100 Under $100
Tools for Reducing Postharvest Losses

Betsy Teutsch, author
and Lisa Kitinoja, technical editor
Postharvest loss reduction is an enormous global challenge: up to 40% of crop yields go missing from farm to table. These losses, all along the value chain, hit hard. Smallholder farmers’ pockets are emptier than they could be and there is less available food overall, exacerbating food insecurity. The planet loses as well, since all the seed, water, fertilizers, and other inputs, including transportation, that have already been consumed contribute to global warming, without producing any nutrition for our hungry world.

The Postharvest Education Foundation, headed by Dr. Lisa Kitinoja, has worked tirelessly to educate and disseminate skills and postharvest tools for conserving the harvest. This book is a compilation of their resources, presented in an accessible and engaging format.

Waste also presents an opportunity. Reducing postharvest loss and waste by 50% is Sustainable Development Goal 12.3, as well as #3 in the DrawDown project that ranks solutions to climate change.

Approximately 90% of agricultural investments are aimed at increasing farmer yield, leaving only 10% devoted to postharvest handling, storage, and processing of the resulting crops. Investing in postharvest improvements represents high potential for impacts and high returns on investment:

- Raising farmers’ income
- Increasing food supply and food security
- Building local capacity
- Developing regional value supply chains
- Improving gender equity, since about half of smallholder farmers are female

100 Under $100: Tools for Reducing Postharvest Losses, modeled after my earlier book 100 Under $100: Tools for Empowering Global Women, zooms in on the value supply chain from farm through end-consumers [eaters!], encompassing a wide variety of techniques and tools. Some are tried and true, others are innovations. While some are relatively affordable and manageable by a householder, others require farmer groups or cooperative investments. Each tool pays for itself and then some by reducing losses, effectively expanding the harvest.

Our target audience is the vast network of Agricultural Extension Workers employed by governments, intergovernmental organizations, and NGOs who work directly educating smallholder farmers. But anyone with an interest in poverty alleviation and agricultural innovation to improve health of people and planet will find these postharvest solutions inspiring and compelling.

The book icons follow the value supply chain:

Farm: This section’s focus is tools and methods for decreasing the amount of food lost at the source, on smallholder farms.

Transport: Reoccurring throughout the value supply chain, this icon focuses on methods for reducing losses incurred moving produce, both on short and long hauls.

Packinghouse: This section enumerates best practices and methods to avoid food loss when crops are packed. Packing can take place right in the field, or in specifically designated sheds or packinghouses.

Processing: This section focuses on value-added activities that both preserve food surpluses and add market value to the food itself.
Storage: This section features tools to lengthen the shelf life of horticultural products (fruits and vegetables, root and tuber crops), grains and pulses, thereby decreasing losses.

Market: This section focuses on improved marketing. Whether a wholesale or retail market, at the farm or exported to far away cities, best practices decrease the quantity of foodstuffs lost at the market.

Consumer: This section details methods for end-user households, cafeterias, or food purveyors to decrease the amount of food that spoils before consumption.

Super-tools that reappear throughout the value chain are specifically highlighted:

Gentle Handling: From farm to table, taking care to avoid bruising and damage reduces food losses.

Cold Chain: Managing temperatures so foods do not spoil due to loss of moisture and/or rapid decay increases marketable quantities.

Sanitation: Careful monitoring of sanitation along the food chain decreases the chances that foods will be contaminated.

ICT: Many digital tools to help manage the movement of product from field to table are now available, maximizing the quantity of food that actually reaches consumers and provides sustenance.

Highlighted Features and Benefits:

Eco-Benefits: All postharvest loss reduction provides environmental benefit. This logo points to specific value in this area, both local and global. In some cases, it reflects harm reduction (such as eliminating pesticide use). In other cases, it might reflect carbon footprint shrinking through decreased transport or reusable packing, for example.

Female Friendly: Women make up about half of the farmers worldwide, generally clustered at the lowest-income generating end of the value supply chain. Female-friendly tools can help women perform tedious jobs more quickly and redeploy time-savings elsewhere. They may also offer opportunities for women to start microenterprises, moving up the supply chain and increasing income.

Do-It-Yourself: These tools can be fabricated locally, using available materials. Some of them are applicable to small farmers in the industrialized world, as well. Where possible, links to plans are included.

Technology Transfer: In our connected world, ideas flow from locale to locale. This icon points to great examples of technology transfer in ways that may surprise readers.

What follows are five representative tools chosen to follow the supply value chain. We welcome response, and look forward to the completion of all 100. We would love to hear your anecdotes and success stories, and use your great photos, illustrating affordable Tools for Reducing Postharvest Losses.

Please send them to postharvest@postharvest.org.
Fruit-bearing trees have sustained people since the dawn of human life. Once established, trees propagate fruit without requiring farmers to sow, plant, or tend. Each fruiting cycle trees grow larger, increasing their output for a generation or more.

Humans have developed many methods of gathering fruit.

- The easiest method of harvesting fruit is simply enlisting gravity, letting ripe fruits fall. Fallen fruit is very ripe, often post-peak, and will quickly spoil. Hitting the ground bruises fruit, adding more likelihood of spoilage.

- A more proactive approach, shaking or hitting the tree to cause the fruit to drop—“beating the bushes”—also has a high damage rate. Working in pairs, with one worker cutting fruit and the other catching it with a tarp or bag and guiding it into a receptacle, reduces damage.

- Plucking reachable fruit and gently placing it in bins is effective, but limited to a picker’s reach. “Low hanging fruit”, an expression popular with organizational development professionals, describes realistically accomplished goals.

- People the world over have devised clever collection pole pickers to harvest high-hanging fruit at its prime, cradling its descent.

- Fashioned from locally available materials, a simple tool like the large tin can and wooden pole used on the South Pacific island of Maré, New Caledonia, gets the job done. Catching baskets of net, wire, or plastic handle the fruit more gently. A blade, kept sharp, or prongs to pluck the fruit from the stem is a useful upgrade.

An inverted plastic bottle (image A) makes a good receptacle. The narrow “funnel” end can be left open for small twigs and debris to drop through. Directions are posted at www.practicalgardening.blackdovenest.com.

A hoop used as a catching basket rim and cutting edges can be fashioned from sheet metal, steel tubing or recycled scrap metal. [SSPH Manual 2015, p. 24–25]

Bill Birdsall posted his design for a net basket pole picker on Instructables (images B, C). The “finger” shape of the basket’s rim helps the fruit drop in the basket and not bounce when picked.

- Bamboo is readily available and works well for making poles. Telescoping poles, available commercially, are easier to transport, but are more expensive.

- Sturdier tools are needed for harvesting large quantities of fruit. An American urban orchard gleaning project’s favored design, posted at Instructables, is a commercial pronged wire basket (image D).

- Painting the front of the basket white provides contrast so pickers can more easily discern what they are picking from 20 feet (6 meters) away.

- Adding foam to cushion the bottom of the basket is a further upgrade (image E).
Plastic bottles work, too © www.practicalgardening.blackdovenest.com

The finger shape on the net’s rim guides the fruit into the basket © John Birdsall

Cloth bag fruit picker, Ethiopia © Lisa Kitinoja

Painting the front of the basket helps pickers to see what is going into the basket from a distance © NeighborhoodFruit

Foam lining added to cushion fruit © The Urban Farmers, Lafayette, CA
Produce is routinely washed in the packing-house to remove field dirt and debris. Rinsing improves aesthetic appearance and enhances food’s market value, but if the wash water is dirty, pathogens will spread from infected items to healthy ones, contaminating them all.

Washing should, therefore, only be done if the water is clean. If no potable water is available, it is better to skip the washing process.

Chlorination is an easily implemented, quick, inexpensive, and readily available treatment. When chlorine (powered or liquid) is dissolved in the washing water, it disinfects the harvested produce, halting the spread of bacteria. Chlorine is generally recognized as safe.

Chlorine is the familiar smell of swimming pools. Chlorine is also used to treat municipal drinking water and in households where pre-treated water is unavailable.

Chlorine kills pathogens on the surface, but does not penetrate the fruit or vegetables' tissues. When sodium hypo-chlorite is mixed with water it produces hypochlorous acid (HOCl), the active compound that kills microorganisms.

Chlorine needs to be measured carefully to be maximally effective. The desired chlorine level is measured in parts per million, ppm. In the packhouse, using 150-200 ppm free chlorine solution prevents contamination (about 2 ml of chlorine bleach per liter of clean water). Inexpensive chlorine test strips are a low-tech way to check the chlorine levels.

- If chlorine concentration is too high, it can corrode equipment and will emit unpleasant smells.
- If chlorine levels are too low, it will not properly disinfect.

The pH (acid/base) needs to be monitored as well. The pH range of 6.5-7.5 is optimal for sanitizing. Litmus paper, an affordable tool, can be used to test the pH of the water.

Chlorine ppm and pH both need to be monitored and adjusted as needed, generally hourly, throughout the process. Wash tanks need to be cleared of debris which lock up chlorine and adversely affect the treatment, and water needs to be filtered or changed.

While chlorination wash is generally a packing-house function, it can also take place directly at the farm after the harvest (as pictured), provided the concentrations can be properly monitored and maintained.

There is an app for this: Sensorex's water testing probe. Under $100, it attaches to a smart phone and can perform pH tests, along with many other water testing functions. Over time this can save money that would have been spent on one-time paper strip tests.

For farmers and processors meeting American organic certification standards, which fetch higher prices, a clear water rinse following the chlorine is required, to reassure people there is no detectible chlorine residue.
What kinds of organisms can cause decay that spoils harvested food?
Here are common terms:

**Microorganisms**: microscopic organisms, especially bacterium, virus, or fungus.

**Pathogen**: a bacterium, virus, or other microorganism that can cause disease.

**Microbes**: microorganisms, especially bacterium causing disease or fermentation.

**Bacteria**: members of a large group of unicellular microorganisms that have cell walls but lack organelles and an organized nucleus, including some that can cause disease.

**Fungi—Fungus**: any of a group of unicellular or multicellular spore-producing organisms feeding on organic matter, including molds, yeast, mushrooms, and toadstools.
Food processing adds value to crops, utilizing the abundance of produce at harvest time. When too much product goes directly to market, the oversupply can cause prices to plummet. Due to supplies exceeding demand, some of this yield therefore goes begging and spoils before it is purchased.

The result is a classic lose-lose poverty trap: farmers earn less for their labor, and lost food means less is available for them or others to consume.

Food processing is a win-win:

- Absorbing surplus yield
- Adding value
- Preserving nutritional value
- Creating local jobs
- Expanding local infrastructure and capacity

Food processing ranges from simple to complex. For some foods, a single step is required to create a saleable commodity. Fresh ginger, for example, can be bottled and sold all over the world after just being grated.

Cassava, the third largest staple crop in the world, requires a whole series of processing from fresh root to HQCF, high quality cassava flour. These include peeling, washing, grating, pressing, disintegration, sifting, drying, milling, screening, packaging, and storage, according to The Cassava: Adding Value for Africa (C:AVA) Project.

Food can be processed for the local market, like slicing and frying chips. Or it can become a transported to another processor as part of a multi-ingredient end product, like chopping mangoes that are then sent on to processors to makes juices or to use as pulp in cakes and candy.

As urban centers expand, women enter the workforce in ever greater numbers, and global income rises, demand for time-saving prepared foods has increased.

Food professionals track marketing opportunities and trends across the global food supply system, from local to international. When this information is available to local farmers and farmer co-ops, they can take advantage of lucrative market trends in their planning. For example, Esoko.com provides smallholder farmers with vital market information via mobile phone in Ghana, Kenya, and Tanzania.

The closer food prep is to the original food source, the more efficient it is, with less opportunity for spoilage. Local labor is readily available if funding can be found for launching small microenterprises, as well as for training.

Trimming and eliminating waste portions of the product lightens its weight and compacts its transportation footprint, providing eco-benefits as well, if the waste is managed in an ecologically responsible manner such as by composting on the farm.

Any chef will tell you that great food preparation is all about high quality knives. Or, for a broader perspective,
tools that grate, chop, and slice. Safety is always a consideration when workers are wielding sharp tools.

Popular techniques for common products include:

**Grating:** ginger, garlic, onions, turmeric

**Slicing:** mangoes, bananas, peaches, apples

**Chopping:** most vegetables (before drying or cooking to make sauces)

**Mincing:** garlic, onions
Traditional crop storage—typically woven sacks or porous storage structures—do little to protect the food supply against invasion by insects, rodents, and pathogens.

If a farmer stores what her family will need for eating until the next harvest, and much of it spoils, the result is often a hunger season for farmers and their families, when they run low on food while awaiting the next season's output. Losing out on stored crops results in the loss of the inputs purchased or procured as well as the labor expended to grow, harvest, and process the crop.

Losing food supply is a poverty trap that perpetuates itself.

- Farmers may be motivated to sell their crops at harvest time when prices are at their lowest.
- Farmers whose food supplies are diminished due to storage loss must purchase food late in the season when it’s the most expensive (or go without.)

Infestation damage by storage pests adds extra labor for women who must sort through the grains, separating edible from now inedible.

All this can change with the purchase of a household sheet-metal silo for storing dried grains, beans and legumes hermetically, protecting from air, moisture and pest damage. Introduced in Central America by SDC, The Swiss Agency for Development and Cooperation, in the 1980s, silos are a very popular innovation. They automatically add back at least the 10-15% of the stored yield that farm families formerly lost. At present, they are introducing metal silos to Eastern and Southern Africa where crop loss is estimated to be higher, 16-23%, so the benefit is even greater.

With safe storage, farmers are confident that not only can they expand their edible yield, but they will be able to feed their family and still have surplus to sell when the general supply diminishes. This enables them to become sellers, rather than buyers, when prices are high.

Safe storage also affords opportunity for income generating from year-round value-added activities. Women can prepare processed foods as time permits, not just during the harvest season bounty.

A household metal silo with a capacity of 1000 kg can conserve the grain needed to feed a family of five for one year. Farmers dry the grain to 14% moisture or less (according to type of grain) before placing it in the silo. According to Kenyan tinsmith Benjamin Njue Ngari, once filled with grain, a small space is left at the top where a burning candle is placed just before it is finally closed. The candle helps eliminate all the oxygen in the container to suffocate any pests trapped inside.
Metal silos

- Reduce losses to nearly zero
- Helped to increase food security by 30-35 days per year in Central America
- Save money by eliminating the purchase and use of insecticides
- Require a tight cover and outlet cap, crucial for preventing moisture, insects or fungus from entering the silo
- Must be placed on strong wooden pallet platforms to prevent contact with ground moisture corroding the metal
- Should be kept sealed up for as long as possible (at least 2 months) before removing grain so any insect pests will die, and any eggs will have time to hatch and be suffocated
- Are successfully adopted by local farmers; they “sell themselves”. Silo numbers kept on increasing after the Central American program ended. Local artisans continued to find a strong market for their silos.
- Are valued by their owners. The first silos from the 1980s are now considered family heirlooms in Central America. They are perceived as more aesthetically pleasing than cheaper plastic options.
- Come in a variety of sizes. Farmers can start with an entry level household size and invest in additional silos when income and yield expand. Note three different sizes are pictured.

Damaged silos can be repaired, lasting for a decade but often much longer.

- Rust is a common problem, solved by sanding and painting.
- A hole either punched or rusted can be patched, though the silo must be empty.

A farmer from Mbeere, Kenya, stands by her two larger metal silos © W. Ojanji/CIMMYT

CIMMYT representative demonstrating a silo metálico in El Salvador © CIMMYT
Adopters are enthusiastic:

“Six mouths are a lot to feed so Pamela Akoth, a 39-year-old Kenyan farmer and mother to half a dozen children, doesn’t want any weevils or borers—two of the most common post-harvest pests—nibbling at her grain supply. Akoth grows maize on 0.7 hectares in Homa Bay, western Kenya. In the past, she stored her grain in a traditional granary: a structure built with mud, branches, and cow dung that allows free entry to the maize weevil and the larger grain borer, the two most damaging pests of stored maize in Africa. Infestation starts in the field and continues after harvest when grain is stored. Losses of 10-20% are reported three months after storage, and this goes up to more than 50% after six months.

With help from a subsidy program—the Agriculture and Environment Program (AEP) of the Diocese of Homa Bay helps needy farmers to acquire metal silos by providing interest-free loans—Akoth purchased a metal silo able to store 20 bags (1,800 kilograms) of maize; roughly what her land yields. Made of galvanized metal, the silo is airtight, so it keeps out insects and suffocates any that might have snuck in with the stored grain. “I am happy that since I started using the silo I don’t experience any loss of grain,” Akoth says. “I have enough to feed my family and even some left over that I can save and later sell, when there is a shortage in the market.”

— CIMMYT.org
From time immemorial, people have gathered at outdoor markets buying and selling. Farmers bring their bounty; news and gossip are exchanged, too. Direct retail markets can eliminate middlemen along the value supply chain, allowing farmers to sell food directly to customers at fair prices.

From a makeshift roadside stand with fruits or vegetables direct from the field to a permanent stall rented in a full-service market with ongoing infrastructure, quick product turnover is the goal. In an exercise of pure market economics, vendors want to maximize prices while selling all they have transported; buyers want the lowest prices possible. Lively bargaining ensues.

Sellers generally lower the price towards the end of the day, to avoid carrying their harvest home; leftovers are not only burdensome, a day outside in a hot market increases the likelihood of spoilage.

Transporting products to market is a logistical challenge for any farmer, but even more so for those without access to mechanized transport. Carrying a cloth to the local marketplace, spreading it out on the ground, and arranging wares on it is common the world over. However, this practice should be avoided.

Just as people gather at the market place, so do a wide variety of pests, attracted by the same foods the shoppers are seeking. Raised racks and tables protect the products from contaminants, dirt, insect pests, and rodents.

- Raised racks have the additional benefit of bringing the offerings closer to customers. Creative solutions abound for raising the height of displays to grab eye-level attention.
- Inverted crates, plastic or wood, can be used to support a flat table as well as for vendor seating.
- An upgrade is a slanted table with a ledge, providing more visibility to passersby as well as allowing for a display on a bed of ice to conserve perishables, with the melt running off.
- A trestle table, a flat surface supported by free-standing supports, or a simple folding table work.
- A flatbed on wheels can be pulled to the market and double as a selling platform, as pictured with an Evaptainer, a prototype evaporative cooler.
- Vendors who transport their wares by bike or wheelbarrow creatively use them to support their stalls.
- Adding a sunshade slows down water loss and can be used to suspend items, expanding the booth and catching customers’ attention.
- It is important not to pile too many layers of perishable fruits and vegetables to avoid damaging the bottom level.
- Artful presentation of fruits, vegetables, grains, and spice help attract customers. Complex arrangements are not only eye-catching, but can cut down on customer handling, which can also damage produce.
Creative use of wheelbarrows on the streets of Coyoacan Borough, Mexico City © Ted McGrath

Vendors chat at a market in Ubud, Bali. © Michal Osmenda @ Flickr.com
Value Chain
16-page Teaser ISBN: 978-1-62027-010-3 (Publication date: October 2017)
Completed book ISBN: 978-1-62027-011-0 (Publication date: January 2018)
Publisher: The Postharvest Education Foundation, La Pine, Oregon
100 Under $100 © Betsy Teustch