculating Costs and Benefits

Example 2: Dried Cowpeas storage in PICS bags

Postharvest costs & benefits worksheet: assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:	Storage in jute sacks	Storage in PICS bags (hermetic 3 layer bags)
COSTS (US$)		
1 100 kg jute sack	1	
2 PICS bags (50 kg capacity)		4
Relative costs	1	4
EXPECTED BENEFITS		
% postharvest losses in 6 months	10%	1%
Amount for sale	90 kg	99 kg
Value/kg	US$ 0.70 30% penalty for insect attack	US$ 1.00
Total market value	63	99
Total market value (BENEFITS) minus relative costs for 1st load	$62	$95
Relative profits 1st load (fully pays for the cost of the PICS bags) – can be reused 2 or 3 times		+ $33

Total market value (BENEFITS) minus relative costs for 2nd load	$62	$99
Relative profits 2nd load and subsequent loads		+ $37

If the actual volume harvested per load is 500 kg, then 5 x $37 = US$ 185 increased relative profits for each load. 1000 kg, then 10 x $37 = US$ 370 increased relative profits for each load.

2000 kg, then 20 x $37 = US$ 740 increased relative profits for each load.

Slide 61

Priority training needs

Topics that need attention in order to solve postharvest problems for a variety of cereals and pulses

- Basic postharvest handling practices
- Temperature management and relative humidity control in storage
- Postharvest pest and disease management in storage

Slide 62

Advocacy issues

Problems that require attention in order to reduce postharvest losses for a variety of cereals and pulses

- Improving infrastructure (roads, power, water)
- Promoting the development of an on-farm, low-cost drying process that is able to bring down the moisture content of grains to 13% as fast as possible
- Investing in postharvest facilities (storage structures)
- Investing in agro-processing (SMEs) for cereals and pulses
- Improved marketing (facilities, farmer/trader organizations, cooperatives)
- Providing incentives for using improved postharvest practices and investments

Slide 63

This concludes Module 1.2

Reducing Postharvest Losses in Sub-Saharan Africa: Cereals and Pulses

Manual 1 contains a full reference list.

Module 1.3 Reducing Postharvest Losses in SSA: Roots and Tubers

Slides of coordinating Module 1.3 PowerPoint presentation (57 illustrated slides)

Slide 1

Learning objectives:

- Practitioners will gain an understanding of the many options available for addressing the causes of food losses identified in food loss assessments for root and tuber crops.
- Practitioners will be introduced to key postharvest technologies, improved handling practices and management skills that can help the 5 beneficiary groups reduce postharvest food losses for roots and tuber crops
- Practitioners will be able to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology
- Practitioners will be made aware of topics or areas of training/extension and advocacy that are needed to solve postharvest problems for a roots and tuber crops

Slide 2

Key crops:

- Cassava
- Sweetpotatoes
- Yams
- Cocoyams

These crops are underground plant storage organs, mostly composed of carbohydrates, and are produced in tropical or sub-tropical conditions. They have low respiration rates and are generally considered to be less perishable than other types of fresh produce.

Slide 3

This module covers 5 segments of roots and tuber crops supply chain

(1) harvesting & postharvest handling (on-farm)

(2) storage

(3) transportation

(4) agro-processing

(5) wholesale and retail

The majority of the total of 67.7 million tonnes per year of food losses for R&T crops in SSA occur during production/harvesting (26.4m tonnes), during postharvest handling and storage (29.3m tonnes) and during processing/packaging (7.4m tonnes). Source: Gustavsson et al., 2013.

Slide 4

These six practices are very important for reducing losses of R&T crops for reducing postharvest losses during (1) harvesting & postharvest handling on the farm.

- Maturity / age of plant
- Harvesting/digging as gently as possible
- Sorting to remove damaged or decayed produce
- Curing before postharvest handling, packing, storage or marketing
- Use of improved containers to reduce damage

- Use of shade to provide a source of natural cooling

Slide 5

Maturity/age of plant

To optimize shelf life, quality and nutritional value, maturity assessment is critical to achieving good quality yams, as well as for roots and tuber crops in general. In the field, the mature crop is generally recognized by the end of vegetative growth and yellowing of the leaves. For cassava, leaving the crop in the ground after full maturity will increase susceptibility to pest attacks. IITA recommends harvesting cassava storage roots as soon as they are mature; this will reduce the length of time they can be exposed and damaged by the pests. (James et al, 2010). For cassava, the food quality of roots (the starch content), increases with time up to an optimal period of 12 to 15 months after planting, after which there is a loss of quality, mainly due to increased lignification (which makes the texture stringy).

Harvesting/digging

Training on how to reduce damage during harvesting will help farmers to produce higher quality R&T, and lead to higher market value. For cassava, wounds and bruises are the triggers of primary deterioration (vascular streaking with blue-black or brownish occlusions and chemical deposits). For most R&T crops, decay organisms are wound pathogens and will infect the crop via the sites of an injury.

It is easy to damage R&T crops when digging, especially when using large hand tools or mechanical harvesters (lifters). The produce can be cut or broken, leaving wounds that provide easy access for disease organisms. Harvesting losses for cassava tend to be higher during the dry season because it is more difficult to dig; roots break and remain in the soil.

Slide 6

Sorting to remove damaged or decayed produce

Pre-sorting in the field immediately after harvest is used to remove any defective produce from the harvested lot, especially decayed or insect infested R&T. If these units are not removed before packing, transport and/or storage, the decay pathogens or insect pests can spread to the rest of the load.

Sorting may occur again later in the food supply chain, so if farmers voluntarily remove any severely damaged produce, and make sure none of the produce is decaying or carrying insects, the entire load will be of higher initial quality, and will be more likely to remain that way. Buyers may be willing to pay more if they are regularly provided with higher quality produce at the farm gate.

Slide 7

Curing before postharvest handling, packing, storage or marketing

The curing of root and tuber crops such as sweetpotatoes, cassava, yams and cocoyams is an important practice if these crops are to be stored for any length of time. Curing heals any harvest wounds and protects these crops from water loss. The process will be described fully in the next Slide.

Curing is accomplished by holding the produce at high temperatures and high relative humidity for several days while harvesting wounds heal and a new, protective layer of cells form.

Cooler temperatures will slow the curing process. While curing is associated with a small amount of weight loss, the long extension of storage life makes the practice economically worthwhile. Storage life is longer with good quality and appearance (less sprouting, nicely healed wounds, less decay, firm peel). Well cured sweet potatoes can be stored for 7 months at 15 °C.

Slide 8

Recommended curing practices for R&T crops

	Temperature	Relative humidity	Duration
Cassava (Manioc)	30-40°C	90-95%	2 to 5 days
Sweetpotatoes	28-32	85-90	4 to 7
Yams (Igname)	32-40	90-100	1 to 4
Cocoyams (Malanga)	30-35	95	3 to 5

(Sources: Kitinoja and Kader, 2015; and Kader 2002)

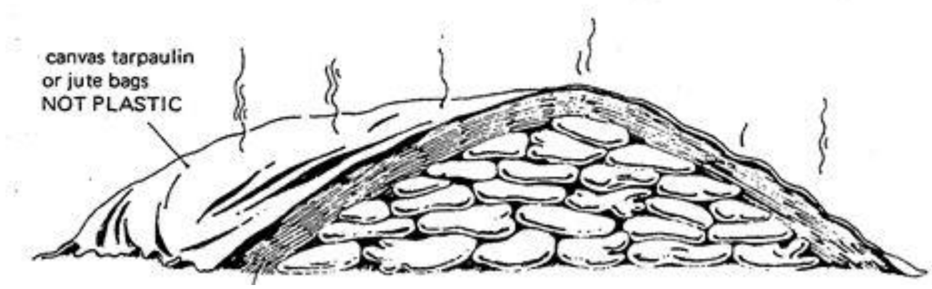
Cured R&T crops experience less water loss and lower weight losses during storage and marketing. Booth (1974) reported that loss of weight in sweetpotato after 113 days of storage was 17% in the cured samples and 42% in uncured roots. Sweetpotatoes will lose about 3% of their weight during curing, then water losses will be reduced to about one half of that experienced by uncured roots during long term storage.

Slide 9

Curing on the farm

Yams and other tropical root and tuber crops can be cured outdoors if piled in a partially shaded area. Cut grasses or straw can be used as insulating materials and the pile (about 1m high) should be covered with canvas, burlap or woven grass mats. Successful, rapid curing requires high temperature and high relative humidity, and this type of natural covering will trap self-generated heat and moisture. Plastic should not be used since it will allow too much moisture to accumulate and lead to high rates of decay.

Successful, rapid curing requires high temperature and high relative humidity, and this type of natural covering will trap self-generated heat and moisture. The stack should be left for about four days (yams) or five days (cassava, sweetpotatoes or cocoyams) and then checked to feel the peel of the produce. If the peel is firmly attached and does not slip when pressed sideways using light finger pressure, the curing process is complete (Kitinoja and Kader, 2015).



Cut-away view of a pile of yams being cured in the field (covered with straw and canvas cloth, under shade). Source: Wilson (no date).

Slide 10

Improved containers

Polypropylene sacks of sweetpotato roots weighing more than 100 kg is the common practice in eastern Africa, and results in significant skinning and bruising injuries (Ndunguru et al 2000). Postharvest loss assessments have documented 85% peel damage in Tanzania (Tomlins et al 2002), and 100% damaged roots in Ethiopia (Parmar et al 2016) after transport to market. Smaller sized sacks can reduce damage and losses.

100kg sack of sweetpotatoes in Ethiopia (Left, Photo credit Aditya Parmar) and a 50kg bag full of cassava in Tanzania (Right) Photo Credit: Joseph Mpagalile, FAO).

Tomlins et al. 2002 pointed out that using 20kg fiberboard cartons can significantly reduce the skinning and mechanical damages during loading, unloading and transportation. Packaging roots and tubers in full telescopic fiberboard cartons with paper wrapping or excelsior (shredded paper or wood fiber) reduces bruising and enables large quantity of tuber to be transported over long distances. R&T crops can be contained in loose packs, or units of 10-11 kg or 23-25 kg (McGregor, 1987).

Large sized reusable plastic crates (holding 30 to 40 kg) are another improved container that is more suitable for local handling, storing, transporting and marketing of root and tuber crops. The use of plastic crates can reduce physical damage to less than 5%.

Ventilated plastic crates must be utilized as part of a carefully planned postharvest handling system, such as that organized and managed by a marketing cooperative, food processing buyer, supermarket buyer, farmers' association or exporter, since the crates must be transported to the packinghouse or end buyer, emptied, washed and returned to the farmer's fields to be used again.

Slide 11

Use of shade

Exposure to the sun should be avoided as much as possible during and after harvest, since roots and tubers left out in the sun will gain heat and may become sun-burned and dehydrated. Produce exposed to sunlight can soon become 4 to 6 °C warmer than air temperature. Field containers should be placed in the shade, under a tree, or loosely covered (e.g. with light colored heavy cloth, leafy plant materials, loose straw, a woven matt or an inverted empty container) if delays are expected in removing filled containers from the field.

Slide 12

Reducing postharvest losses during (2) storage

There are five important factors/practices that can help to reduce postharvest losses of R&T crops during storage.

- Improved storage structures on farm
- Curing before storage
- Waxing
- Commercial storage using evaporative cooling technologies
- Pest control

Slide 13

Improved storage structures on farm

Traditional R&T storage on the farm includes 1) leaving the crop in the soil (unharvested) until needed, 2) underground storage structures (e.g. in loose piles of ashes and soil, pits lined with straw or field clamps) and 3) above ground ventilated structures (such as the yam barn). Leaving R&T in the ground until required is the simplest storage technique practiced by rural small-scale farmers, but this type of storage prevents the use of the farmland for growing the next crop. Sweetpotatoes are susceptible to attack by weevils if left in the ground after full maturity.

Sweetpotatoes can be stored in pit storage or field clamps for 3 to 5 months. Harvested yams can be put in piles, mixed with ashes and covered with soil, and can be successfully stored for a few months if well protected from flooding and pest attacks. Pit storage and field clamps must be constructed in shady location, or include a roof that provides shade.

In barn storage, where the yams are tied on ropes and a wooden frame, yams have a maximum storage life of 6 months. Field clamps, pit storage and barn storage are not recommended for on farm storage of R&T crops unless there is no other option, since they are difficult to manage and the R&T crops are not well protected from pests. Storage losses can be high with up to 10-15% losses in 3 months, and 30-50% losses after 6 months if tubers are not treated for rotting using fungicides (Opara 2003).

Slide 14

Improved on-farm structures

Improved on farm storage structures can double the storage life of R&T crops, mainly by lowering temperature and providing better protection from rodents and insect pests.

- Ventilated storage, cooled naturally via evaporative cooling systems
- Walk-in storage room, with cement floor, pallets, shelving or racks
- Low cost storage structures, made locally from indigenous materials (wooden frame, charcoal pieces) and wire mesh (chicken wire mesh or similar type screening materials)

Walk-in charcoal cool rooms in East Africa (mesh walls filled with pieces of charcoal).

The storage room walls are kept wet and natural evaporation acts to carry heat away from the chamber and the produce stored inside. (Photo credits: Bertha Mjawa, Lisa Kitinoja)

Plans for construction of a charcoal cool room can be found on this website: http://www.postharvest.org/images/CharcoalcoolstoragePNACQ751.pdf

Slide 15

Curing before storage of R&T crops

If you are storing R&T crops in a modern cool storage (at 14-16°C) and selling by weight, curing can reduce weight losses from the typical level of about 22% (for uncured) to 10% losses during 6 months of storage time.

Shed curing: if the weather is rainy or it is too hot in the field, R&T crops can be cured under shade. A tent or three walled open shed is a good option, since these are low cost and allow for plenty of air circulation.

Heat added curing: if the weather is cold and damp, then added heat may be needed to accomplish the curing process. Heat can be added via a propane burner, electricity or even via a small wood or charcoal fire. The warmed air can be moved through the pile of curing crops using a small fan.

Slide 16

Waxing R&T crops before storage and marketing

Paraffin wax can be applied to cassava roots and will reduce water loss by 50% and extend shelf life from less than 2 days to about 10 days (Baldwin et al 2012). The heated wax is generally applied as a spray or a dip. The roots must be clean and completely dry, or the wax will flake off after drying (Grant and Burns 1994). Paraffin wax has been successfully used since the 1940s, but newer, water-based carnauba waxes can be used with the same positive effects (Sargent et al 1995).

Waxed cassava root in Ghana (Photo credit: Lisa Kitinoja)

Slide 17

Commercial storage structures and evaporative cooling technologies

If R&T crops need to be stored for more than a few months, temperature management and relative humidity control are required. Cassava can be stored for up to 6 months at 0-5°C and high RH%. Storing sweetpotatoes at 14 °C can inhibit sprouting.

Evaporative cool storage structures (e.g., use of electric powered "swamp coolers", or passively cooled charcoal cool rooms) are cost effective and practical for longer term storage of the R&T crops that have a good storage potential at 12 to 15°C. The challenge for the use of the electric powered equipment is a lack of reliable electricity especially in rural areas.

	Temperature	Relative humidity (RH)	Storage period
Cassava (Manioc)	5-8°C 0-5°C	80-90% 85-95%	2 to 4 weeks 5 to 6 months
Sweetpotatoes	12-14°C	85-90%	5 to 6 months
Yams (Igname)	13-15°C 27-30°C	99% 60-70%	5 to 6 months 3 to 5 weeks
Cocoyams (Malanga)	7-10°C	85-90%	4 months

Modern style sweetpotato storage structure with evaporative cooling unit on the roof. Vents along bottom of the structure are opened so cooled air can flow downward from the ceiling, circulate through storage room and exit at floor level. (Photo credit: J F Thompson)

General maintenance tips and an illustration of internal design of an evaporative cooler can be found online:

http://www.perfect-home-hvac-design.com/swamp-cooler-maintenance.html

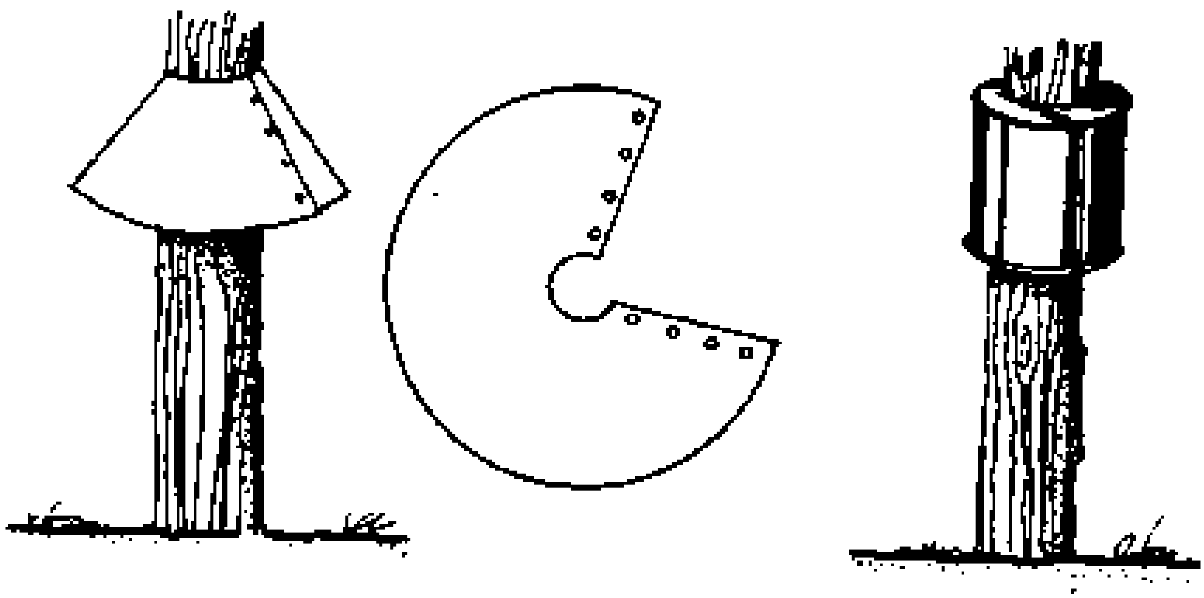
Slide 18

Pest control

Damage from harvesting wounds and insect pests provide the entry points for postharvest decay organisms, so the best defense against decay is to properly cure R&T crops before storage.

Ray and Das (1998) reported complete growth inhibition by three antagonistic yeasts, *Debaryomyces hansenii*, *Pichia anomala* and *Saccharomyces cerevisiae* against *Botryodiplodia* rot of sweetpotato.

If possible a store should be raised to 1m above ground height, and rodent guards should be placed on the legs to prevent rodents from being able to access the stored commodity.



Rat guards made from metal sheeting or empty cans. Source: FAO. 1985.

It is quite difficult to keep insect pests out of storage structures used for R&T crops, so it is common to use traps (for rodents and insects), pesticides and/or fumigation practices. Curing should precede any fumigation treatment against insects (Afek and Wiseblum, 1995).

Slide 19

Reducing postharvest losses during (3) transportation

- Loading/unloading

- Stacking, ventilation
- Covering open loads

Relatively low losses are experienced for R&T crops in SSA during transportation. Damage from rough handling and poor quality packages cause bruising and scuffing that can lead to postharvest losses that will be noticed later on in the food supply chain.

Traders are generally in charge of postharvest handling during transportation. As a rule, traders are rarely included in postharvest extension/training programs, and they can be a difficult clientele group to reach, since they are usually on the move from farm to farm and market to market, and rarely have time to attend long meetings or classroom style educational programs. Postharvest demonstrations in the marketplace may be a practical way to reach these FSC actors. For R&T crops, gentle loading/unloading can reduce physical damage, and covering open loads can help reduce loses by avoiding direct sun.

Slide 20

Loading/unloading practices

Gentle handling can help to reduce postharvest losses during loading and unloading of R&T crops. Containers that are too large will tend to be dropped by workers.

Loading and unloading sacks of sweetpotatoes in Ethiopia. (Photo credit: Aditya Parmar)

Slide 21

Stacking, ventilation

For crops in packages, the stacks should not be too high, and people should not walk on the sacks or on the top of the load. For bulk loads, adding some cushioning on the bottom and sides of the vehicle can reduce damages during transport, and making sure there is some space left for ventilation under the load and along the sides and top can help reduce postharvest losses. A heavily packed, overloaded truck will allow the R&T crops to heat up during transport. Also, the risk of damage due to compression is high.

Vehicle with vents in the front panel and a tall cover over the load to provide air circulation during transport of R&T crops (Photo credit: Lisa Kitinoja).

Slide 22

Covering open loads

Protecting the crops from the sun, wind and rain during transport will help to reduce contamination and reduce postharvest loses of R&T crops.

Loads of R&T crops should be covered during transport in small and in large vehicles. (Photo credits: Lisa Kitinoja and Joseph Mpagalile)

Slide 23

Reducing postharvest losses during (4) agro-processing

- Use of mechanical peelers, chippers, graters
- Improved drying practices
- Improved packages and containers
- Containers for dried R&T products
- Sanitation

Slide 24

Use of mechanical peelers, chippers, graters

Processing of cassava into dried products (gari, chips, high quality cassava flour): Use of a package of improved mechanical devices developed by IITA for peeling, grating or grinding, chipping, dewatering, sifting and frying, along with proper training, can reduce processing losses from 22% to 10%.

A motorized cassava grater manufactured by Intermech Engineering in operation in rural Tanzania (Source: Joseph Mpagalile, FAO)

R&T chips or granules from a chipper or grater are spread on a drying surface exposed to the sun. The more chips loaded on a drying surface, the slower the drying rate will be, so the chips should be thinly spread. Thin chips dry faster than thicker ones. The quality of the chips (e.g. starch content, colour) is higher if the drying time is short. However, for cassava, the cyanogenic potential of cassava decreases when the drying time is longer. Therefore, drying parameters that affect the drying rate, especially the loading rate (weight of drying material per unit area of drying surface), are important in determining the residual cyanogen content of the dried cassava (Opara 2003).

Slide 25

Improved drying practices: solar drying or heating in an oven

Reducing moisture to a point where all physiological reactions and microbial growth are inhibited can tremendously increase the short shelf-life of cassava roots. For cassava, this point is at 14% moisture content. Most cassava food products are dried to 8 to 12% moisture for long term storage (Opara 2003).

It is not recommended to dry roots and tuber crops such as cassava using mats placed directly on the ground. However, drying of chipped or shredded R&T crops on a cement pad, raised platform or heat-assisted system will speed drying and improve the product quality.

Peeled cassava being dried on mats placed on the ground, a process that should be discouraged (Source: Joseph Mpagalile, FAO)

Raised mesh tables for drying cassava in Ethiopia (Left) and in Tanzania (Right) (Photo credit: Aditya Parmar and Joseph Mpagalile, FAO).

Slide 26

Improved packages and containers

Storage containers that can be sealed and protect the dried products from light, water, insects and rodents will greatly increase their storage life.

Containers for dried R&T products

Metal foil packages are low cost and can protect dried R&T and processed food products against light, moisture and the damage they can cause (rancidity and discoloration) for up to one year (Fellows and Axtell, 2002; USU 2013). The polyethylene (PET) layer is food-grade plastic with no known toxicities (Castle, 1989).

Metal foil packages are available in zip lock or heat sealed versions (Source: www.uline.com).

Heat sealed, heavyweight plastic pouches are used for packaging flours made from R&T crops in Nigeria, while heavyweight paper packages are used in Rwanda (Photo credits: Lisa Kitinoja and Dan McLean)

Slide 27

Plastic buckets can be cleaned and reused many times for storage of dried R&T crop food products. Typically, the plastic lids will break after a few uses. A new type of lid for plastic buckets of several sizes, known as a gamma-seal, can be permanently attached to a bucket, and then the center portion can be screwed on and off whenever needed without damaging the container or the lid.

Three types of plastic buckets and a gamma-seal screw-on style lid. (Source: uline.com)

Slide 28

Sanitation practices

Regular sweeping of the floors is a required practice for buildings used for handling fresh and processed foods. The prompt removal of spillage prevents insect populations developing in cracks and crevices from where they can infest the foods.

Slide 29

Reducing postharvest losses during (5) wholesale and retail marketing

- Gentle handling
- Use of shade
- Sanitation

Slide 30

Gentle handling

Large sacks of R&T are often dropped while being unloaded and are sometimes treated like furniture. It is not uncommon to see people sitting on sacks while they rest in the marketplace. An extreme example comes from Addis Ababa market, where a buyer was photographed while doing his paperwork as he sits on a chair which has been set on top of a stack of sacks of sweetpotatoes.

Unloading sweetpotatoes in Addis Ababa market, Ethiopia. (Photo credit Aditya Parmar).

Slide 31

Use of shade

Undamaged sweetpotatoes in the marketplace in Ethiopia, kept for 7 days in the shade, lost about 15% of their weight, while those without shade lost more than 30% of their weight (Parmar et al 2016).

Partial shade in Awassa main market, Ethiopia. (Photo credit Aditya Parmar).

Slide 32

Details on how to work with and train the 5 target groups/ beneficiaries to reduce postharvest losses of R&T crops

(1) small-holder farmers

(2) village and community storage operators

(3) micro, small and medium enterprises

(4) small stores

(5) market and street vendors (excluding supermarkets)

The majority of postharvest losses for R&T crops in SSA will be experienced by small-holder farmers, traders and village/community storage operators. Relatively low levels of postharvest losses occur during transport and marketing.

Bringing representatives of these five target groups together and offering comprehensive training programs on reducing postharvest losses along the entire food supply chain can assist the community to develop a more market-oriented approach to reducing postharvest food losses. Handling practices and technologies used by an actor early in the chain may affect the type and amount of postharvest losses experienced by those later on in the FSC.

Providing access to improved postharvest technologies is not by itself sufficient to reduce food losses. Any new technologies or recommended handling, storage or processing practices have to be supported by training of the potential users, and by local capacity building for extension agents and key food supply chain actors.

Any food loss reduction solutions promoted need to be available, cost effective and accessible in the intervention areas. There must be support for changes in practices or adoption of new technologies, via the existence of suppliers, manufacturers/fabricants, distributors and repair services.

Slide 33

Improved postharvest handling practices for (1) small-holder farmers

Training on these four topics will assist smallholder farmers to harvest R&T crops of good quality, and to protect the crops from the most common causes of damage and losses.

- Maturity/age of plant
- Harvesting/digging
- Curing on the farm
- Market access

The first three topics were introduced and discussed earlier in this module. For further information, trainers can refer to the following training manuals:

Small-scale postharvest handling practices: a manual for horticultural crops

English: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230101.pdf

French: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230102.pdf

Amharic: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230098.pdf

Afrikaans:
http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230097.pdf

Swahili: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230107.pdf

Postharvest Compendium (INPhO)

http://www.fao.org/in-action/inpho/crop-compendium/roots-tubers/en/

Slide 34

Market access

Smallholder farmers often have limited knowledge regarding market prices and consumer demand or preferences. Advocating and promoting the formation of farmer's groups as formal or informal associations, cooperatives or small businesses is one approach to improving access to markets (WFLO 2010, Ferris et al, 2014). Promoting a market-driven approach not only helps to improve access but ensures there is sufficient market demand for the products. A market-oriented approach can demonstrate economic and technical feasibility, hence a higher adoption rate and improved sustainability.

For more information:

FAO 2015. Inclusive Business Models: Guidelines for improving linkages between producer groups and buyers of agricultural produce. http://www.fao.org/3/a-i5068e.pdf

Slide 35

Learning by Doing

Smallholder farmers and farm workers may not be able to read well, so using hands-on teaching methods and demonstrations can be a practical way of reaching this target group.

"Learning by doing" and providing results demonstrations that compare two or more practices or simple technologies side by side, where farmers can make their own observations are often the most effective extension methods.

The shortened shelf life of sweetpotato is due to breakage, cuts, infestation by weevils, rotting, and superficial damages (Rees et al 2001). All these together accounted for 41 to 93% of root damage when sweetpotato arrived in the urban Tanzanian markets (Mtunda et al., 2001). Smallholder farmers need to better understand how their on-farm practices can contribute to these kinds of food losses later on in the food supply chain.

Examples of results demonstrations for food loss reduction for R&T crops.

- Curing R&T crops: compare the quality and rate of weight loss for sweetpotatoes that have been cured in the field prior to storage versus those stored without curing.
- Waxing R&T crops: compare the rate of weight loss at ambient temperature for 3 days for a sample of root crops that are waxed versus a sample that has not been waxed.
- Drying methods: compare the drying rate and cleanliness of R&T crops being dried directly on the ground/soil versus spread out on a clean tarpaulin
- Storage technologies: compare storage life and quality of a small volume of dried cassava chips stored in a woven sack versus stored in a sealed plastic container such as a used oil jug or a bucket with a tight fitting lid.

- Processing methods, demonstrate the yield of cassava milled to flour using 3 methods: a traditional village scale stone mill versus a well maintained, mechanical mill operated at a fast speed and operated at a slower speed

Slide 36

Improved postharvest handling practices for (2) village and community storage operators

- Curing before storage of fresh R&T crops
- Loading and stacking the stored R&T crops
- Insect control
- Rat / rodent control
- Containers for dried R&T products
- Temperature and RH management
- Improved storage management

Postharvest training for storage operators typically focuses upon introducing the key features of improved storage structures (for adequate protection from weather and pests), and on improved storage management (loading or stacking practices, sanitation, inventory management, temperature and RH). For R&T crops, it is important to make sure that any fresh produce placed into storage has been properly cured. Storage operators are in business to make money, so they will be interested in the costs and benefits of any recommended practice or technology.

Slide 37

Curing before storage

If you are storing R&T crops in a modern cool storage (at 14-16°C) and selling by weight, curing can reduce weight losses from the typical level of about 22% (for uncured) to 10% losses during 6 months of storage time.

Containers for dried R&T products

Storage containers that can be sealed and protect the dried products from light, water, insects and rodents will greatly increase their storage life. Plastic buckets can be cleaned and reused many times. A new type of lid for plastic buckets, known as a gamma-seal, can be attached once, and then screwed on and off whenever needed without damaging the container.

Three types of plastic buckets and a gamma-seal screw-on style lid.

Slide 38

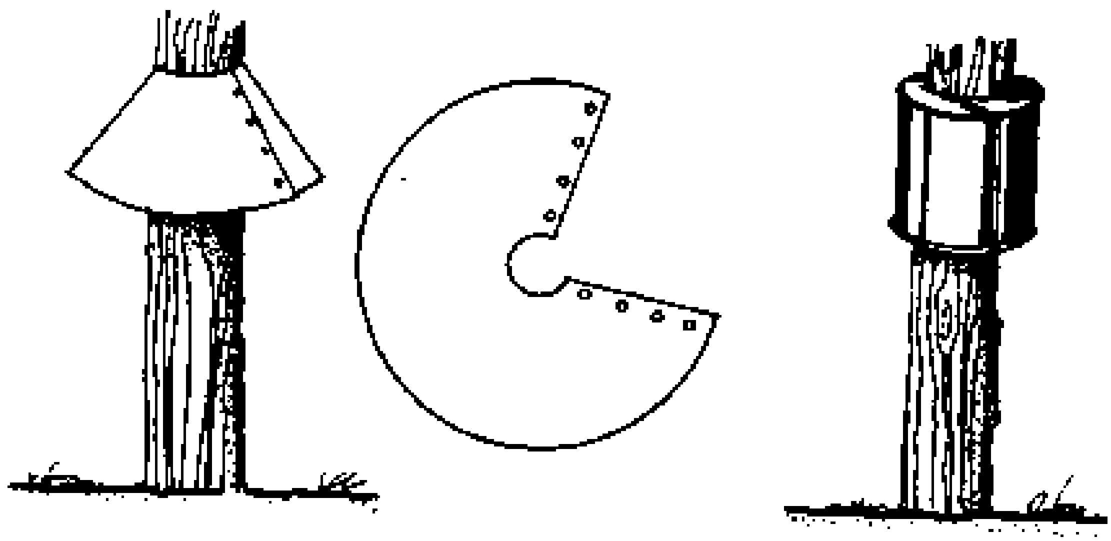
Insect control

IITA has determined that the main insect feeding on dry cassava chips in Benin Republic was *Dinoderus* sp. (Saizonou, 1996). Other insects of importance belong to the species *Carpophilus* sp., *Araecerus fasciculatus* and *Rhizopertha dominica*. Infestation by all insects is heavier in the rainy season than in the dry season, is more prevalent in the humid zone than in the savannas, and is found more in large chips than in smaller ones (Dossou, 1996).

Rat / rodent control

Traps and rat guards are commonly used to provide low cost pest control.

Generic wooden rat trap



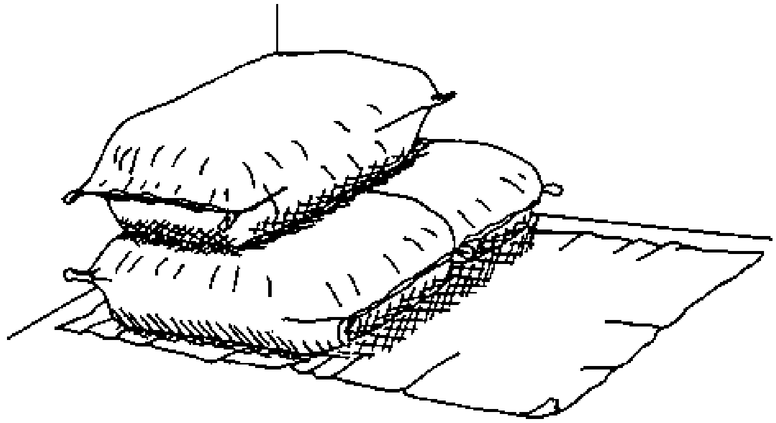
Rat guards made from metal sheeting or empty cans. Source: FAO. 1985.

Slide 39

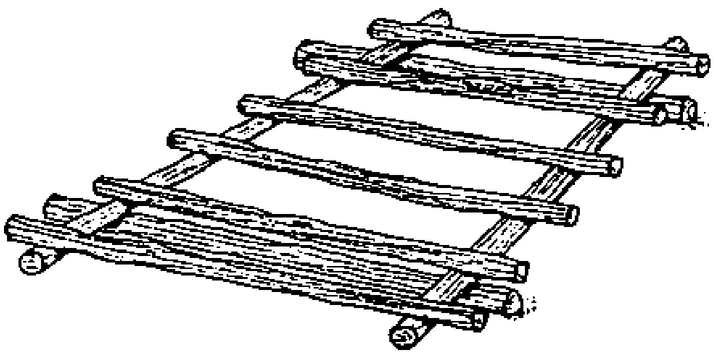
Improved storage management

Pallets, Inspections, Sanitation/food safety protocols

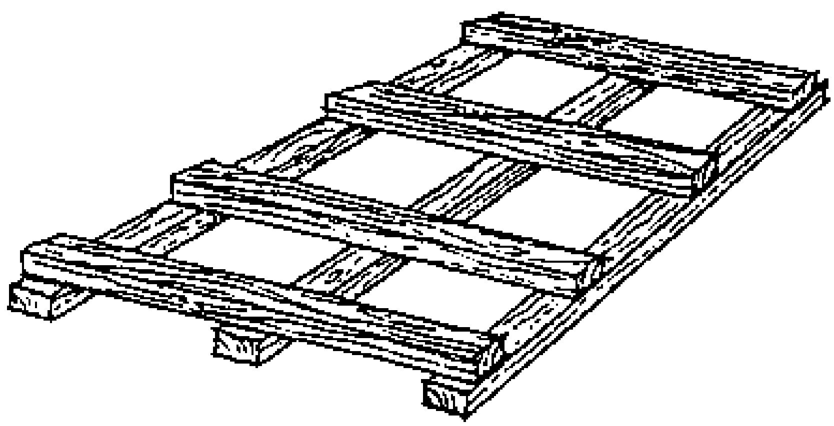
Placing materials on the floor beneath sacks or cartons of produce prevents dampness from reaching produce suited to dry conditions in storage. This helps to reduce the chance of fungal infection, while also improving ventilation and/or sanitation in the storeroom.



Water-proof sheet



Poles cross stacked



Wooden pallet

Some examples of useful materials for making pallets. (Source: FAO. 1985)

Cleaning the storage room (Source: FAO 1985)

Slide 40

Improved postharvest handling practices for (3) micro, small and medium enterprises

- Peeling, trimming
- Drying and Food safety

The volume of crops that requires handling or processing will often determine which technologies make the most sense economically. There are sometimes tradeoffs to be made between fast processing and inexpensive technologies, and decisions to make regarding labor for manual practices versus capital costs for machinery.

Slide 41

Peeling and trimming

Workers who peel and trim R&T crops can waste food if the practices are not done carefully. Machine peeling may remove more of the outer layers than manual peeling. Peeling is not considered a loss if the peel is not edible, but if the practice removes edible food then it is possible to refine the process and reduce postharvest losses. There is usually a tradeoff to be made between speed and quality.

Slide 42

Drying to a safe moisture level for long term storage/Food Safety

A survey of cassava chips processing areas of Benin, Ghana and Nigeria has indicated that the most common fungi were *Rhizopus* sp. (47.5% of total samples) and *Aspergillus* sp. (29.6%) (IITA, 1996) and 13 different aspergillus fungi were isolated from dried cassava chips in Cameroon (Ossono et al, 2007). These fungi grow quickly when the moisture content of cassava chips is higher than 14%.

Aflatoxins can be a problem in dried R&T crops if they are not properly dried and protected from moisture during storage and marketing. A highly toxic metabolite produced by the ubiquitous *Aspergillus flavus* fungus is a major public health issue in Africa. IITA studies measured contamination in 30 to 65% of stored maize (also a problem in sorghum, rice, millet, groundnuts, and dried R&T crops).

Slide 43

Aflatoxin management

The fungus infects crops and produces the toxin in the field and in stores, then the fungus is carried from field to store. Contamination is possible without visible signs of the fungus, and very low levels are toxic (maximum allowable levels = 20 ppb US; 10 ppb WFP; 4 ppb EU).

Slide 44

Some predisposing factors for aflatoxin contamination:

- pre-harvest high night-time temperatures and drought stress

- wet conditions or high humidity at harvest and during post-harvest periods
- insect or bird damage
- rain on the mature crop increases contamination.
- improper crop storage or transportation.

Source: PACA and IITA http://www.aflatoxinpartnership.org/

Slide 45

Improved postharvest handling practices for (4) small stores

Inventory management for small stores and food shops can help to reduce postharvest losses of fresh R&T crops. A first-in/first-out system can ensure that older crops are not forgotten until they are too old and deteriorated to sell.

Net bags for R&T crops in a retail shop in Ghana (Photo credit: Adel Kader)

Slide 46

Improved postharvest handling practices for (5) market and street vendors

The most important practices for reducing postharvest losses for R&T crops in open markets are:

- Use of shade
- Gentle handling


Open market in Ethiopia (Photo credit: Aditya Parmar) and a roadside market in Ghana showing the use of shade (Photo credit: Adel Kader)

Slide 47

Details on how to reduce losses for these key root/tuber crops in SSA

- Cassava
- Sweetpotatoes
- Yams
- Cocoyams

Slide 48

Improved postharvest handling, storage and processing of Cassava

Harvest index

Cassava roots can be harvested at any time of the year. Some farmers harvest as early as six months after planting while others may leave the crop to grow for 18 to 24 months. The food quality of roots (the starch content), increases with time up to an optimal period of 12 to 15 months after planting (Opara 2003).

Harvesting practices

Prune cassava plants by removing the top of the plant and leaving a short (20 cm) leafless stem 2 to 3 weeks before harvest. Gently dig around the base of the plant to free the roots from the soil. Lift the whole plant, gently, to avoid breaking the roots.

Marriott et al (1979) found that pruning of cassava plants by removing the top of the plant and leaving a short (20 cm) leafless stem 2 to 3 weeks before harvest resulted in roots resistant to primary deterioration even if the roots are severely damaged during the harvest. Gently dig around the base of the plant to free the roots from the soil. Lift the whole plant, gently, to avoid breaking the roots.

Field containers

Plastic crates can protect cassava from damage after the harvest.

Temperature management/use of shade

Covering the field containers, or providing shade (trees, cloth, umbrellas) during any delays after the harvest can help to reduce the temperature.

Curing

Should be practiced in healing harvesting wounds if cassava roots will be stored for any length of time after harvest, or transported for long distances. Curing requires 2 to 5 days at 30-40°C and 90-95% RH.

Temporary storage (on-farm)

Cassava has a relatively short storage potential (less than one week at 20°C), so it is not typically stored on farm for more than a few days before processing or marketing.

Long term cool storage

Cassava is not typically stored for long periods of time.

Processing

Use of improved mechanical devices can reduce processing losses from 22% to 10% (IITA 1996).

For additional information on cassava: Cassava Postharvest Operations (via the FAO INPhO Postharvest Compendium). http://www.fao.org/3/a-au998e.pdf

Slide 49

Improved postharvest handling and storage of Sweetpotatoes

Harvest index

Sweetpotatoes are harvested when roots have reached the desirable size. Irrigation is typically stopped 2 to 3 weeks before harvest so that vines begin drying before they are removed and roots are harvested.

Harvesting practices:

Dig carefully to avoid damaging the roots. Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiration and ethylene production rates. All of these factors will, in turn, lead to quicker deterioration. In general, harvesting by machine will cause more damage than harvesting by hand, although root and tuber crops can be severely damaged by careless hand digging.

Curing:

Curing requires 4 to 7 days at 30-32°C and 85-90% RH. CIP (2014) has reported that sweetpotatoes can be cured “in-ground” before harvesting. Pre-harvest curing consists of removing the foliage 2 to 4 days before harvesting the roots, which strengthens the skin, helping to prevent damage.

Temporary storage (on-farm):

Storage in evaporatively cooled structures can reduce storage temperature to 2 to 3 °C above the dew point temperature.

Long term cool storage:

The recommended storage temperature for sweetpotatoes is 15 °C. Temperatures above 15°C (59°F) lead to more rapid sprouting and weight loss.

For additional information on sweetpotatoes: Stathers, et al 2013.

Sweetpotato Produce Facts https://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/

Sweetpotato Knowledge Portal: WWW.SWEETPOTATOKNOWLEDGE.ORG

Slide 50

Improved postharvest handling and storage of Yams and Cocoyams

Harvest index:

Most edible yams reach maturity in 8-11 months after planting. White yam (*Dioscorea rotundata*) matures in 200-330 days, while yellow yam (*D. cayenensis*) matures in 280-350 days (Opara 1999).

Harvesting practices:

Gently dig around the tuber to loosen it from the soil, lift it, and cut it from the vine. Harvesting is done by hand using sticks, spades or diggers. Sticks and spades made of wood are preferable to metal tools as they are less likely to damage the fragile tubers (Opara 2003). The harvesting process involves gently digging around the tuber to loosen it from the soil, lifting it, and cutting the tuber from the vine.

Yams for long-term storage (for later marketing or for planting materials for the next season) are usually harvested during December – January, the harmattan period in many parts of southeastern Nigeria. At this time, the crop has reached its maximum growth and maturity. During this season, the soil is generally hard and tuber breakage during harvesting can be a problem, leading to economic losses due to quality losses.

Curing:

Curing yams requires 1 to 4 days at 32-40 °C and 90-100% RH. Cocoyams require 3 to 5 days at 30-35 °C and 95% RH for proper curing.

Cleaning:

Prior to long-term storage and marketing, yams are cleaned (without water) by scrapping off soil and other debris on the surface. This is known as “dry brushing”.

The root hairs are also removed to so that the tubers have a smooth surface. Water must not be used to clean tubers before storage because of increased susceptibility to microbial infection and growth under the ambient humid storage conditions (Opara 2003).

Temporary storage (on-farm):

Cool storage under evaporatively cooled conditions can extend the shelf life of cocoyams, malanga, and yams to a few weeks.

Long term cool storage:

Yams can be stored for 6 to 7 months if they are kept cool (16°C) and in 70-80% RH conditions.

For additional information:

Yams Postharvest Operations (via the FAO INPhO Postharvest Compendium). http://www.fao.org/3/a-ax449e.pdf

Slide 51

Costs and benefits

It is easy to learn how to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology. Consider only the relative differences between the two (and ignore any costs that are the same). Using 100kg or 1000kg of produce to make the calculations allows the user to perform easy math, then multiply the results by whatever volume will actually be harvested/handled and sold.

POSTHARVEST COSTS & BENEFITS WORKSHEET: Assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:		
COSTS		
Relative costs		
EXPECTED BENEFITS		
% postharvest losses		
Amount for sale		
Value/kg		
Total market value		
Total market value (BENEFITS) minus relative costs		

Slide 52

Cost/Benefit examples

Roots:

Curing sweetpotatoes before storage

Curing can reduce postharvest losses in storage from 25% to less than 10%

Tubers:

Processing fresh yams using fee for service equipment, and packaging flour.

Yam flour is made from yams that have been peeled, sliced, cleaned, dried and then blended into a flour, used to make àmàlà ịṣu in Nigeria.

Slide 53

Cost/Benefit Example #1: Curing sweetpotatoes before long term storage

POSTHARVEST COSTS & BENEFITS WORKSHEET: Assume harvest 1000 kg

	Current /traditional practice	New /improved practice
Describe:	Storage of roots in heaps in a shed for 3 months	Cure sweetpotatoes and store in a shed for 6 months
COSTS (US$)		
Labor for field curing (piling, covering)	0	20
Relative costs	0	20
EXPECTED BENEFITS		
% postharvest losses	25%	7%
Amount for sale	750 kg	930 kg
Value/kg	US$ 0.50 33% penalty for decay and water loss/shrivel	US$ 0.75
Total market value	375.00	697.50

Total market value (BENEFITS) minus relative costs for 1st load	375.00	677.50
Relative profits 1st load (fully pays for the cost of curing)		+$300.50

If the actual volume harvested and cured per load is:

500 kg, then 0.5 x $300.50 = US$ 150.25 increased relative profits for each load.

2000 kg, then 2 x $ = US$ 601 increased relative profits for each load.

Slide 54

Cost/Benefit Example #2: Processing yams to flour

POSTHARVEST COSTS & BENEFITS WORKSHEET: Assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:	Selling freshly harvested yams	Process yams to make flour
COSTS (US$)		
Labor for washing, peeling, grating, drying	0	10
Fees for grinding/sieving/ blending	0	5
Packaging materials (25 heavyweight plastic bags/labels) for 25 kg of flour		5
Relative costs	0	20
EXPECTED BENEFITS		

% postharvest losses	10%	
Amount for sale	90 kg	25 kg
Value/kg	US$ 1.00	US$ 5.00
Total market value	$90	$125
Total market value (BENEFITS) minus relative costs for 100kg	$90	$105
Relative profits 1st load (fully pays for the cost of processing and packaging)		+ $15

If the actual volume harvested and processed per load is:

500 kg, then 5 x $15 = US$ 75 increased relative profits for each load.

1000 kg then 10 x $15 = US$ 150 increased relative profits for each load.

2000 kg, then 20 x $15 = US$ 300 increased relative profits for each load.

Slide 55

Priority training needs

Topics that need attention in order to solve postharvest problems for a variety of roots and tuber crops

- Careful harvesting
- Basic postharvest handling and curing practices
- Use of improved containers to reduce postharvest damage
- Temperature management and relative humidity control
- Postharvest pest and disease management

Slide 56

Advocacy issues

Problems that require attention in order to reduce postharvest losses for a variety of roots and tuber crops

- Improving infrastructure (roads, power, water)
- Investing in postharvest facilities (packinghouses, storage structures)
- Investing in agro-processing (SMEs) for root and tuber crops
- Improved marketing (facilities, farmer/trader organizations, cooperatives)
- Providing incentives for using improved postharvest practices and investments

Farmers have been struggling with the ability to adopt the use of smaller containers. Governments have been promising to enforce some control to avoid extra-large size bags in Ethiopia, for example, but enforcement has been very poor.

Slide 57

This concludes Module 1.3

Reducing Postharvest Losses in Sub-Saharan Africa: Roots and Tuber Crops

Manual 1 contains a full reference list.

Module 1.4 Reducing Postharvest Losses in SSA: Fruits and Vegetables

Slides of coordinating PowerPoint presentation Module 1.4 (99 illustrated slides)

Slide 1

Learning objectives:

- Practitioners will gain an understanding of the many options available for addressing the causes of food losses identified in food loss assessments for fruits and vegetables.
- Practitioners will be introduced to key postharvest technologies, improved handling practices and management skills that can help the 5 beneficiary groups reduce postharvest food losses for fruits and vegetable crops
- Practitioners will be able to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology
- Practitioners will be made aware of topics or areas of training/extension and advocacy that are needed to solve postharvest problems for a variety of fruits and vegetable crops

Slide 2

Key fruits and vegetable crops in Sub-Saharan Africa (SSA):

- Banana
- Plantain
- Mango
- Papaya
- Tomato
- Hot peppers

- Onions
- Leafy greens/cabbage
- Green beans

Slide 3

This module covers 5 segments of the fruit and vegetables (F&V) supply chain

(1) harvesting & postharvest handling (on-farm)

(2) storage

(3) transportation

(4) agro-processing

(5) wholesale and retail

The majority of the total of 25.7 million tonnes per year of postharvest losses for F&V in SSA occur during production/harvesting (7.1 million tonnes), postharvest handling and storage (6 million tonnes) and distribution/transport/marketing (9.1 million tonnes). Source: Gustavsson et al., 2013.

Relatively lower losses are experienced during agro-processing.

Slide 4

Reducing postharvest losses during (1) harvesting & postharvest handling (on-farm)

- Maturity and harvest indices
- Harvesting
- Pre-sorting to remove damage/decay and sorting for market
- Curing onions and garlic
- Field containers and packages
- Temperature management/use of shade

Slide 5

Maturity and harvest indices

There are many types of indices used to estimate maturity and/or predict the proper time to harvest F&V crops. Using maturity indices will ensure the best quality and reduce losses during and after the harvest.

Size:

E.g., All fruits and many vegetables, including Leafy greens/cabbage and Green beans

Shape:

E.g., The angularity of Banana and Plantain soften to a rounded shape; the cheeks become full and shoulders of the Mango rise as the fruits reach maturity (an immature fruit is more flat near the stem end)

External Color:

E.g., All fruits and most vegetables, including Papaya, Tomato, Hot peppers, which begin to change color as they ripen

Internal color:

E.g., Pink color of tomato jellylike formation

Sugar/acid ratio:

E.g., Papayas

Leaves die off:

E.g., tops of Onions and garlic bend and fall over at maturity

Photo of mango shoulder, rising above the flat top of an immature fruit. The black line shows where the more flattened shape of the stem end of an immature fruit. (Photo credits: Lisa Kitinoja)

Slide 6

Example: Harvest indices for onions

(Photo credit: Lisa Kitinoja)

Harvest index for onions:

Onion tops will fall over when the crop is nearly ready to harvest. Allow the leaves to dry out and turn brown before harvesting the onions.

Slide 7

Harvesting practices

Poor timing and using poor methods and tools to harvest F&V can damage the crops and lead to increased postharvest losses.

Time:

Harvest early in the morning when it is typically cooler and less stressful to F&V crops

Tools:

Knives and clippers should be sharp and kept clean

Picking bags:

Using shoulder harnessed harvesting bags can reduce damage

Workers:

Should be well trained in how to harvest without causing damage and on how to keep their hands and fingernails clean; should wash before touching the crop to harvest, and wash their hands again after using the toilet or touching anything that is unsanitary

Field containers:

Should be clean, smooth on the inside and kept up off the soil (placed on pallets or tarpaulins) to prevent contamination and food safety problems

Slide 8

Harvesting tools

Six types of produce harvesting knives. Curved blades and blunted tips can help reduce damage. Source: www.harrisseeds.com

Slide 9

Harvesting bags

These picking bags are harvesting aids that can be made by sewing heavy canvas or vinyl bags with openings on both ends, and fitting the bags with simple shoulder straps or adjustable harnesses. The bag can be worn during harvesting, and the worker can use both hands to pick the crop, and gather a good sized load without throwing or dumping the produce on the ground. When the bag is full, the two bottom straps are released and the produce can roll gently out of the bag and into a waiting field container.

Picking bags (commercial product, left. http://www.orchardvalleysupply.com)

and handmade canvas cloth version (right; Photo credit: Lisa Kitinoja).

Slide 10

Field Containers

Using field containers that are sturdy, smooth on the inside and easy to clean can help to reduce postharvest losses for F&V crops. Well-ventilated containers are preferred.

A selection of field containers, in different styles and sizes. Sources: www.thunderbirdplastics.com and www.tedthorsen.com

Slide 11

Gentle harvesting

Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiration and ethylene production rates. All these factors will, in turn, lead to quicker deterioration. In general, harvesting by machine will cause more damage than harvesting by hand.

There are tools such as ladders and picking poles that can be used to gently harvest fruits from trees. If the trees are extremely tall it is common in SSA to see the branches being shaken or beaten, and the fruits being knocked to the ground, which causes a lot of physical damage and bruising. A picking pole with a basket is used to pluck fruits (a small knife can be attached to the edge of the basket if the fruit needs to be cut from the plant). The Twister Fruit Picker is new tool that can harvest mangoes, small to medium sized papayas, or smaller fruits of just about any size. A drop-cloth, suspended from the bottom limbs beneath the tree, can help to catch the fruits and reduce damage.

Picking pole basket and the Twister Fruit Picker.

Source: http://www.twisterfruitpicker.com/

Slide 12

Cloth to catch fruits during the harvest in Mali (Photo source: UNDP)

Slide 13

Sorting: There are two types of sorting used to reduce postharvest losses

Pre-sorting to remove damaged and decayed produce:

- packing damaged, insect infested or decayed foods in the same container with good quality foods will spread disease or insects to the entire load.

Sorting to match market demand:

- tomatoes harvested red ripe will have a very short postharvest life and be susceptible to bruising and crushing during transport and marketing, so they are typically harvested only for immediate use.

Slide 14

Sorting tomato fruits after harvest can enhance market value and shelf life, for example:

- Red ripe – for local processing or home consumption
- Pink – sell in nearby markets
- Breaker/turning - for marketing a few days later or to sell in a long distant market
- Mature green – for short term storage before marketing (Note: It is very difficult to see when fruits are mature green, so it is usually a good idea to wait until the “breaker” stage before harvesting.)

Ripeness Classes Of Tomatoes

Score	Class	Description*
1	Green	Entirely light- to dark-green, but mature
2	Breaker	First appearance of external pink, red or tannish-yellow color; not more than 10%
3	Turning	Over 10% but not more than 30% red, pink or tannish-yellow
4	Pink	Over 30% but not more than 60% pinkish or red
5	Light-red	Over 60% but not more than 90% red
6	Red	Over 90% red; desirable table ripeness

*All percentages refer to both color distribution and intensity.

Color chart for tomatoes (Source: UC Davis)

Slide 15

Curing onions and garlic

Curing, when used for preparing onions and garlic for storage or marketing, refers to the practice directly following harvest of allowing the external layers of skin and neck tissue to dry out prior to handling and storage. If local weather conditions permit, these crops can be undercut in the field, windrowed and left there to dry for five to ten days. The tops of the plants can be arranged to cover and shade the bulbs during the curing process, protecting the produce from excess heat and sunburn. If the weather is rainy or too hot, onions and garlic can be cured in an open sided shed or under a simple shade cover.

Onions: Field curing (left) and under shade curing (right). Photo credits: Lisa Kitinoja

Slide 16

Field containers and packages

Baskets and sacks offer little or no protection for handling F&V crops after the harvest. When baskets are stacked on top of one another, the produce inside, especially in the lower layers, is compressed and can be crushed.

Large baskets of tomatoes with cloth covers in Rwanda and sacks in Ghana

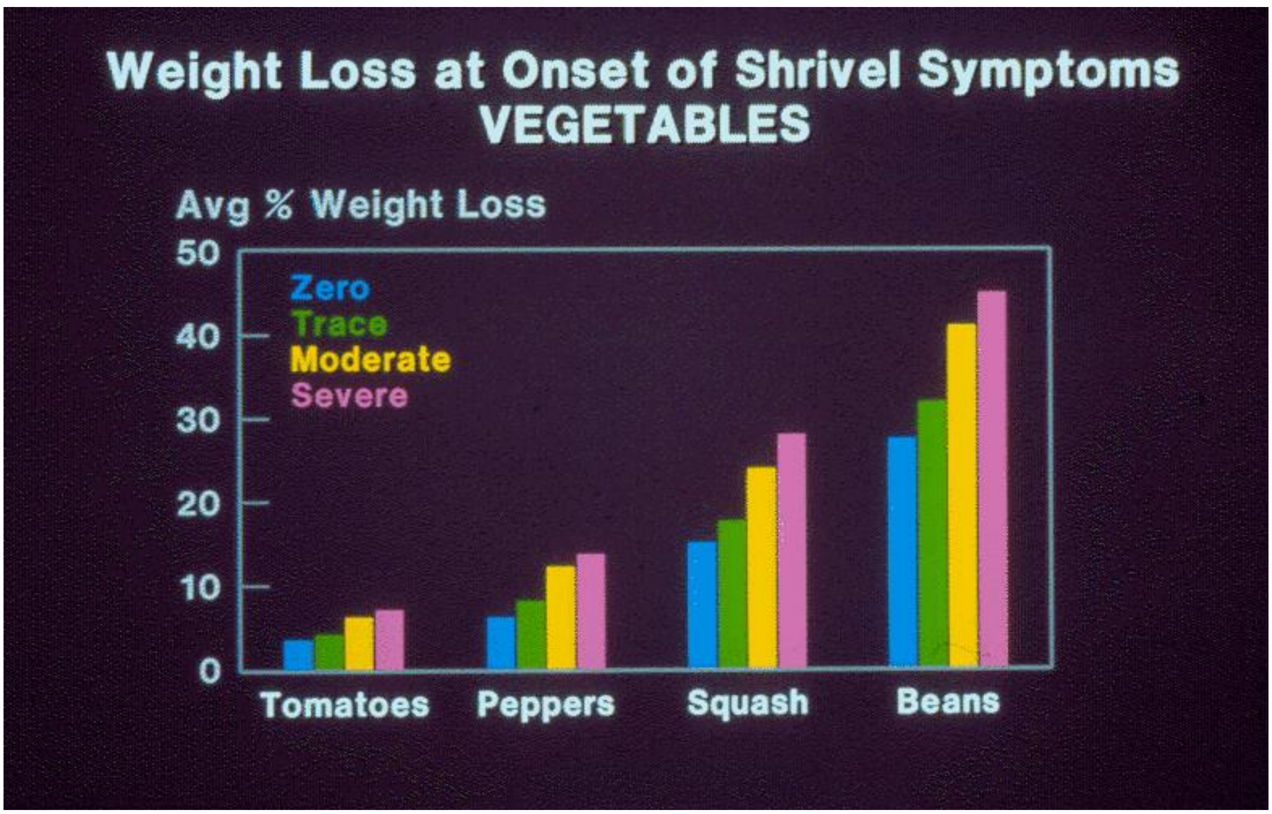
(Photo credits: Lisa Kitinoja and Adel Kader)

Leafy greens packed in a cloth bundle in Benin. This type of package provides little or no protection from physical damage, especially when stacked (Photo credit: Hala Chahine).

Slide 17

Use of shade

Exposure of fresh F&V to the sun after harvesting will lead to heat gain, water loss and weight loss. If a trace of shrivel symptoms are noticeable in tomatoes, losses due to weight loss of 4 to 5% has already occurred. If a trace of shrivel is observed in green beans, more than 30% losses due to weight loss has occurred.



Source: UC Davis postharvest outreach program slide set archives (circa 1980)

Slide 18

Since wholesale buyers travel and visit various farms and fields to buy fresh produce, it can be convenient to use shade umbrellas. In Ghana, a shade umbrella costs about 20 Ghanaian cedis (20 GHC = US$15) and can protect F&V crops from heat gain and water loss after harvesting and during on-farm delays, sorting and packing.

Portable shade umbrellas for farm, packing and marketing in Ghana

(Photo credit: Hussein AlHassan).

Slide 19

Reducing postharvest losses during (2) storage

- Pre-cooling
- Heat treatments and bicarbonate salts for disease management
- Curing onions and garlic before long-term storage
- Evaporative cool storage of tropical and sub-tropical F&V
- Commercial cold rooms for temperate F&V
- Self-built cold rooms
- Improved containers
- Avoiding storage of incompatible mixed loads

- Inspection and resorting

Slide 20

Pre-cooling

Whenever warm produce is placed inside a cold room, the refrigeration unit is stressed by the amount of heat that has to be removed from the room. Pre-cooling is a postharvest technology that removes the majority of heat from packed produce before the load is placed into a cold storage room. It is possible to pre-cool F&V using cold water, cold air or ice.

- Hydro-cooling
- Evaporative cooling
- Forced air cooling
- Use of ice

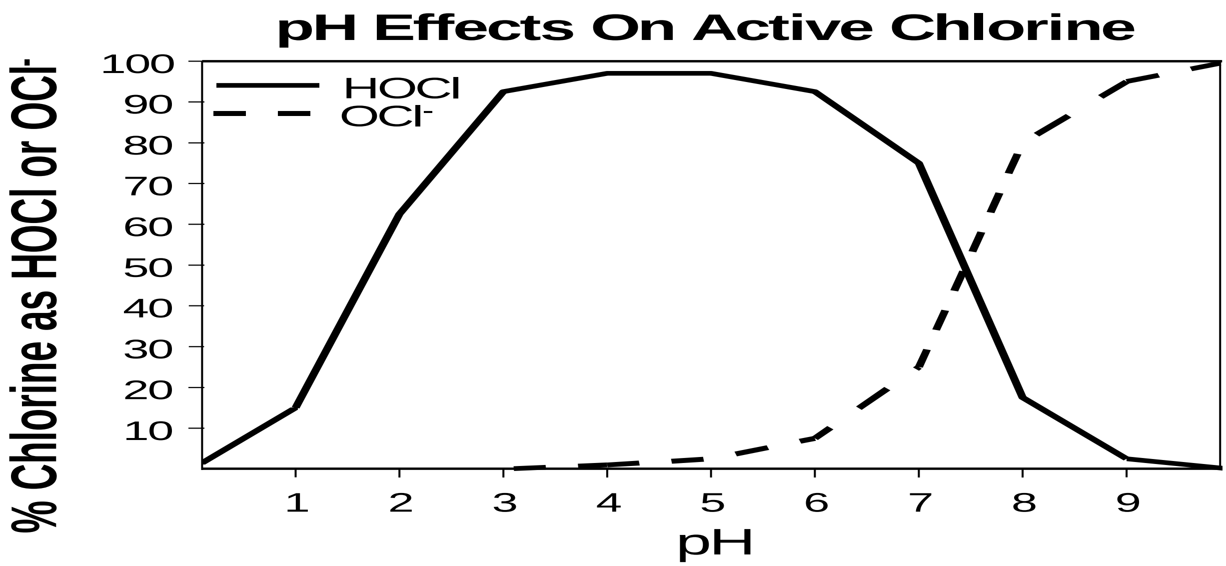
Slide 21

Hydro-cooling

Hydro-cooling provides fast, uniform cooling for some F&V crops. The commodity as well as its packaging materials must be tolerant of wetting, chlorine (used to sanitize the hydro-cooling water) and water beating damage (Mitchell in Kader, 1992).

The water used for hydro-cooling must be clean, very cold and kept sanitized by adding chlorine. Unsanitary water or warm water increases the risk of creating a favorable environment for the growth of microorganisms, especially warm weather or hot climates. Chlorination of wash water is very important. Chlorine can reduce the spread of contamination from one item to another during the washing stage. The pH of the wash water should be maintained at 6.5 to 7.5 for best results. Typically, 1 to 2 mL of chlorine bleach per liter of clean water will provide 100 to 150 ppm total

Cl. More chlorine will be required if temperatures are high or if there is a lot of organic matter in the wash water (Kitinoja & Kader 2015).



Effect of water pH on the active chlorine

Slide 22

Mixing chlorine solutions for washing fresh produce

Desired ppm of free chlorine	ml of 5.25% NaOCl solution per 100L of clean water	ml of 12.75% NaOCl solution per 100L of clean water	grams of 65% Ca $(OCl)_2$ per 100L of clean water
100	188	75	16
125	234	100	20
150	288	112	23
175	338	138	27
200	375	163	32

Source: Ritenour, M.A., S.A. Sargent and J.A. Bartz. 2014. Chlorine Use In Produce Packing Lines. UF/IFAS HS-761. https://edis.ifas.ufl.edu/ch160

Slide 23

The simplest versions of hydro-cooler is a hand-held water spray from a hose pipe, or a tank of cold water in which produce is immersed.

Cooling and cleaning vegetables with cold water. Source: Leopold Center, Iowa State University training center

The Leopold Center also uses a large tub of cold water and a net bag for holding fresh leafy greens. Dipping the bag and swirling it in the water for 30 seconds will quickly reduce the temperature of the vegetables. Lifting the bag will allow most of the water to drain off. Swinging the bag gently after it has drained into the tub for a few moments will drain off any remaining water.

Slide 24

Immersion type hydro-coolers

Small scale and large-scale immersion style hydro-coolers.

Sources: Iowa State University www.leopold.iastate.edu ; Groupe Claire Fontaine www.machines-briand.com

Slide 25

A shower type hydro-cooler showers a batch of produce with icy water.

Shower type hydro-coolers. Sources: www.fao.org ; www.weiku.com

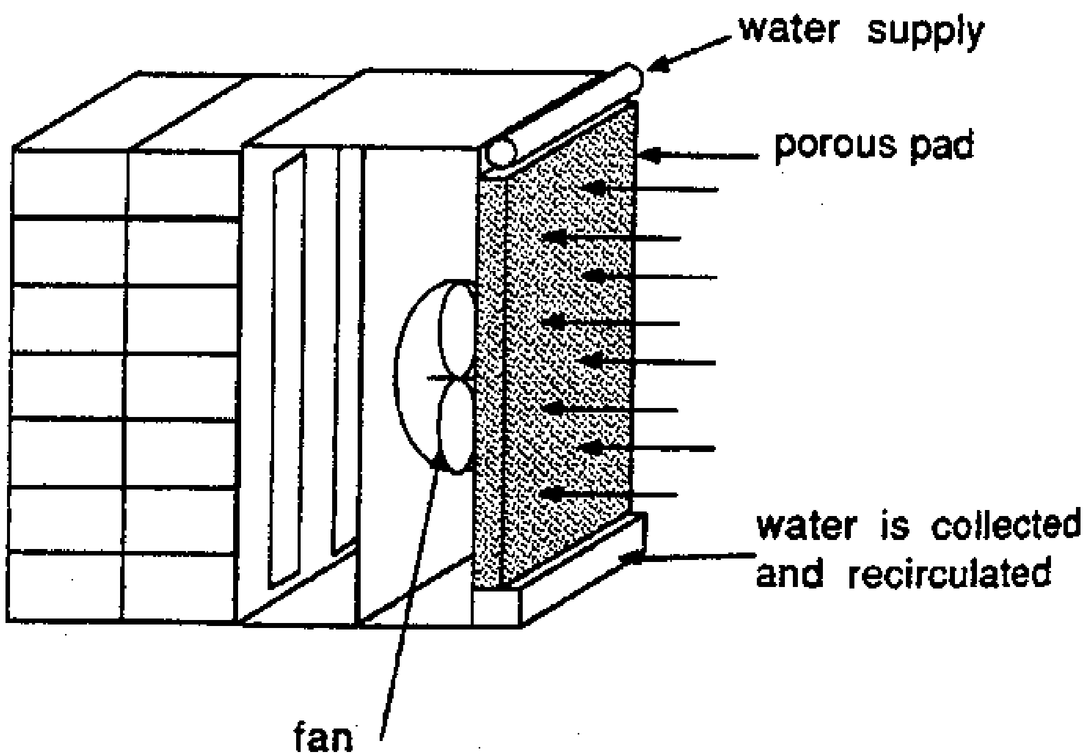
A batch-type immersion or shower hydro-cooler can be constructed in any needed size, in order to hold one container or entire pallet-loads of produce. The water is captured, filtered and recirculated to save energy and reduce wastewater run-off.

Slide 26

Evaporative cooling using electricity

Evaporative coolers can be constructed to cool the air in an entire storage structure or in just a few containers of produce. These coolers are best suited to lower humidity regions, since the degree of cooling is limited to 1 to 2° C above the wet-bulb temperature. A cooling pad of wood fiber or straw is moistened with water and air is pulled through the pad using a small fan. In the example provided here, 3 L of water per minute is dripped onto a 1m square pad, providing enough moist air to cool up to 18 to 20 crates of produce in 1 to 2 hours. Water is collected in a tray at the base of the unit and re-circulated using a small water pump.

An evaporative cooler can be used as a forced air cooler for pre-cooling small lots of tropical or sub-tropical fresh F&V. The air is cooled by passing through the wet pad, and the fan then pushes the cool air through the vents in the packages, cooling the packed produce.



Simple design for a small-scale evaporative forced air cooler

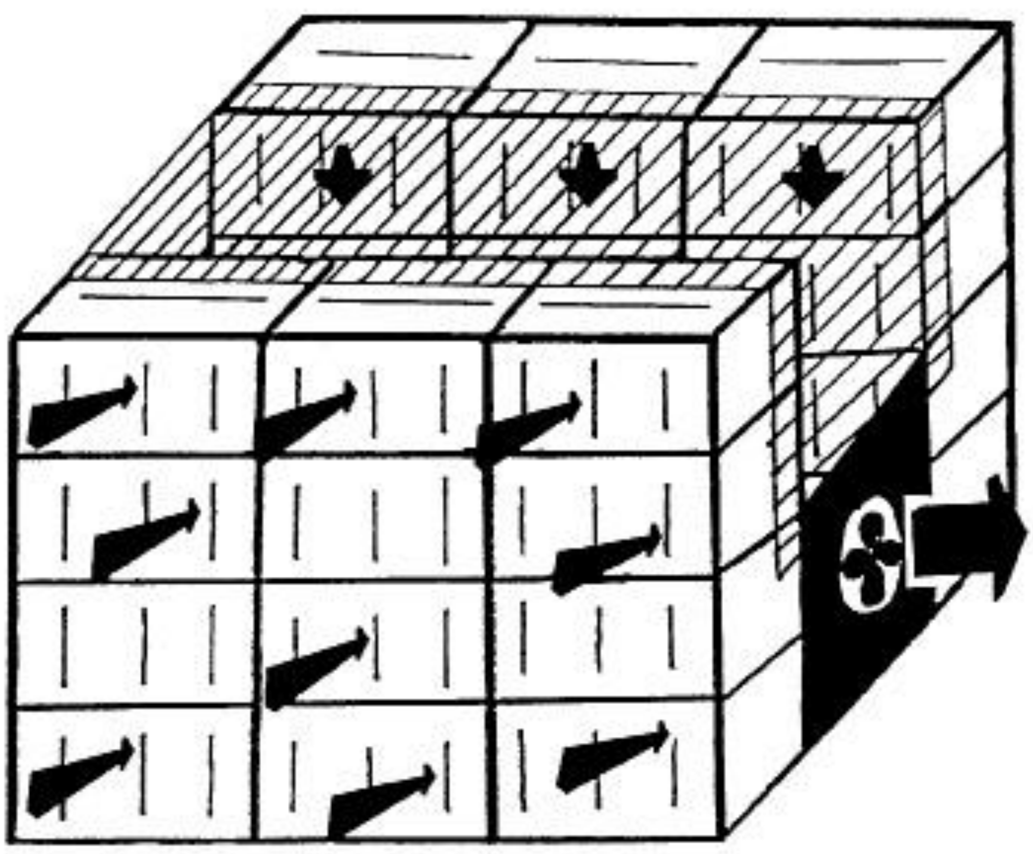
Sources: Thompson and Kasmire 1981; Mitchell in Kader, 1992.

Slide 27

Forced air (FA) cooling

Pre-cooling can be accomplished quickly by using a portable forced air cooler, placed inside a cold room. Many different sizes of FA coolers can be constructed, using a portable box style fan and a piece of heavy plastic sheeting.

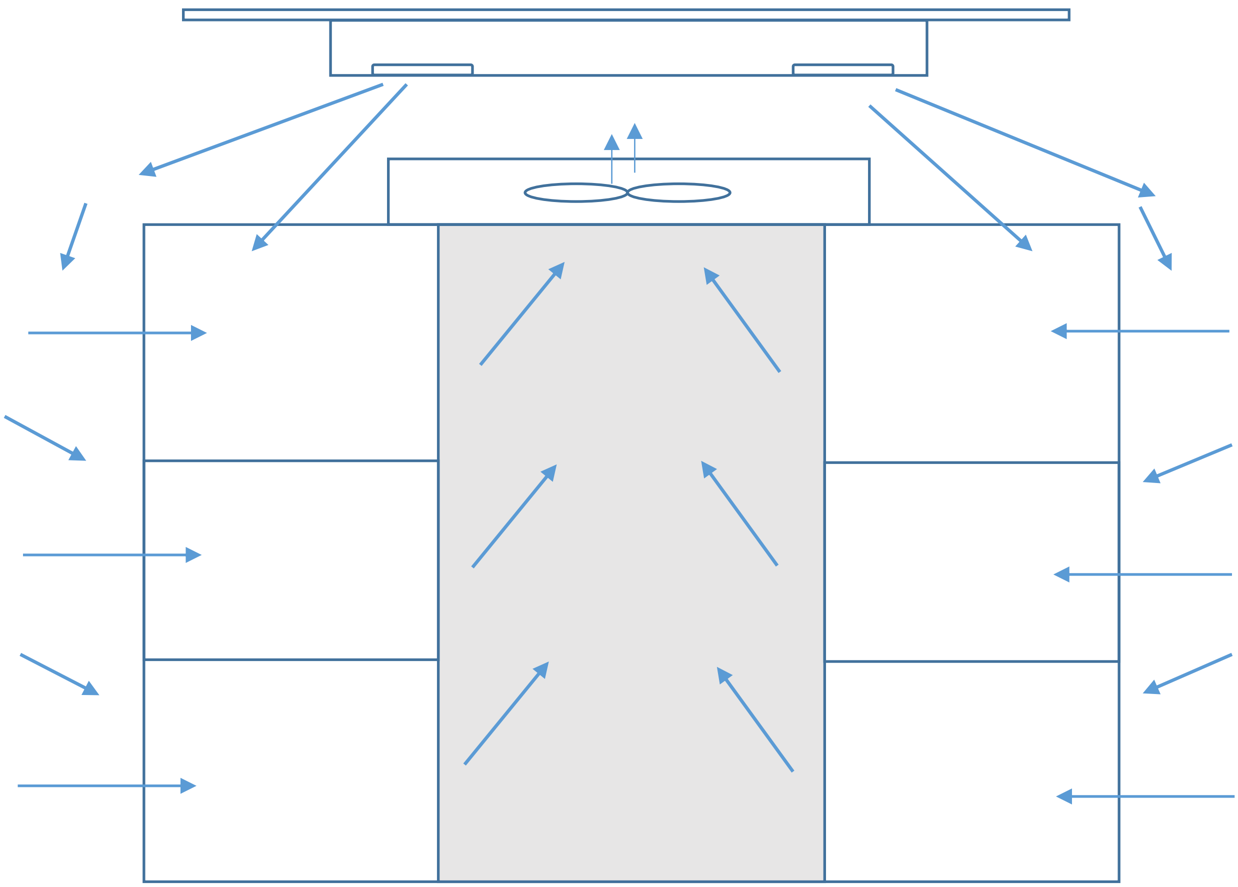
Small-scale forced air-cooling tunnel



FA Cooling tunnel for 24 cartons or crates of F&V. Source: aces.nmsu.edu

Slide 28

A portable forced air cooler should be located so the cold air in the cold room blows up over the top of the load. The air is pulled into the center of the tunnel by a small fan. The only way the air can get into the tunnel is to pass through the cartons or crates of produce (illustrated by the blue arrows).



Design for a simple forced air cooling tunnel set up inside a cold room, overhead view, showing 6 pallet loads (Source: Kitinoja for MCC Project, Cape Verde, 2009)

Larger scale pre-cooling unit, AB Speedbox Forced Air Cooler. Source: AB Coolservice (Belgium) www.abweb.be

Slide 29

Use of ice

Ice can be used either directly as package ice (only for temperate vegetables such as green onions, spinach, turnip greens, chard, mustard greens, broccoli and radishes), to cool water for use in a hydro-cooler (for crops that are water tolerant such as stone fruits, pome fruits, sub-tropical fruits, leafy vegetables, lettuces, green onions, green beans, melons, sweet corn), or as an ice bank for a small forced air or room cooling system. Melting 1 kg of ice made from water has the cooling effect of

315 BTU. One kg of ice will drop the temperature of produce 3 times its weight by about 28°C.

Using ice to cool water for use in a hydro-cooler. (Photo credit: Adel Kader)

Slide 30

Hot water or hot air treatment

High temperature may be used to control postharvest decay on crops that are injured by low temperatures, such as mango, papaya, pepper, and tomato (Spotts 1984). Heat treatments must always be followed immediately by cooling (hydro-cooling or forced air cooling) to bring the temperature down.

Slide 31

Postharvest decay control

The use of bicarbonate salts for prevention of postharvest decay has been used on fresh peppers, melons, potatoes, carrots and citrus fruits. These salts are very inexpensive, safe to use, readily available and accepted as “certified organic” and “chemical free” for marketing purposes.

Bicarbonate salts include:

Bicarbonate of soda, or “baking soda” ($NaHCO_3$)

Potassium bicarbonate ($KHCO_3$)

Method	Rate
overhead spray or dip	2% solution (use 2g in 100ml water or 20g per liter)

Source: Kitinoja and Kader (2015)

Slide 32

Curing onions and garlic before long-term storage

Curing, when used for onions and garlic, refers to the practice directly following harvest of allowing the external layers of skin and neck tissue to dry out prior to handling and storage. If forced heated air is used for curing onions and other bulbs, one day or less at 35 to 45 °C and 60 to 75% relative humidity are recommended. The dried layers of 'skin' can then protect the produce from further water loss during storage.

Onions and garlic prefer lower RH storage conditions (65-70%), and a higher RH% in storage will lead to decay and rapid deterioration. Providing shade, good ventilation and raising the storage room up off the ground will provide a beneficial storage environment.

Slide 33

The ventilated onion storage structure shown in the photo allows onions to be stored at ambient temperature for about 3 months with minimal postharvest losses.

Ventilated onion storage structure in Semera, Ethiopia. (Photo credit: Lisa Kitinoja)

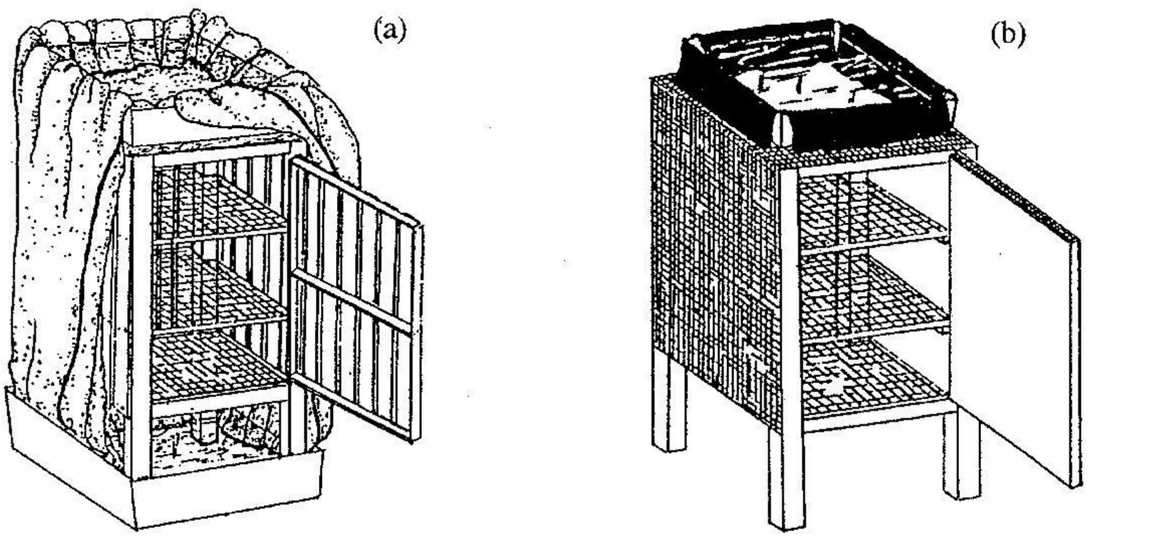
Design adapted from storage structures being promoted in India, and construction organized by Mekbib Seife Heilegebrile.

Slide 34

Evaporative cool storage of tropical and sub-tropical F&V

These crops will have enhanced storage life when the temperature is maintained at 12 to 15°C. In dry climate zone and during the dry season in many countries in SSA, these temperatures can be achieved using simple evaporative cooling practices.

Evaporative coolers can be constructed from simple materials, such as burlap and bamboo. A "drip cooler" operates solely through the process of evaporation, without the use of a fan. The storage unit can be a small box, a tall set of shelves or a full-sized room. Cooling will be enhanced if the unit is kept shaded and used in a well-ventilated area.



Two types of bamboo chamber drip coolers: a) burlap walls and b) double mesh walls filled with straw or rice hulls. On top is a pan filled with clean water. Source: Acedo (1997).

Slide 35

Natural forms of low cost cool storage

Radiant cooling

Can be used to lower the air temperature in a storage structure if a solar collector is connected to the ventilation system of the building. By using the solar collector at night, heat will be lost to the environment. Temperatures inside the structure of 4°C less than night temperature can be achieved.

Use of well water

Well water is often much cooler than air temperature in most regions of the world. The water temperature of a deep well tends to be in the same range as the average air temperature of the same locality. Well water can be used for hydro-cooling and as a spray or mist to maintain high relative humidity in the storage environment.

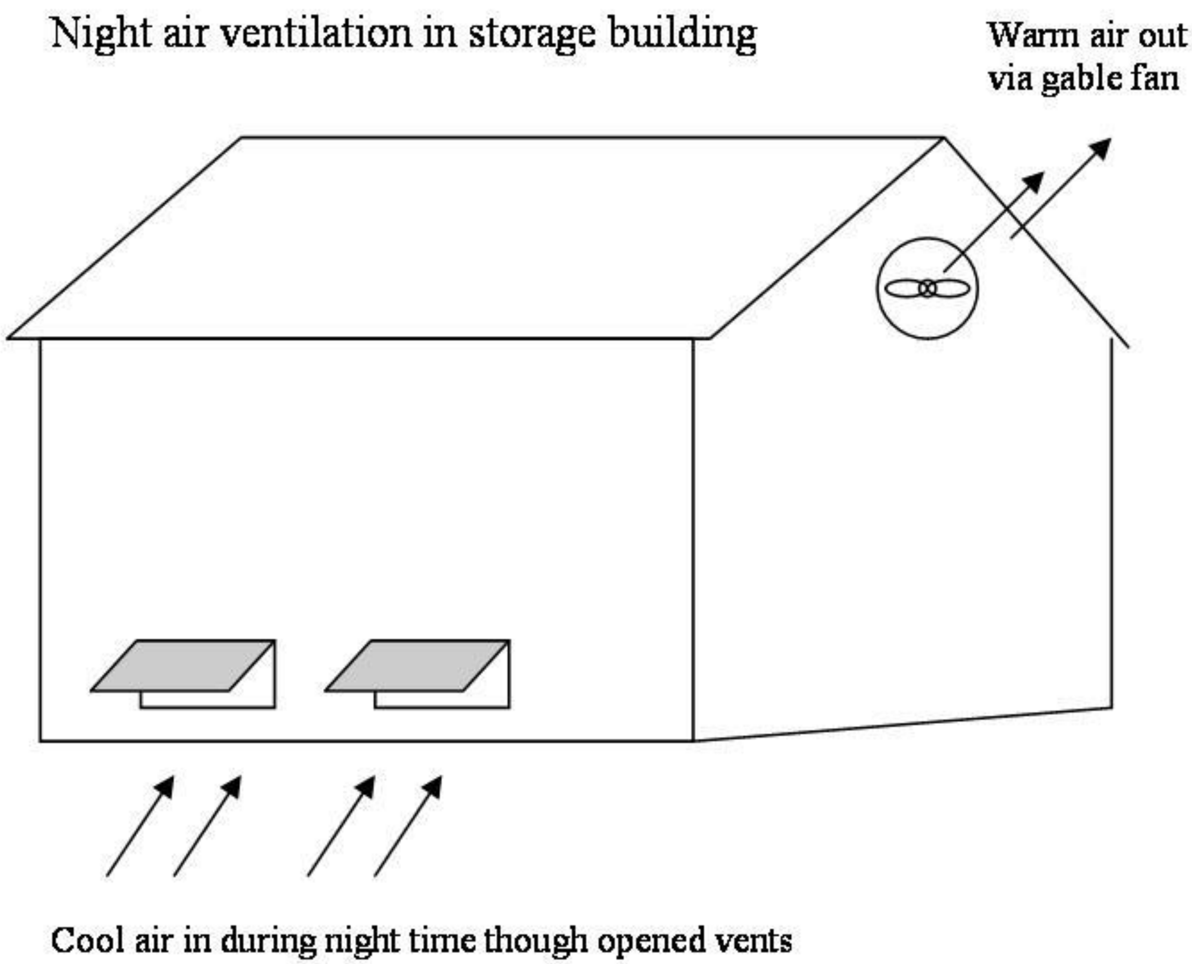
High altitude storage

Typically, air temperatures decrease by 10 °C for every one kilometer increase in altitude. If handlers have an option to pack and/or store F&V at higher altitude, cool storage costs could be reduced. Cooling and storage facilities operated at high altitude would require less energy than those at sea level for the same results.

Slide 36

Night air ventilation

Storage structures can be cooled using night air if the difference in day and night temperature is relatively large (Thompson in Kader, 2002). The storage facility should be well insulated and vents should be located at ground level. Vents can be opened at night, and fans can be used to pull cool air through the storeroom. The structure will best maintain cool temperatures during the heat of the day if it is very well insulated and vents are closed early in the morning when the air temperature is still low. As a rule, night air ventilation effectively maintains product temperature when the outside air temperature is below the desired product temperature for 5 to 7 hours per night.



Night air ventilation: cool air is allowed in at night to cool the storage room

(Source: Kitinoja and Kader, 2003)

Slide 37

Commercial cold rooms for temperate F&V

The cost of constructing and operating cold rooms will depend upon the size of the room, the set temperature required for what is being stored, and the refrigeration technologies utilized.

Approximate Refrigeration Capacity for Small-scale Cold Rooms

Size of Cold Room (meter²)	Storage Capacity (MT)	Range of Refrigeration Capacity (MT of refrigeration)	
		Target = 1°C	Target = 13°C
10	3	1.0	0.75
20	6	1.5 – 2.5	1 – 1.5
40	12	3.5 - 4	2 - 3
60	18	5 – 6.5	3 – 4
80	24	6.5 – 8.5	4 – 5.5
100	30	7.5 -10	4.5 – 7

Source: Thompson and Spinoglio, 1996 (as modified for Winrock, 2009)

The range of tons of refrigeration shown in the above table reflects the climate in which the cold room is located. A standard metric tonne (MT) of refrigeration equals 12,000 BTU/hour, equivalent to about 3.5 kW. The higher number in each range will be for the hottest times of the year or hot climates such as lowland tropics or semi-arid regions. Approximately 60% of the floor space is usable for storage, as the rest is taken up by doorways, aisles and open space left along the walls.

If cold rooms are loaded with warm produce or are over-loaded (stacked too close to the walls, or too high) the F&V crops in storage will experience temperature management problems. Postharvest losses can increase if the refrigeration system is overloaded.

Slide 38

Self-built cold rooms

Commercially constructed cold rooms can be very expensive, costing about US$ 30,000 for a small walk-in size room. Winrock (2009), WFLO (2010) and the Horticulture Innovation Lab (2014) have published information on self-built cold rooms using the CoolBot™ controller, and an 18,000 BTU window style air conditioning unit. These cold rooms can be constructed for about 10% of the cost for a commercial cold room.

Example of a self-built cold room. Source : storeitcold.com

Low-cost cold rooms can be constructed using concrete for floors and polyurethane foam as insulation materials. Building the storeroom in the shape of a cube will reduce the surface area per unit volume of storage space, also reducing construction and refrigeration costs. All the joints should be carefully caulked, and the door should have a rubber seal around the edges. While cooling produce, the ventilation system should be set to create an air flow rate of 5 L/sec/ton). Once cooling is completed, air flow rates should be decreased to the lowest speed that will keep produce cool (1 to 2 L/sec/ton is usually sufficient, according to Thompson et al. 1998). The greater the refrigerator's evaporator coil area, the less of a temperature difference there will be between the coils and the target room temperature, and the less moisture will be lost from F&V crops as they cool.

The publication "Empowering Agriculture: Energy Options for Horticulture" provides a variety of cold storage options and information on many ways to reduce cost and improve energy use efficiency (Winrock 2009). http://pdf.usaid.gov/pdf_docs/PNADO634.pdf

Slide 39

Improved containers for proper storage management

Overloading storage structures for F&V, or packing the cool room with assorted types of containers that cannot be properly stacked and organized will lead to higher postharvest losses.

The lot of produce placed into storage must not contain damaged or diseased F&V, and containers must be well ventilated and strong enough to withstand stacking. In general, proper storage practices include temperature control, relative humidity control, air circulation and maintenance of space between containers for adequate ventilation and avoiding incompatible product mixes.

Slide 40

Avoiding storage of incompatible mixed loads

Commodities stored together should be capable of tolerating the same temperature, relative humidity and level of ethylene in the storage environment. High ethylene producers (such as ripe bananas, mangoes, tomatoes) can stimulate physiological changes in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, sweetpotatoes) leading to often undesirable color, flavor and texture changes.

Slide 41

Inspection and resorting

F&V crops are perishable in nature and generally cannot be kept in storage for a long time.

It is important to perform regular inspections of the storage structure, check the produce for decay or damage, and remove any produce that is ripe and ready to eat.

Slide 42

Reducing postharvest losses during (3) transportation

- Improved containers
- Loading/unloading
- Stacking, ventilation
- Covering open loads
- Proper handling and transport of mixed loads

Traders are generally in charge of postharvest handling during transportation. As a rule, traders are rarely included in postharvest extension/training programs, and they can be a difficult clientele group to reach, since they are usually on the move from farm to farm and market to market, and rarely have time to attend long meetings or classroom style educational programs. Postharvest demonstrations in the marketplace may be a practical way to reach these FSC actors. For F&V crops, improved containers, gentle loading/unloading and proper stacking can reduce physical damage, and covering open loads can help reduce loses by avoiding exposure to wind and direct sun.

Slide 43

Improved containers

Cabbages in Ghana are typically packed in enormous, enlarged sacks, each weighing up to 100kg. During FLA in Tamale (northern Ghana), half sized sacks were shown to have lower rates of head splitting, and averaged 23% losses in small sacks vs 32% losses in large sacks when assessed after transport (WFLO, 2010).

Cabbage heads packed into enormous sacks in Ghana (Photo credit: Adel Kader)

Slide 44

Plastic crates

The GEM4 project in Nigeria is using well-ventilated plastic crates to pack, transport, store and market tomatoes. "Transportation of tomatoes in raffia baskets result in 41% of tomatoes being lost in transit from North to South but with plastic crates, losses have been reduced to 5%," (DFID, 2015). In addition, market prices for tomatoes sold in plastic crates can be twice as much as for tomatoes sold in baskets.

GEMS4 tomato crates in Nigeria (DFID 2015)

For produce intended for sale in distant markets, containers will not be returned to the farmer or packinghouse. They should be sturdy, stackable and ideally, made of materials that can be recycled (e.g. fiberboard cartons).

Slide 45

Fiberboard cartons

The best design for a fiberboard carton includes venting on all 4 sides (about 5% of the surface area, with a few vertically placed long oval vents), cut outs for hand holds to make lifting and stacking easier for workers.

Fiberboard cartons for packing fresh vegetable crops in Ghana (Photo credit: Lisa Kitinoja).

A telescoping top or cover will protect the F&V from dust and physical damage during the postharvest handling period.

Example of carton designs suitable for packing fresh F&V crops.

Source: www.uline.com and www.proagonlin.com

Slide 46

Liners, trays and wraps

For delicate F&V that need extra protection, package liners, trays, paper wraps or dividers can be added to a standard crate or carton.

Trays made from paper pulp

Paper wrapped papayas

Slide 47

Package dividers

Folded fiberboard used as a carton divider

Simple package dividers can be used to provide extra protection for F&V and improve the stacking strength of containers. (Source: USDA Handbook 668) http://naldc.nal.usda.gov/download/CAT89930509/PDF

Slide 48

Loading/unloading vehicles

Avoid overloading vehicles or stacking produce too high. If it is a bulk load, produce in a large pile will gain heat during transport, from friction, the sun and from natural process of respiration. If it is an open load, cover the top with a large canvas cloth or plastic tarpaulin. If a cover is not available, it may be possible to use plant materials such as banana leaves.

Unloading a bulk shipment of mangoes in Burkina Faso (2015)

A pick-up truckload of bananas being driven onto a ferry in 2009 in Mindelo, Cape Verde (Photo credit: Lisa Kitinoja)

Slide 49

Bananas in Rwanda are bruised by very rough handling during loading, throwing bunches, stacking the load too high, loading vehicles too densely, walking on the load - all of which cause postharvest losses (WFLO 2010).

No packaging is used for plantains in Ghana or for bananas in Rwanda, and the fruits often suffer broken tips, cracks and bruises as they move along the value chain.

Unloading banana bunches in Rwanda (Photo credit: Dan McLean)

Damage to bananas during transport in bulk loads in Rwanda (WFLO 2010)

Slide 50

Covering open loads

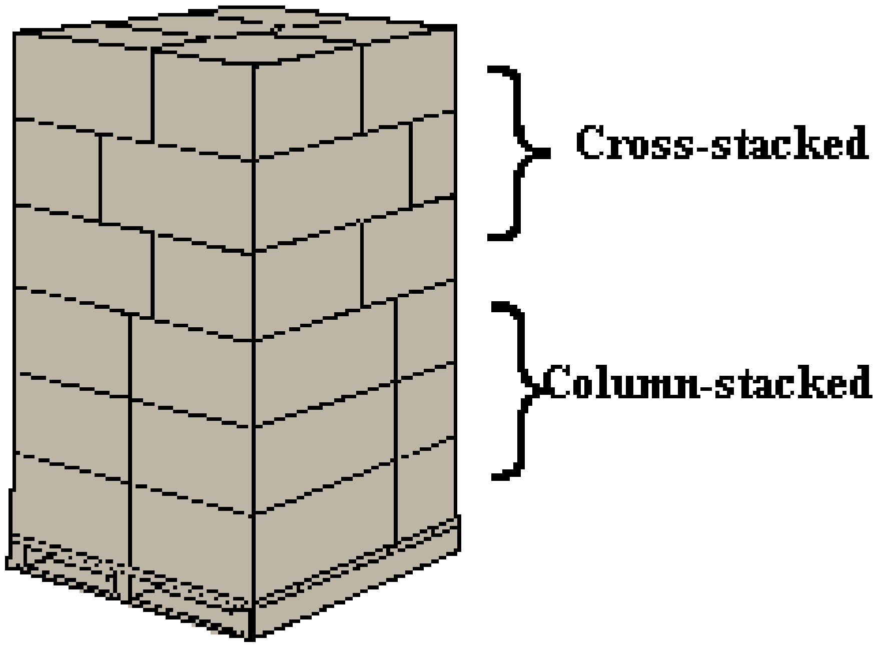
Protecting F&V crops from direct sunlight, wind and dust can help to reduce postharvest losses.

Covered HILUX pick-up truck bed in Cape Verde (Photo credit: Lisa Kitinoja) and a covered truck in Ethiopia (Photo credit: Joseph Mpagalile, FAO)

Slide 51

Stacking packaged F&V crops

Proper stacking of packages will help reduce damage and food losses. Cartons should not hang over the edge of the pallet, and the corners should line up when stacked on top of one another. Using uniformly sized packages makes proper stacking easier.



Source: North Carolina State University (www.bae.ncsu.edu)

Slide 52

Reducing postharvest losses during (4) agro-processing

- Preparation for processing
- Improved solar drying
- Heat processing
- Improved food safety
- Improved packages and containers

Slide 53

Preparation for processing

Some produce requires blanching before freezing, canning or drying. Blanching by dipping in a boiling water bath or in steam stops certain enzymatic reactions in the product and helps retain color and flavor after processing. Always rinse blanched produce under very cold water or dip blanched produce into an ice water bath to stop the cooking process and quickly bring the temperature down.

Blanching time for each commodity varies, depending upon its physical structure (see table below for examples). Use 8 liters of boiling water per kg of produce, and add one minute for each 650m altitude for elevations over 1200m.

Blanching times for selected F&V crops.

Crop	Blanching time (minutes)
Green beans	3
Cabbage wedges	5
Collard greens, kale	3
Leafy greens, amaranth	2
Peas	2
New potatoes	4 to 10 (or until soft)

Source: Chioffi & Mead (1991)

Slide 54

Improved solar drying

Traditional sun drying in SSA often involves laying produce on the ground, either directly on the soil or on a cement pad. This exposes the F&V crops to contamination from soil, dust, insects and birds.

Simple direct driers can be made from trays of screening material propped upon wooden or concrete blocks to allow air to circulate under the produce. When air can pass over and below the produce, drying will speed up and there will be reduced losses due to overheating. A layer of cheesecloth can be draped loosely over the produce, protecting it from insects and birds while drying. Check the produce each day and move it under cover if rain threatens.

An improved solar drier is enclosed to protect the drying foods from dust, insects and birds.

This solar drier in Tanzania is a direct model originally developed for East Africa by NRi (UK), which has been enhanced with the additional of a simple solar reflector made of stainless-steel sheet metal (Stiling et al. 2012). The solar reflectors need to be cleaned regularly to remove dust.

Solar drier in Tanzania (a direct model). Photo credits: Lisa Kitinoja

Slide 55

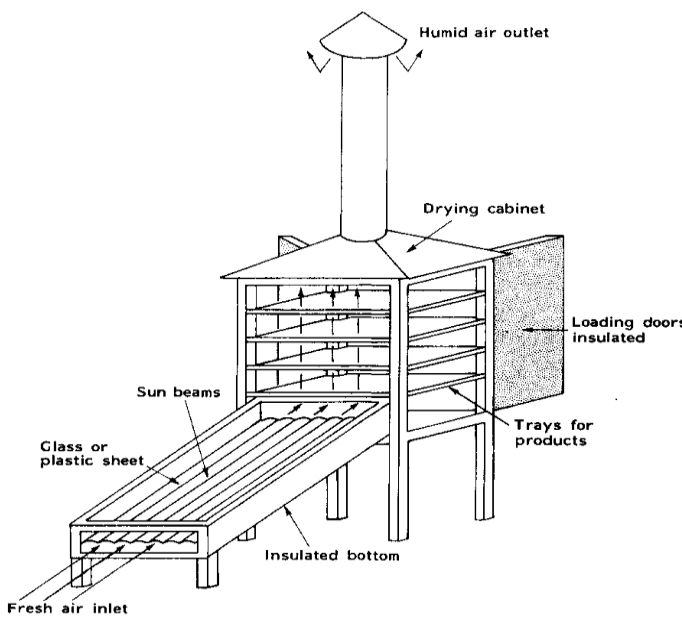
In Rwanda, postharvest training on solar drying of pineapples resulted in the adoption of improved solar drying practices and the launch of a massive solar drying business for organic pineapple exports.

Rwanda: Pineapple solar drying operations (Photo credit: Herve Ineza, 2014)

Slide 56

Indirect solar driers

Another improved solar drier is an indirect model, where the produce is protected from direct sunlight, and a solar collector heats air before it enters the drying chamber. Usually, the drying takes place on trays stacked inside a cabinet style chamber, and solar heated air passes upward through the trays, carrying away the water in the drying produce.



Indirect style solar driers (FAO and Mother Earth News). Free construction plans are available. Source:

http://www.builditsolar.com/Projects/Cooking/cooking.htm#Drying

No matter which method of solar drying is being used to F&V crops, proper preparations (blanching, slicing, cutting cubes or small pieces of uniform size) will speed drying and result in a higher quality product.

Preparation of leafy vegetables ready for a simple blanching procedure by placing in clean cloth and dipping in boiling water in rural area in Tanzania.

Slide 57

Heat processing

Canning and bottling operations in SSA are often carried out without using heat processing. This practice is thought to save money, but it leads to poor quality products with short shelf life and can be dangerous in terms of food safety.

Process	Current practices	Recommended practices
Bottling juices in Rwanda	Hot juice is poured into single use plastic bottles, sealed with screw-on type cap, cooled naturally in air. Chemical preservatives and high sugar content are used for protecting flavor, color, food safety.	Boiled juice is poured into sterilized glass bottles or jars, sealed with metal cap or lid. Heat process in boiling water bath for 10 minutes to kill any pathogens. No chemical preservatives are needed.
Making fruit jams in West Africa	Hot jam is poured into single use plastic jars or recycled glass jars, sealed with screw-	Boiled jam (with lower sugar content) is poured into sterilized glass jars, sealed

Process	Current practices	Recommended practices
	on type caps, cooled naturally in air. Chemical preservatives and high sugar content are used for protecting flavor, color, food safety.	with metal lid. Heat process in boiling water bath for 10 minutes to kill any pathogens. No chemical preservatives are needed.
Tomato products (sauces, ketchup, juices)	Hot product is poured into single use plastic bottles, sealed with screw-on type cap, cooled naturally in air. Chemical preservatives and high sugar content are used for protecting flavor, color, food safety. pH should be corrected to less than 4.5 by adding lemon juice or citric acid.	Boiled tomato product is poured into sterilized glass bottles or jars, sealed with metal cap or lid. pH is corrected to less than 4.5 by adding lemon juice or citric acid. Heat process in boiling water bath for 10 minutes to kill any pathogens.

Slide 58

Aflatoxin management

Aflatoxins can be a problem in dried vegetable products if they are not properly dried and protected from moisture during storage and marketing. A highly toxic metabolite produced by the ubiquitous *Aspergillus flavus* fungus is a major public health issue in Africa. IITA studies measured contamination in 30 to 65% of stored maize (also a problem in sorghum, rice, millet, groundnuts, and dried roots, tubers. IITA (2009) provides details on mycotoxins found in dried vegetable crop products in the wholesale markets of Togo.

The *Aspergillus flavus* fungus infects crops and produces the toxin in the field and in stores, then the fungus is carried from field to store. Contamination is possible without visible signs of the fungus, and very low levels are toxic (maximum allowable levels = 20 ppb US; 10 ppb WFP; 4 ppb EU).

Slide 59

Some predisposing factors for aflatoxin contamination:

- pre-harvest high night-time temperatures and drought stress
- wet conditions or high humidity at harvest and post-harvest periods
- insect or bird damage
- rain on the mature crop increases contamination.
- improper crop storage or transportation.

Source: PACA and IITA http://www.aflatoxinpartnership.org/

Slide 60

Improved food safety

There are global standards for food safety, and protocols have been developed by many countries for domestic food processing and markets. An entire training program is required for complete coverage of the subject, but the following key points need to be protected against in order to ensure safe postharvest handling of F&V crops.

Physical Hazards

- Nails, screws, pieces of glass, wood splinters etc.

Chemical Hazards

- Pesticides, fungicides, machine lubricants, heavy metals, cleaning compounds etc.

Human Pathogens

- Soil associated bacteria (*Clostridium botulinum, Listeria monocytogenes*)
- Fecal associated bacteria (*Salmonella spp., Shigella spp., E. coli* 0157:H7 etc.)

HACCP: Example protocol for juice processing https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-juice-hazard-analysis-critical-control-point-hazards-and-controls-guidance-first

Slide 61

Improved packages and containers for processed products

Improved containers for processed products such as jams, jellies, preserves and juices have the following characteristics:

- Made from glass of high quality (thick, free of chips or cracks) that can be heat processed without breaking
- Made of metal (if the required sealing equipment is available)
- Metal, glass or plastic lids that fit tightly, and seal well to the container when heated
- Reusable if possible, especially for processed foods produced for home use or local sale and packaged glass jars or bottles
- Recyclable if metal or single use glass

High quality glass jars and metal cans for heat processed products. Source: www.ball.com

Slide 62

Containers for dried F&V products that can be sealed and protect the dried products from light, water, insects and rodents will greatly increase their storage life. Metal foil packages are non-toxic (Castle 1982), low cost (US$0.05 to $0.10 per package depending upon size) and can protect dried F&V and other dry food products for up to one year (USU 2013).

Metal foil packages (Source: www.uline.com)

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Plastic buckets can be cleaned and reused many times for storage of dried foods. Typically, the plastic lids will break after a few uses. A new type of lid for plastic buckets of several sizes, known as a gamma-seal, can be permanently attached to a bucket, and then the center portion can be screwed on and off whenever needed without damaging the container or the lid.

Three types of plastic buckets and a gamma-seal screw-on style lid.

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Reducing postharvest losses during (5) wholesale and retail marketing

- Temperature management practices
- Sanitation
- Inspection and resorting

Slide 65

Temperature management practices

Keeping fresh produce cool is a key to extending the shelf life and reducing postharvest losses for F&V crops. Produce exposed to the sun after harvest gains an enormous amount of heat and will have reduced shelf life. Tomatoes left in the sun for one hour after harvest will be at least 15°C hotter than fruit held in the shade (Kitinoja and Kader, 2003).

In Ghana, the investment cost for a shade umbrella is quite low and it can be carried around and set up whenever and wherever the seller moves. The unit cost of an umbrella (20 GHC or about US$15) is lower than using erected sheds or permanent shade covers at various sites. Shading resulted in reduced weight loss for tomato. There was greater decline in un-shaded fruits (8%) than shaded fruits (4%) over a 6 hour exposure at market conditions, with the use of shade resulting in a 50% reduction in weight loss (WFLO 2010).

Slide 66

Sanitation, inspection and resorting

Fresh F&V will slowly deteriorate and lose quality during the marketing period. It is important to keep the sales and temporary storage areas clean, and to sanitize the displays and storage areas between uses. During the course of a typical marketing day, produce may need to be inspected, with any damaged/decayed items sorted out and discarded to prevent the decay from any affected F&V from spreading to the rest of the lot.

Retail display of vegetables and fruits in a small shop in Kigali, Rwanda (Photo credits: Dan McLean)

Slide 67

Details on how to work with and train the 5 target groups/beneficiaries to reduce postharvest food losses

(1) small-holder farmers

(2) village and community storage operators

(3) micro, small and medium enterprises

(4) small stores

(5) market and street vendors (excluding supermarkets)

The majority of postharvest losses for F&V crops in SSA will be experienced by small-holder farmers, traders, village/community storage operators and marketers. Relatively low levels of postharvest losses occur during agro-processing of F&V crops.

Bringing representatives of these target groups together and offering comprehensive training programs on reducing postharvest losses along the entire food supply chain can assist the community to develop a more market oriented approach to reducing postharvest food losses.

Handling practices and technologies used by an actor early in the chain may affect the type and amount of losses experienced by those later on in the FSC.

Providing access to improved postharvest technologies is not by itself sufficient to reduce food losses. Any new technologies or recommended handling, storage or processing practices have to be supported by training of the potential users, and by local capacity building for extension agents and key food supply chain actors.

Any food loss reduction solutions promoted need to be available and accessible in the intervention areas. There must be support for changes in practices or adoption of new technologies, via the existence of suppliers, manufacturers/fabricants, distributors and repair services.

Slide 68

Improved postharvest practices of F&V crops for (1) small-holder farmers

Several practices are highly recommended for the focus of training programs aimed at assisting smallholder farmers to reduce postharvest losses.

- Use of harvest indices
- Gentle handling
- Plastic crates
- Use of shade
- On-farm storage
- Market access


Displaying vegetables and fruits on the ground at a village market in Tanzania (Photo credit: Ikunda Teri, MVIWATA)

The first four topics were introduced and discussed in detail earlier in this module. For further information, trainers can refer to the following training manuals:

Small-scale postharvest handling practices: a manual for horticultural crops.

English: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230101.pdf

French: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230102.pdf

Amharic: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230098.pdf

Afrikaans:
http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230097.pdf

Swahili: http://ucanr.edu/sites/Postharvest_Technology_Center_/files/230107.pdf

Postharvest Compendium (INPhO)

http://www.fao.org/in-action/inpho/crop-compendium/fruits-vegetables/en/

The Postharvest Education Foundation website and free book download:

100 under $100: Tools for reducing postharvest losses. http://postharvest.org/100_under_100.aspx

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Market access

Smallholder farmers often have limited knowledge regarding market prices and consumer demand or preferences. Advocating and promoting the formation of farmer's groups as formal or informal associations, cooperatives or small businesses is one approach to improving access to markets (WFLO 2010, Ferris et al 2014). Promoting a market-driven approach not only helps to improve access but ensures there is sufficient market demand for the products. A market-oriented approach can demonstrate economic and technical feasibility, hence a higher adoption rate and improved sustainability.

After the introduction of the compulsory GlobalGAP certification in Kenya in 2005, a survey of ten exporters by Graffham, Karehu, and MacGregor (2009) found that over 50% of the Kenyan export horticulture market was controlled by these exporters. The survey found a 60% drop in formal participation of small-scale growers in these companies' supplier networks. The authors suggest that the primary reason for this decline was financial, as the standards necessary for acquiring the certification are likely to require far more capital than many small-scale farmers can afford on their own (Ferris et al 2014).

For more information:

FAO 2015. Inclusive Business Models: Guidelines for improving linkages between producer groups and buyers of agricultural produce. http://www.fao.org/3/a-i5068e.pdf

Slide 70

Learning by Doing

Smallholder farmers and farm workers may not be able to read well, so using hands-on teaching methods and demonstrations can be a practical way of reaching this target group.

"Learning by doing" and providing results demonstrations that compare two or more practices or simple technologies side by side, where farmers can make their own observations are often the most effective extension methods.

Demonstration: Use of shade

Fresh F&V exposed to sun, heat and dry air will lose water quickly, and will soon wilt, become dull or shriveled. Tomatoes lose their shiny appearance, leafy crops become limp, and green beans lose weight.

Postharvest trainers can set up a simple demonstration at the beginning of a program by putting one sample in the shade, and a second sample in the sun, and have visual results in a few hours. Participants are shown how to feel and/or measure the temperature of produce after it has spent a few hours in the sun, and compare this to the cooler temperatures of the same produce that has been kept in the shade. A digital scale can be used to measure the initial and final weight of the produce sample.


Lizanne Wheeler is setting up a shade demonstration for tomatoes and leafy greens (samples are weighed and then kept in the shade versus exposed to the sun for 3 hours); results for tomatoes show the obvious loss of glossiness. (Photo credits: Lisa Kitinoja)

Slide 71

On-farm storage

Farmers may need to keep fresh produce overnight or for a few days before sale to traders or direct marketing. In drier climates, the use of simple evaporative cool storage structures can provide up to 10°C reduction in temperature, which will double the postharvest life and reduce losses due to water loss and decay.

In the semi-desert region of Afar, Ethiopia, three on-farm cool storage technologies were demonstrated side by side, and each was able to reduce the storage temperature and increase RH% for a period of up to 24 days.

Cool storage technologies in Afar, Ethiopia

Ambient temperature/ RH%	Cool Storage Technology	Temperature/ RH% inside the cooler
29.5 °C 51% RH	 Pot-in-pot (clay pots, sand)	21°C 88% RH

Ambient temperature/ RH%	Cool Storage Technology	Temperature/ RH% inside the cooler
	 Desert cooler cabinet (Wood frame/burlap cloth cover)	21.5°C 80.7% RH
29.5 °C 51% RH	Zero energy cool chamber (bricks/sand)	21.5°C 87.7%
43°C 23% RH	Zero energy cool chamber (bricks/sand) 	23°C 96% RH

Source: Abiso (2013) and Hailegebrile (2015)

Slide 72

Improved postharvest handling practices for (2) village and community storage operators

- Temperature and relative humidity management
- Plastic crates to protect perishable crops

- Sanitation
- Inventory management
- Use of simple tools for moving packed F&V

Postharvest training for storage operators typically focuses upon introducing the key features of improved storage structures (for adequate protection from physical damage, weather and pests), and on improved storage management (sanitation, inventory management, temperature and RH).

F&V crops are typically held in cool storage for short periods of time, so having an easy way to move the crates or containers will help to manage inventory and reduce losses. Storage operators are in business to make money, so they will be interested in the costs and benefits of any recommended practice or technology.

Slide 73

Demonstrations of reduced F&V losses

Providing demonstrations of improved postharvest practices for storage operators can be a simple way to increase awareness and assist this target group to reduce postharvest losses.

One example is the use of simple tools for moving packed F&V crops. The cost of the unit and the associated losses from physical damage can be compared to manual handling (cost of labor and level of damage).

A hand dolly, hand cart or hand operated fork lift can ease the workload and reduce damage when moving packaged F&V crops in the storage facility (Source: www/uline.com)

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Improved postharvest handling practices for (3) micro, small and medium enterprises

- Gentle handling
- Reducing delays
- Packinghouse operations
- Use of improved packages and containers
- Food safety

The volume of crops that requires handling or processing will often determine which technologies make the most sense economically.

There are sometimes tradeoffs to be made between fast processing and inexpensive technologies, and decisions to make regarding labor for manual practices versus capital costs for machinery.

For F&V crops, gentle handling will provide the best quality results, and training workers in proper handling practices and reducing delays can pay off quickly.

Slide 75

Gentle handling and reducing delays

Any time the crop is left waiting in the sun, in a truck, on a loading dock, or dropped, thrown or stacked too high, postharvest losses will tend to increase. Planning the timing of harvesting and deliveries to the packinghouse, processing plant, distribution center or market will help reduce unnecessary delays.

Slide 76

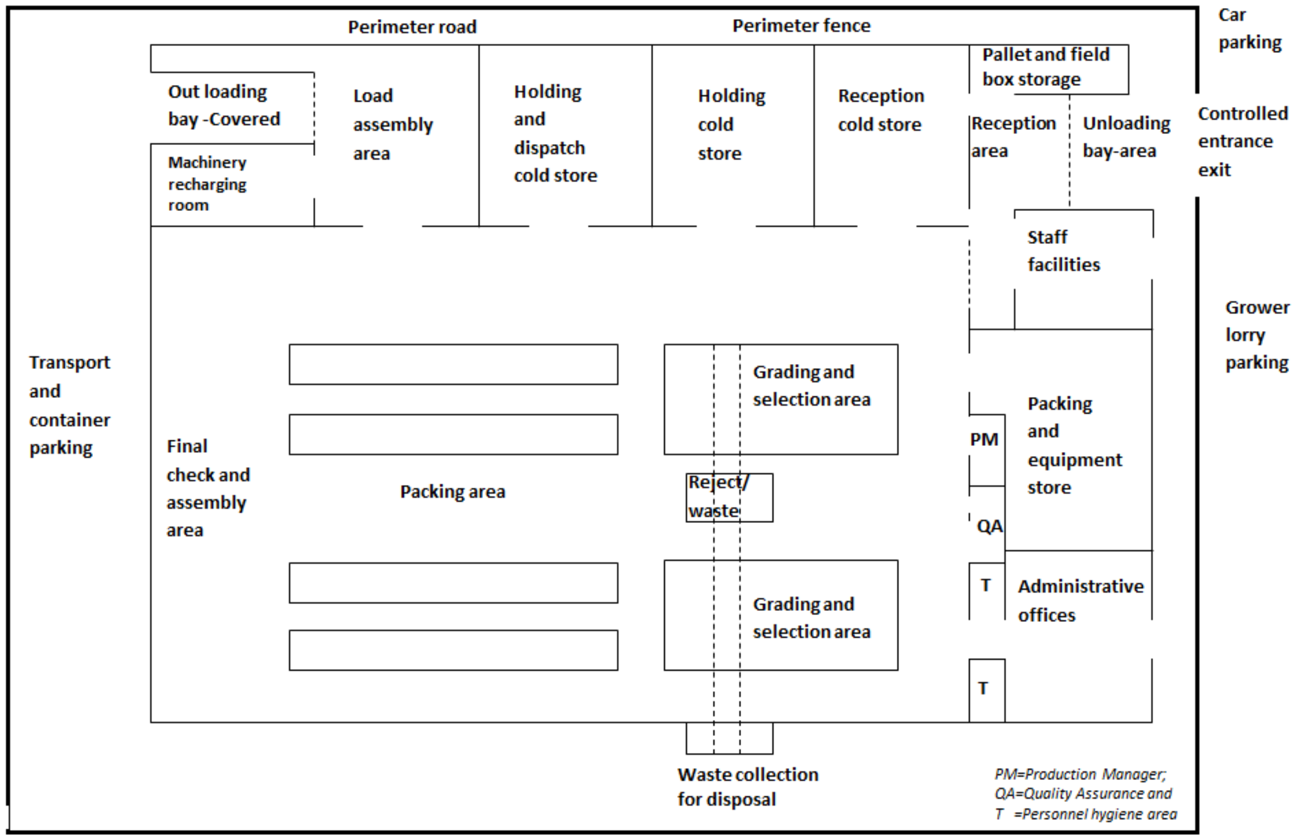
Packinghouse operations

Many of the operations that take place in a packinghouse are intended to add value to the produce. If the handling is rough the F&V crops will be damaged, and if the practices are not well suited to the crop, postharvest losses can increase.

There is no single packinghouse design that will work well for every kind of fruit and vegetable crop, but following a few simple guidelines can help to reduce postharvest losses.

- Design packing lines to have a one way flow
- Avoid unneeded steps in the packing process (keep it simple) to prevent damage
- Avoid drops, throws and bumps by getting the produce close to workers so they can easily reach and gently place the produce into the packages
- Provide plenty of workspace (sufficient elbow room) and lighting for workers to do their jobs
- Keep the facility clean, whether it is a simple outdoor shed or a complicated mechanized system

Example of pack-house layout



(Manual for Horticultural Export Quality Part I; NRI, 1994)

A simple design of a packing house

Slide 77

Examples of appropriate packinghouse operations for F&V crops in SSA

Crops	Operation	Purpose
Bananas, mangoes, papayas	Washing after harvesting, before packing	To remove latex (released from cuts during harvesting or de-handing) before staining can occur
Tomatoes, hot peppers	Sorting into maturity grades	To match different market demands or a buyer's preference
Leafy greens, cabbages	Trimming to remove long stems, broken leaves, any damaged outer leaves	To improve appearance and reduce susceptibility to decay

Onions, garlic	Dry brushing, trimming roots and tops, to remove soil, loose scales, dead leaves and roots	Avoid wetting the produce and improve appearance and reduce susceptibility to decay

If water is used for washing, sanitation practices are critically important. The general rule is to use chlorinated wash water, with 150-200 ppm Cl- at pH 6.5 to 7.5 for best results (2 to 3 ml of chlorine bleach per liter of clean water). More chlorine will be required if temperatures are high, or if there is a lot of organic matter in the wash water.

Slide 78

Use of improved packages and containers

Package liners can help reduce water loss in F&V crops. Lightweight or vented liners will decrease water loss without seriously interfering with oxygen, carbon dioxide and ethylene movement.

Video of bananas being packed into cartons (Source: Fresh 'n' Smart®):

https://www.youtube.com/watch?v=CZKPIOfKKM8

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Food safety

There are global standards for food safety, and protocols have been developed by many countries for domestic food processing and markets. An entire training program is required for complete coverage of the subject, but the following key points need to be protected against in order to ensure safe postharvest handling of F&V crops.

Physical Hazards

- Nails, screws, pieces of glass, wood splinters etc.

Chemical Hazards

- Pesticides, fungicides, machine lubricants, heavy metals, cleaning compounds etc.

Human Pathogens

- Soil associated bacteria (*Clostridium botulinum, Listeria monocytogenes*)
- Fecal associated bacteria (*Salmonella spp., Shigella spp., E. coli* 0157:H7 etc.)

Food safety starts on the farm with Good Agricultural Practices (GAPs), and must be protected all the way through processing (HACCP) to the final consumer.

For further information:

Cornell University GAPs Program (includes self-assessments).

https://gaps.cornell.edu/educational-materials/food-safety-begins-farm/

HACCP: Example protocol for juice processing http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ucm072557.htm

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Improved postharvest handling practices for (4) small stores and for (5) market and street vendors

- Inventory management
- Temperature management/ use of shade
- Sanitation
- Displays/use of tables and shelves

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Inventory management

Fresh produce has a limited postharvest life, even when handled and stored under the best conditions (kept cool and at high relative humidity). Small stores and open air retail markets rarely can provide these conditions, and so the F&V on display will tend to lose water and begin to look less appealing to customers. Keeping good records and using a first-in/first out inventory management system will help reduce postharvest losses.

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Temperature management/ use of shade

Keeping produce cool during marketing is difficult for vendors, but nature can provide some assistance. Using shade will help keep temperatures lower, and using evaporative cooling (e.g. covering produce with a wet cloth, misting with clean water) will help keep the RH% higher. Both of these simple practices will decrease the rate of water loss in fruits, fruit-vegetables such as tomatoes and peppers, and all kinds of green vegetables.

For onions/garlic bulbs, which must be kept dry and cool, the use of deep shade and adequate ventilation is recommended. Net bags are often used for packaging these crops, to allow good air ventilation.

Sanitation

The temporary storage areas and displays in marketplaces must be kept clean. Sweeping the floors will reduce the chances that plant debris and dried or rotting produce may attract insect pests and rodents.

Cleaning the storage room (Source: FAO 1985)

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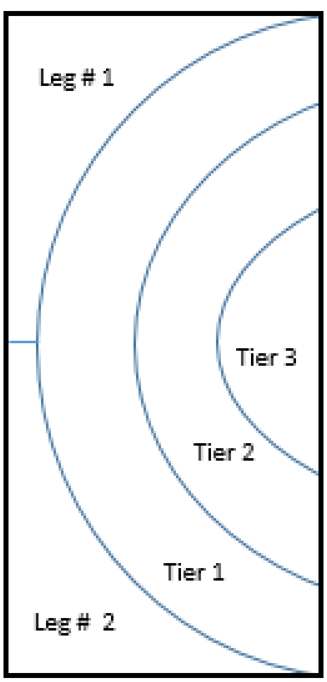
Displays/use of tables and shelves

Lifting the produce up off of the ground or the floor during marketing is a simple practice that will help to reduce postharvest losses. Using tables or shelves for displays can ensure that produce is not stepped on or exposed to dust or pests. Allowing air to pass under the display can help keep the produce cooler.

Simple display shelves (Photo credit: Lisa Kitinoja)

A simple semi-circular display table can be constructed from one standard size (four foot by eight foot) sheet of plywood.



Source: Cornell University Extension Bulletin 851-S.

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Details on how to reduce losses for these key F&V crops in SSA:

- Banana/Plantain
- Mango
- Papaya
- Tomato/Hot peppers
- Onions
- Leafy greens
- Green beans

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Improved postharvest handling, storage and marketing of Banana/Plantain

Harvest index

Fingers begin to fill out and become rounded (loss of angularity). Bananas and plantains are harvested mature-green. Bananas are ripened upon arrival at destination markets since fruits ripened on the plant often split and have poor texture.

Harvesting practices

Avoid early harvest, fruits will be small and light for their size, of lower market value. Handle bunches gently and avoid dropping the fruits.

Cleaning/trimming

Wash off latex (sap) if the hands are cut from the bunches. The water used to wash these fruits must be clean and sanitized (contain 200 ppm chlorine).

Field containers

Use sturdy containers to avoid bruising, avoid stacking loose fruit or full bunches. Abrasions result from skin scuffing against other fruits or surfaces of handling equipment or shipping containers. When exposed to low (<90%) relative humidity conditions, water loss from scuffed areas is accelerated and their color turns brown to black.

Temperature management/use of shade

Provide shade (via tree cover, umbrella or shade cloth) during delays between harvest and transport from the farm.

Storage

The optimum temperature for storage and transport is 13-14°C. Bananas and plantains are chilling sensitive.

Marketing

Bananas are often ripened before marketing to improve market value. The optimum temperature for ripening bananas is 15-20°C.

For further information:

Banana Product Facts:

https://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/

Plantain Postharvest Operations (via the INPhO Postharvest Compendium):

http://www.fao.org/3/a-ax439e.pdf

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Improved postharvest handling, storage, and marketing of Mango/Papaya

Harvest index

Mangoes change in fruit shape (fullness of the cheeks) as they reach maturity. Papayas change in color from green to yellow or red. Papayas are usually harvested at color break to ¼ yellow for export or at ½ to ¾ yellow for local markets. There are also internal color changes in flesh color from greenish yellow to yellow to orange.

Harvesting practices

Gentle harvesting and avoiding drops and bruises.

Cleaning/trimming

Sap must be removed (washed off) immediately after mangoes are harvested. A dark-brown to black discoloration of mango skin is due to chemical & physiological injury from exudate (sap) from cut stem. The water used to wash these fruits must be clean and sanitized (contain 200 ppm chlorine).

Field containers

Use of protective containers such as plastic crates can reduce compression damage and bruising during transport. Liners in rough containers (baskets or wooden crates) can reduce abrasion damage.

Temperature management/use of shade

Provide shade (via tree cover, umbrella or shade cloth) during delays between harvest and transport from the farm.

Storage

Both mangoes and papayas are chilling sensitive. Optimum temperature is 13°C for mature-green mangoes and 10°C for partially ripe and ripe mangoes. Optimum temperature is 10°C for partially ripe (¼ to ½ yellow) papayas and 7°C for ripe (>½ yellow) papayas. Typically, mangoes and papayas are not stored for more than 1 to 2 weeks.

Marketing

Fruits harvested mature green are usually ripened before marketing to increase market value. Mangoes will soften, change color and increase in sweetness, but papaya will soften and change color without any increase in sweetness.

For more information:

Mango Postharvest Operations, and Papaya Postharvest Operations (via the INPhO Postharvest Compendium):

http://www.fao.org/3/a-av008e.pdf http://www.fao.org/3/a-av012e.pdf

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Improved postharvest handling, storage and marketing of Tomato/hot peppers

Harvest index

These vegetables are harvested at various colors (maturities) depending upon the market demand and distance from the farm.

Harvesting practices

Gentle handling is required to reduce bruising and physical damage.

Sorting and grading

Fruits can be sorted to remove any decayed or damaged units, and graded by color or size during the harvesting process – and if packed directly into shipping containers in the field, this is called "field packing".

Cleaning/trimming

A soft, clean cloth can be used to wipe the fruits clean. If water is used to wash these fruits it must be clean and sanitized (contain 200 ppm chlorine).

Field containers

Use of protective containers such as plastic crates can reduce compression damage and bruising during transport. Liners in rough containers (baskets or wooden crates) can reduce abrasion damage.

Temperature management/use of shade: Provide shade (via tree cover, umbrella or shade cloth) during delays between harvest and transport from the farm.

Storage

Tomatoes and peppers are chilling sensitive. Optimum temperature is 18 to 20 °C for mature-green tomatoes and 15°C for partially-ripe and ripe tomatoes. Peppers store best at temperatures of 7 to 13°C. One to two weeks is the most common period of storage for these fresh fruits. Dried fruits (2 to 5% moisture) can be successfully stored at ambient temperature for months.

Processing

These fruits are often dried to extend shelf life. Tomatoes can be heat processed to make juice, sauce, ketchup, salsa and many other food products.

Marketing

Sorting tomatoes or hot peppers into maturity classes can improve market value. The red ripe fruits can be sold for immediate use and the less mature fruits can be held overnight and will continue ripening.

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Improved postharvest handling, storage and marketing of Onions

Harvest index

Tops beginning to dry out and fall down

Harvesting practices

Undercut (break roots) and allow onions tops to completely dry down.

Lift bulbs carefully and shake to remove loose soil.

Curing

Make windrows in the field (short long piles) and cover the onions with dry tops. Allow to dry (cure) for up to 7 days before further handling or packing.

Cleaning/trimming

Remove loose foliage, dried leaves should fall off or can be pulled off easily.

Field containers

Use of protective containers such as plastic crates can reduce compression damage and bruising during transport. Liners in rough containers (baskets or wooden crates) can reduce abrasion damage. If sacks are used, choose smaller sizes and do not overfill.

Temperature management/use of shade

Provide shade (via tree cover, umbrella or shade cloth) during delays between curing/packing and transport from the farm.

Long term storage

The optimum storage temperature for onions is 0°C and for long term storage onions require low relatively humidity (65-70%). Depending upon the variety, onions can be stored from 1 to 8 months.

Processing and marketing

Onions are often sliced or chopped and then dried to extend shelf life and add value.

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Improved postharvest handling, storage and marketing of Leafy greens

Harvest index

Adequate size

Harvesting practices

Manually harvest larger outer leaves for vegetables grown for multiple harvests. Alternatively, cut or pull up the whole plant for a single harvest.

Cleaning/trimming

Remove any broken or bruised leaves. Some leafy greens are bunched before packing. This practice needs to be done very gently, using a smooth twine or cord.

Field containers

Use of protective containers such as stackable ventilated plastic crates can reduce compression damage and bruising during transport. Liners in rough containers (baskets or wooden crates) can reduce abrasion damage and slow water loss.

Temperature management/use of shade

Provide shade (via tree cover, umbrella or shade cloth) during delays between harvest and transport from the farm.

Storage

Leafy vegetables are highly perishable and are typically not stored for more than a few days, unless very cold temperatures can be provided. Spinach and chards, for example, can be stored for 2 weeks at 0°C. Cabbages have a longer storage life (3 to 6 weeks for early cabbage, up to 6 months for late cabbage) if stored at very low temperature (0°C). At ambient temperatures in SSA, the storage life of leafy greens is very short.

Processing and marketing

Leafy greens can be dried (after blanching) to extend shelf life and add value.

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Improved postharvest handling, storage and marketing of Green beans

Harvest index

Green beans (also known as French bean, haricot vert, and string bean) can be harvested when the pods are well filled but before seed bulges appear.

Harvesting practices

Green beans are manually harvested. Indeterminate varieties should be continuously harvested (every day or two days).

Field containers

Use of protective containers such as plastic crates can reduce compression damage and bruising during transport. Liners in rough containers (baskets or wooden crates) can reduce abrasion damage.

Temperature management/use of shade

Provide shade (via tree cover, umbrella or shade cloth) during delays between harvest and transport from the farm.

Storage

Green beans are rarely stored for more than a few days. They are chilling sensitive and the lowest safe temperature is 7 °C.

Processing and marketing

Fresh beans are typically marketed immediately after harvesting. Green beans can be blanched and then dried to extend shelf life and add market value.

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Further details and up to date technical information on the postharvest handling, storage and processing of horticultural crops can be found in the following publications:

USDA Handbook 66. 2014.
https://www.ars.usda.gov/arsuserfiles/oc/np/commercialstorage/commercialstorage.pdf

UC DANR 2016. Postharvest Technology of Horticultural Crops, Fourth Edition. University of California, Agriculture and Natural Resources (in press).

Produce Fact Sheets:
http://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/

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Costs and benefits

It is easy to learn how to use a simple worksheet to calculate the local costs and expected benefits for any new or improved practice or technology by estimating relative changes in comparison to the current practice or technology. Using 100kg to make the calculations allows the user to perform easy math, then multiply the results by whatever volume will actually be harvested/handled and sold.

POSTHARVEST COSTS & BENEFITS WORKSHEET: Assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:		
COSTS		
Relative costs		
EXPECTED BENEFITS		
% postharvest losses		
Amount for sale		
Value/kg		
Total market value		
Total market value (BENEFITS) minus relative costs		

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Cost/Benefit examples

1. Fruits – bananas: Plastic crates for packing washed hands, transport and marketing

Often a produce farmer, handler or trader will hesitate to make investments in extra labor or improved containers, but for many crops, including bananas, the investment will pay off immediately due to reduced loses and higher market prices.

2. Vegetables – hot peppers: Harvesting at red stage, sorting/grading and packing in plastic crates for transport and marketing

Plastic crates can be an expensive investment for small farmers and traders, but if the crop can be protected from damage, the returns can be enough to pay for the investment in a single use. For hot peppers, the price for firm, red ripe peppers can be twice the value as that for green or mixed lots of peppers.

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C/B Example 1: Bananas packed in plastic crates

POSTHARVEST COSTS & BENEFITS WORKSHEET: Assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:	Handle in bunches	Cut hands from bunch, wash, dry, pack into plastic crates
COSTS (US$)		
Labor for cutting	0	2
Wash/dry/pack	0	5

5 Plastic crates (20 kg capacity)	0	25
Relative costs	0	32
EXPECTED BENEFITS		
% postharvest losses	10%	2%
Amount for sale	90 kg	98 kg
Value/kg	US$ 0.70 30% penalty for bruising	US$ 1.00
Total market value	$63	$98
Total market value (BENEFITS) minus relative costs for 1st load	$63	$66
Relative profits 1st load (fully pays for the cost of the plastic crates) – can be reused 100+ times		+ $3
Total market value (BENEFITS) minus relative costs for 2nd load	$63	$91
Relative profits 2nd load and subsequent loads		+ $28

If the actual volume harvested and packed per load is:

500 kg, then 5 x $28 = US$ 140 increased relative profits for each load.

1000 kg, then 10 x $28 = US$ 280 increased relative profits for each load.

2000 kg, then 20 x $28 = US$ 560 increased relative profits for each load.

The successful use of plastic crates for local marketing of F&V crops requires a system for collection, cleaning and return of the empty crates to the farmers. The relative profits generated by the use of plastic crates provides ample funds for including such a system in the food supply chain.

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C/B example 2: Hot peppers – sorting and packing in plastic crates

POSTHARVEST COSTS & BENEFITS WORKSHEET: Assume harvest 100 kg

	Current /traditional practice	New /improved practice
Describe:	Harvest mixed lot of all colors, sizes/ pack in baskets	Harvest 3 times per week, wait for red color (mature)/ pack in plastic crates
COSTS (US$)		
Labor for harvesting	2	6
10 Plastic crates (10 kg capacity)	0	50
Relative costs	2	56
EXPECTED BENEFITS		
% postharvest losses	30% due to physical damage in baskets	5%
Amount for sale	70 kg	95 kg
Value/kg	US$ 0.50	US$ 1.00 Premium price for red ripe hot peppers
Total market value	$35	$95

Total market value (BENEFITS) minus relative costs for 1st load	$33	$39
Relative profits 1st load (fully pays for the cost of the plastic crates) – can be reused 100+ times		+ $6
Total market value (BENEFITS) minus relative costs for 2nd load	$33	$89
Relative profits 2nd load and subsequent loads		+ $56

If the actual volume harvested and sold per load is:

500 kg, then 5 x $56 = US$ 280 increased relative profits for each load.

1000 kg, then 10 x $56 = US$ 560 increased relative profits for each load.

2000 kg, then 20 x $456 = US$ 1120 increased relative profits for each load.

The use of plastic crates for marketing F&V crops requires a system for collection, cleaning and return of the empty crates to the farmers. The relative profits generated by the use of crates provides ample funds for including such a system in the food supply chain.

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Priority training needs

Topics that need attention in order to solve postharvest problems for a variety of fruits and vegetable crops

- Use of proper maturity indices
- Basic improved postharvest handling practices (avoiding damage)
- Use of improved containers in order to reduce damage

- Temperature management and relative humidity control
- Postharvest pest and disease management

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Gender aspects for postharvest training

There are certain postharvest topics that may be of special interest for women who handle F&V crops (Kitinoja and Barrett 2015):

- Using apron-like harvest bags to pick fruit from trees, or for harvesting row crops like peppers or tomatoes. Women can make these bags themselves, and find the picking bags easy to manage. Drudgery is reduced, as there is much less bending and lifting in the field
- Using smaller containers for harvesting and farm work. This can make the workload easier for women, and it is also good for the crops since using a smaller crate, sack or basket will reduce physical damage
- Using smaller containers for transport. This will reduce the weight of head-loads, and cause less produce damage and lower postharvest losses
- Sanitation from farm to kitchen. This includes food safety for handling fresh produce plus useful practices for keeping the kitchen cleaner and healthier

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Advocacy issues

Problems that require attention in order to reduce postharvest losses for a variety of fruits and vegetable crops

- Improving infrastructure (roads, power, water)
- Investing in postharvest facilities (packinghouses, storage structures, cool trucks)
- Establishing a system for the use of returnable plastic crates (cleaning, repairing and returning empties to producers)

- Investing in agro-processing (SMEs) for juices, bottled products, canning, aseptic packaging, dried F&V products
- Improved marketing (facilities, farmer/trader organizations, cooperatives)
- Providing incentives for using improved postharvest practices and investments

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This concludes Module 1.4

Reducing Postharvest Losses in Sub-Saharan Africa: Fruits and Vegetables

Manual 1 contains a full reference list.

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