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TACKLING POST HARVEST LOSS IN GHANA:

Cost-Effectiveness of Technologies

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Postharvest Loss (PHL) refers to measurable quality and quantity loss of food in the postharvest system. The postharvest system consists of inter-connected stages, from the act of harvest, to crop processing, storage, marketing and transportation, to the stage of consumption. PHL can occur at any stage in the postharvest chain. This note describes common types of PHL, approaches to mitigation, and the cost-effectiveness of technologies to achieve this. We begin with a section on common causes of loss, best practices for preventing these, and barriers to adoption of these practices. We then discuss prevention of loss during storage, for which several technological solutions have been developed and evaluated. Finally, we summarize the evidence on the cost-effectiveness of three such technologies that have been scientifically evaluated: hermetic storage bags, metal silos, and a cooling chamber.

1. UNDERSTANDING AND MITIGATING POSTHARVEST LOSS

Some common types of losses associated with PHL are summarized below [1]:

Table 1: Common losses associate with various post-harvest stages

Stage in PHL	Examples of losses
Harvesting	Pest infestation in the field; quality or quantity loss due to harvesting too early or too late
Threshing	Loss due to poor technique
Drying	Quality and quantity loss during drying
Storage	Pests and disease attacks, mold contamination, spillage, natural drying out of food
Packaging	Grain spillage from sacks; attack by pests, mold contamination
Transport and distribution	Loss owning to spoiling/ bruising/ contamination
Marketing/ distribution	Damage during transport; spoilage; poor handling; losses caused by poor interim storage

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Stage	Best practices	Barriers to adoption of best practices
Harvesting	Harvest at the correct stage of maturity and at peak quality. For instance, in the case of maize, harvest maize as soon as it is dry for optimal quality (grain moisture content at about 17-20%) but not when it is too dry and thus more susceptible to infestation [2].	Farmers may harvest crops too early due to immediate need for cash or food, fear of infestation, and lack of knowledge about optimal harvest period.
Drying	Grains should be dried in such a manner that damage to the grain is minimized and moisture levels are lower than those required to support mold growth during storage (usually below 13-15%). Different drying mechanisms such as solar dryers or mechanical dryers can be used.	Cash constrained farmers may not want to invest in resources such as tarpaulins, plastic sheets, or mechanical dryers. Dryers are especially costly (and not always cost-effective for small-scale individual farmers). Awareness of cost-effectiveness as well as behavioral factors such as putting more weight on the present than the future may also play a role.
Threshing/shelling	Machinery suitable for small small-scale operations exists including: maize shellers and mechanical rice threshers. The latter are actively being promoted by the International Rice Research Institute (IRRI). Mechanical shelling can minimize grain breakage, reduce the quantity of wasted grains, and save labor time.	Access to mechanical shellers may be a constraint to small-scale farmers, in terms of local availability to rent and cost of to purchase. It may not be cost-effective for an individual farmer to purchase larger-scale equipment.
On-farm storage	Storage spaces should be constructed in such a way as to provide dry, well-ventilated conditions to allow air circulation. Produce should be protected from rain and drainage of ground water, entry of rodents, birds and pests, and temperature fluctuations. Hermetic storage techniques should be made use of for optimal storage.	Cash and resource constraints, lack of knowledge about the cost-effectiveness of technologies, and behavioral factors may affect farmers' willingness to adopt recommended storage practices.

Studies have pointed out various best practices whose adoption would minimize post-harvest loss. However, various factors constrain adoption of these practices. The table below summarizes best practices for post-harvest handling and storage that have been identified by the literature, and barriers to their adoption.

2. TACKLING PHL RESULTING FROM STORAGE

Post-harvest losses from insect, rodent, mold and fungi infestations disproportionately affect small-scale maize producers in Sub-Saharan Africa [3]. While insecticides and pesticides protect against such losses, their usage during storage may pose health concerns, and is not necessarily cost-effective [4]. Even with appropriate chemicals and insecticides, studies show that grain storage over a six-month period may still result in dry weight losses of 7.5% and depress grain market value by 27% [5]. Traditional storage methods such as storage directly on the floor, in clay structures, and in cribs are associated with mold and fungal contamination, including proliferation of harmful fungal toxins such as aflatoxin [6]. Pest infestations such as maize weevils (*Sitophilus zeamis*) and the larger grain borer (*Prostephanus truncatus*) are associated with dry weight losses over six months of storage between 10-30%, with 40-80% of grains damaged. Concerns regarding molds and infestations may contribute to the phenomenon of farmers selling immediately after harvest. This common marketing pattern means that farmers do not capture the economic gains from grain storage over a longer period. One study found that farmers who sold immediately post-harvest and were forced to buy in the lean season had an average loss equivalent to 29.3% of the value of their grain sales, owing to seasonal price fluctuations [7].

The problem of post-harvest loss is especially acute for horticultural crops, for which as much of 40-50% is wasted in the production, post-harvest handling and storage, and packaging stages year [8].[2] The importance of proper storage of perishable fruits and vegetables can be gleaned from what FAO's Agriculture and Consumer Protection Department has to say on PHL of horticultural crops: "All fruits, vegetables and root crops are living plant parts containing 65% to 95% water, and they continue their living processes after harvest. Their postharvest life depends on the rate at which they use up their stored food reserves and their rate of water loss [9]." Proper storage post-harvest is key to tackling such losses. Given that demand for fruits and vegetables is on the rise due to shifting patterns of consumption and the rise of the middle class, tackling PHL in fruits and vegetables is essential to minimizing food waste and improving farmers' livelihoods.

To tackle the problems pertaining to storage of cereal as well as horticultural crops, scientists have tested multiple post-harvest innovations for effectiveness and cost-effectiveness. Two technologies on cereal crops and one on fruits and vegetables that can be reliably recommended for use by smallholder farmers are described in the following section.

3. COST-EFFECTIVENESS OF PROVEN STORAGE TECHNOLOGIES

Technology: Hermetic "PICS" bags

Applicability: Storage of maize, rice, cowpeas, and other cereal crops

[2] In contrast, the estimated loss of cereal crops in SSA during these stages is about 17.5%.

Technology details:[3]

"Purdue Improved Cowpea Storage" (PICS) bags were originally created for West and Central African cowpea farmers to protect against cowpea seed beetles, which prevented long-term storage that would allow farmers to benefit from price increases over the marketing season. These triple-layer hermetic bags create an airtight seal in which oxygen levels are dramatically decreased in a relatively short time through insect, fungal, and seed respiration. The high-density polyethylene (HDPE) bags come in 50kg and 100kg capacity sizes and cost around 9 Ghanaian Cedi (US $2) in Ghana. PICS bags have been shown to provide a significant reduction in losses of cassava chips compared to conventional poly-propylene bags over a two-month period. PICS bags can keep dry weight losses in maize below an average of 0.5% after a six-month period. Such hermetic bags are particularly ideal for regions where:

- *P. truncatus* infestation is very high
- Hybrid high-yielding maize varieties, which are highly susceptible to insect attack, are common
- Maize production is meant for market, and not solely household consumption, so that the farmers can exploit price seasonality via storage over several months
- Producers are able to attain adequately low moisture content.[4]

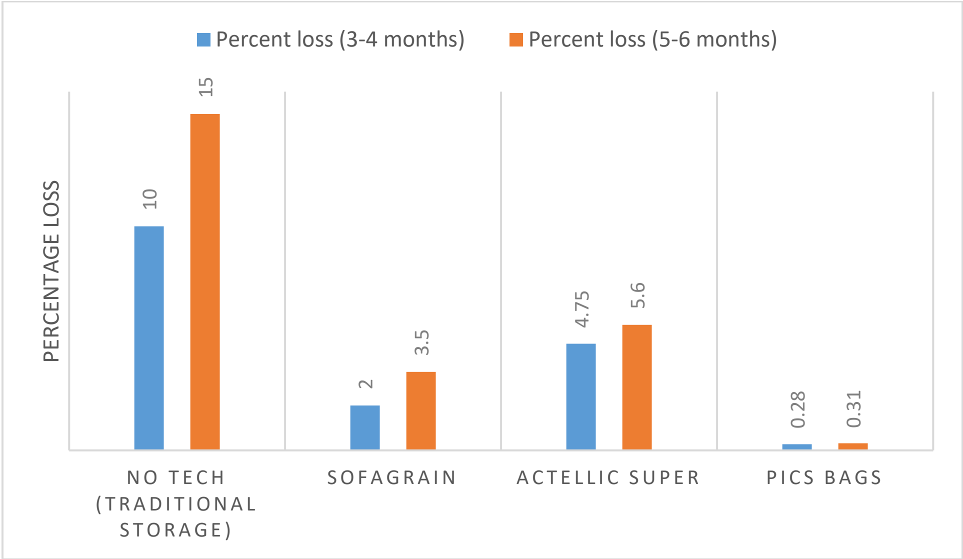
Returns to Technology:

The figures below highlight the advantages of PICS bags compared to two commonly used insecticides, *Sofagrain* and *Actellic Super* in terms of both post-harvest loss prevention and cost-effectiveness. Figure 1 contrasts the effectiveness of PICS bags at minimizing dry weight loss compared to the use of untreated traditional woven bags as well as use of either of the leading insecticides.

[3] This section is adapted from [5].

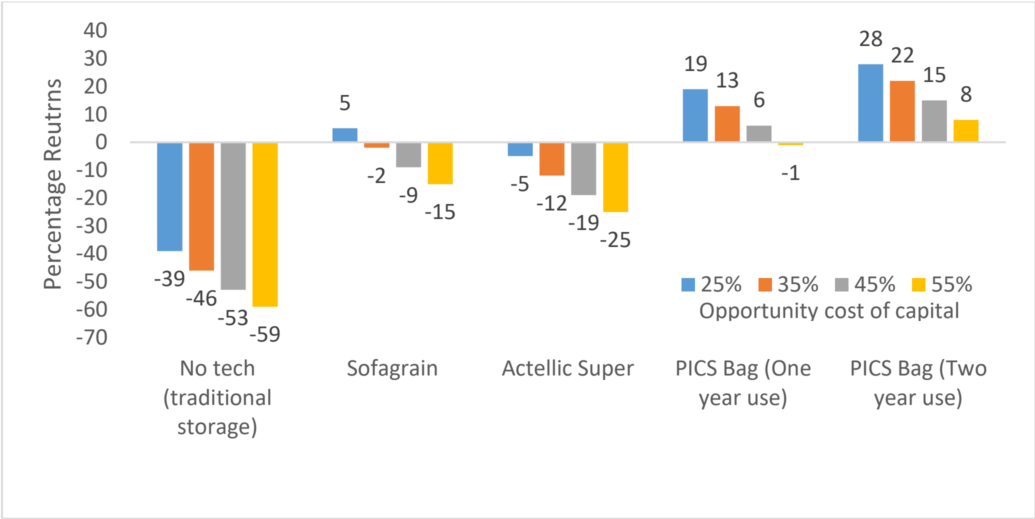
[4] Seed viability is shown to sharply decrease after 35 days of moisture contents above 16% in hermetic storage, discouraging this storage method if lower moisture levels cannot be attained [11]. Proliferation of molds may also be a problem if recommended moisture levels (13.5% for maize) cannot be attained.

Figure 1: Comparing Dry Weight Losses in Ghana under various product usage[5]



Similarly, Figure 2 illustrates that PICS provide consistently higher returns to storage than other options when storing the harvest for a longer period of time, even when the opportunity cost of capital is high.

Figure 2: Returns to various storage technologies in Tamale, Ghana when strictly selling eight months after harvest under different assumptions of the opportunity cost of capital (OCC)[6]



[5] The chart is adapted from Table 11 of [5]. All areas are assumed with LGB infestation as these would be the zones of highest insect losses and thus greatest need of improved storage technology.

[6] The figure is adapted from Table 31 of [5]. All storage returns are benchmarked against the small producers' return from selling directly after harvest.

Technology type: Metal silos

Applicability: Maize, rice, other cereal crops

Technology details[7]:

Similar to PICS bags in their functioning, hermetically sealed metal silos are strong barriers against insect pests and rodents, killing any remaining insects through oxygen depletion. One study reports the cost (in Kenya) of a metal silo with a capacity of holding half a ton at about 906 Ghanaian Cedi (US$200), and holding 2.7-ton at about 2084 Ghanaian Cedi (US$ 460). In contrast to PICS bags, metal silos are a durable long-term solution and allow for longer storage periods. However, metal silos have a high one-time fixed cost that may not be within the budget of small-holder farmers. This technology may not be economical for farmers who do not have easy access to grain markets and are not able to exploit price variations via long term storage of grains. In addition, there are other issues that may arise in the adoption of this technology such as security issues (farmers want grain to be inside their house but may not have space for large silos), and issues around convenience (bags and sacks are easier to store and transport).

Returns to technology:

There are multiple documented benefits to usage of metal silos for grain storage:

- Metal silos helped mitigate losses due to insect pests in a trial in Kenya. The reduced losses saved the farmers an average of 150–198 kg of grain, worth KSh9750 (US $130). The grain saved represents four months of maize consumption by an average family of six. The value of saved grain is substantial, especially when compared to the food poverty line KSh988 (US$13) per adult per month of rural Kenyan farmers.
- Metal silo adopters also spent about KSh340 (US$ 4.5) on storage insecticides, compared with KSh1740 (US$ 22.9) for non-adopters, a gain of about KSh1400 (US$18.4). This represents only part of the potential savings, since grain stored properly in metal silos does not require the addition of insecticide for storage.
- The reduction in storage losses appeared to lead to changes in storage and marketing behavior. Households who adopted metal silos were able to store their maize for 1.8–2.4 months longer than similar non-adopting households. Households without metal silos sold most of their marketed maize grain within the first few months after storage, at the low prices prevailing during that period. The adopters only sold a small portion of their maize in the months after harvest, and sold much of their marketed grain after five months at much higher prices. In another study, Latin American farmers with metal silos were able to store their maize for up to two years with negligible PHL and sell it when prices were high (Fischler et al., 2011). In the same

[7] This section is adapted from [10].

study, subsistence maize farmers with silos saved much of their harvested maize for their own consumption and increased their food security by 30–35 days per year.

Technology type[8]: Zero Energy Cool Chamber

Applicability: Perishable fruits and vegetables

Technology detail:
The Zero Energy Cooling Chamber, or ZECC for short, is a simple storage structure that has been shown to increase shelf life and quality of farm produce, particularly fruits and vegetables, by maintaining cool temperature and appropriate humidity inside the chamber. As suggested by the name, the technology does not require any electricity, which makes it particularly attractive for rural smallholder farmers who may be off the electric grid. A typical chamber consists of a double brick wall, with the space between two walls filled with moist sand; the sand cools the chamber as the water evapo-rates. Farmers can store their fresh produce inside the covered chambers

Returns to technology:
One study designed and field tested a ZECC with thatched roof and concrete floor in Ghana for temporary storage of cabbage. The study measured the temperature inside the unit daily and compared this to the ambient conditions in a typical storage shed. Typical postharvest losses for cabbages in Ghana are extremely high (60%) because of weight loss when handled and stored at ambient temperatures and low relative humidity. Use of the ZECC reduced the weight loss to 36% of the initial level due both to the decrease in temperature and increase in relative humidity in the chamber.

Construction of the ZECC used in this study cost US$ 1040 including labor ($813 if the farmer builds it him or herself and does not account for his cost). The volume of produce available for sale after 6 days of storage at ambient conditions versus in the ZECC increased from 40 to 62% of the harvested crop. While the market price per kg of cabbage did not change, the visual quality of that kept in cold storage was better maintained. The cost of the technology at $1040 would be covered after 18 uses. Compared to the ambient temperature storage or immediate sale, each subsequent 200 kg load would provide $58 in additional profit.

[8] This section is adapted from [12].

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