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Research Article

Post-Harvest Loss Reduction and Improved Grain Storage for Smallholder Food Systems

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Abstract

A large share of the grain that farmers grow never reaches a plate. It is lost during harvesting, drying, threshing, transport, and storage to insects, rodents, mould, spillage, and poor handling, and what survives often loses quality, market value, and nutritional value. Post-harvest loss is therefore not only a technical problem of bins and bags; it is a food security, income, health, and gender problem, because losses fall hardest on households that can least afford them and on women who do much of the drying, cleaning, and storage work. This article reviews post-harvest loss reduction as an integrated agronomic and food-systems problem, covering where losses occur, why they occur, and which interventions work: timely harvesting, improved drying, threshing and cleaning, hermetic storage, metal silos, improved cribs, pest management, moisture measurement, and market and finance arrangements that make storage profitable. It shows that hermetic bags and metal silos can cut storage losses sharply, but only when grain is dried to safe moisture before storage, when pest pressure is understood, and when farmers can afford the technology and can sell later at a better price. It proposes a field-scale decision framework based on measuring loss, drying first, storing safely, and monitoring, and it identifies research and policy priorities for scaling loss reduction without creating new burdens.

Keywords: post-harvest loss; grain storage; hermetic storage; drying; aflatoxin; smallholder food systems

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1. Introduction

Harvest is not the end of farming; it is the start of a second, often invisible, farming system. After a crop is cut, it must be dried, threshed, cleaned, transported, stored, and sold or eaten over months. At each step, grain can be lost or damaged. Global estimates vary by crop, method, and definition, but post-harvest losses of cereals and legumes in sub-Saharan Africa and South Asia are commonly estimated at one-tenth to one-third of production, with higher losses for perishable crops and in humid, poorly connected areas (FAO, 2019; Kumar and Kalita, 2017). For a household that harvests ten bags of maize, losing two bags to weevils, mould, and rodents is equivalent to losing one-fifth of the season's labour, land, seed, and fertiliser.

Losses are not only quantitative. Grain that is stored wet can develop mould and aflatoxin, a toxin produced by Aspergillus fungi that is harmful to people and livestock and that can make grain unsellable in formal markets (Williams et al., 2004; Kamala et al., 2018). Grain that is damaged by insects loses weight, germination, and market value. Grain that must be sold immediately after harvest, because there is no safe storage, is sold when prices are lowest. Post-harvest loss therefore connects agronomy to nutrition, health, income, and gender: the work of drying and storing is often done by women, the risk of aflatoxin exposure falls on the household, and the cash lost to forced early sales falls on everyone.

This article reviews post-harvest loss reduction as agronomy. It asks where losses occur, which interventions reduce them, under what conditions they pay, and what institutional arrangements, markets, finance, and extension, are needed for them to scale.

2. Where Losses Occur and Why

Losses begin at harvest. Harvesting too early can reduce yield and increase drying needs, while harvesting too late can increase shattering, lodging, bird damage, and pest infestation (Kumar and Kalita, 2017; FAO, 2019). In rain-fed systems, a harvest that coincides with rain can make drying difficult and increase mould risk. Threshing and shelling can cause physical damage, spillage, and contamination if equipment is poorly adjusted or if grain is threshed on bare ground. Transport in open bags, baskets, or carts can spill grain and expose it to rain.

Drying is the most critical step. Grain must be dried to safe moisture, typically around 12 to 14 percent for maize and similar cereals, and lower for some legumes and oilseeds, before it can be stored safely (FAO, 2019; Bradford et al., 2018). If grain is stored wet, respiration, mould, and insect activity increase rapidly. Traditional sun-drying on mats, tarpaulins, or concrete can work well when weather is dry and labour is available, but it is slow, labour-intensive, and vulnerable to rain, dust, and contamination. Mechanical dryers, solar dryers, and drying on raised platforms can reduce drying time and contamination, but they require capital, fuel or electricity, and maintenance.

Storage losses are caused mainly by insects, rodents, and mould. The maize weevil, larger grain borer, and cowpea bruchid are major storage pests in many systems, and they can multiply rapidly in warm, humid storage (Kumar and Kalita, 2017; Njoroge et al., 2014). Rodents can consume and contaminate large quantities, and their damage is often under-recorded. Mould and aflatoxin are favoured by high moisture, high temperature, and damaged grain. The common thread is that storage losses are not random: they are highest where grain is stored wet, where storage is not sealed, where pest pressure is high, and where grain is stored for long periods without monitoring.

3. Drying, Threshing, and Handling

Timely harvesting and rapid drying are the foundation of loss reduction. Farmers who harvest at physiological maturity, dry promptly on a clean surface, and protect grain from rain can reduce losses more cheaply than farmers who invest in an expensive store but store wet grain (Bradford et al., 2018; FAO, 2019). Moisture measurement is a key tool: a simple moisture meter, a salt test, or a bite test can help a farmer decide whether grain is dry enough to store. Without a moisture check, a farmer may store grain that looks dry but is still too wet inside.

Improved threshing and cleaning can also reduce losses. Mechanical threshers and shellers can reduce labour, spillage, and grain damage compared with beating grain on the ground, but they must be adjusted to the crop and moisture, and they must be cleaned between varieties to avoid mixing (Kumar and Kalita, 2017). Winnowing and cleaning remove chaff, dust, and broken grain that harbour mould and insects. Sorting out damaged, discoloured, and mouldy grain before storage can reduce aflatoxin risk, because aflatoxin is concentrated in damaged kernels (Kamala et al., 2018; Williams et al., 2004).

Handling matters for quality. Grain that is handled in clean, dry containers, protected from rain during transport, and not mixed with old, infested grain will store better than grain that is handled carelessly. Simple practices, such as cleaning the store before filling, repairing cracks, and using pallets to keep bags off a damp floor, can reduce losses at almost no cost (FAO, 2019; Njoroge et al., 2014).

4. Hermetic Storage, Metal Silos, and Improved Cribs

Hermetic storage seals grain in an airtight container, so that respiration by grain, insects, and mould depletes oxygen and increases carbon dioxide to levels that suppress insect activity (De Groote et al., 2013; Njoroge et al., 2014). Hermetic bags, such as PICS bags with double or triple liners, are widely used for maize, cowpea, and other grains because they are relatively affordable, reusable for several seasons, and do not require pesticide. Studies in several African countries have found that hermetic bags can reduce storage losses to low levels and preserve germination and quality, provided grain is dried to safe moisture before sealing (De Groote et al., 2013; Njoroge et al., 2014). If grain is sealed wet, mould and aflatoxin risk increases, which is why drying first is non-negotiable.

Metal silos provide a durable, rodent-proof, airtight store that can last many years and can be used for larger quantities (Tefera et al., 2011; FAO, 2019). They require a higher upfront investment and skilled fabrication, and they must be sealed and maintained correctly. Improved cribs, with raised floors, ventilation, and rodent guards, can improve traditional maize cribs by reducing moisture and rodent access, while remaining affordable and repairable with local materials (Kumar and Kalita, 2017). The choice among hermetic bags, silos, and cribs should depend on quantity, storage duration, pest pressure, capital, and whether the farmer wants to store for home consumption, seed, or sale. Figure 1 summarises the pattern from the cited syntheses: hermetic and metal storage cut losses most, but only when drying is done first.



Figure 1. Post-harvest loss and retained quality under storage options, based on synthesis of the reviews and evaluations cited in the text. Values vary by crop, moisture, pest pressure, and duration.

5. Pests, Mould, and Aflatoxin in Storage

Storage pest management starts with prevention: dry grain, clean store, seal container, and do not mix new grain with old infested grain. Where pesticides are used, they must be approved for stored grain, applied at the correct dose, and used with a withdrawal period and safety precautions, because residues can harm people and can make grain unsellable (Kumar and Kalita, 2017; FAO, 2019). Botanical protectants, such as neem, and inert dusts, such as diatomaceous earth, are used in some systems, but their efficacy varies with dose, grain, and pest, and they should be tested locally before scaling.

Aflatoxin control requires attention from field to store. Pre-harvest drought, insect damage, and delayed harvest increase aflatoxin risk, while rapid drying, sorting, and dry storage reduce it (Williams et al., 2004; Kamala et al., 2018). Aflatoxin cannot be removed by cooking, and it cannot be seen, so prevention is the only reliable strategy. Farmers who can test grain for aflatoxin, through cooperatives, buyers, or laboratories, can sort and sell more safely, but testing must be affordable and results must be trusted. Where aflatoxin is prevalent, public health and market incentives must align: buyers who pay a premium for safe grain create an incentive to dry and sort, while buyers who accept any grain at the same price remove that incentive.

6. Economics, Markets, Finance, and Gender

Storage pays only if the price later is higher than the price now by enough to cover storage cost, loss, and the value of cash forgone. In many markets, prices rise after harvest as supply falls, but the rise is uncertain, and a farmer who needs cash for school fees, health care, or debt repayment may have to sell early regardless of storage (De Groote et al., 2013; Tefera et al., 2011). Warehouse receipt systems, cooperative storage, and inventory credit, where stored grain serves as collateral for a loan, can help farmers store and wait for better prices, but they require trusted warehouses, price information, and legal frameworks (FAO, 2019).

Gender and labour shape who benefits from storage. Women often do drying, cleaning, and storage, but may have less control over decisions to sell or to invest in a silo or hermetic bags (Farnworth et al., 2017; Huyer et al., 2015). Storage technologies that are heavy, expensive, or require travel to a distant warehouse may be less accessible to women than bags that can be stored at home. Programmes that involve women in technology choice, that schedule training at accessible times, and that ensure income from stored grain is shared fairly are more likely to produce durable adoption. Table 1 summarises storage options, while Table 2 proposes indicators for monitoring.

A practical framework for post-harvest loss reduction can be stated in six steps. First, measure: estimate loss by stage, from harvest to storage, by weighing and recording. Second, dry first: dry to safe moisture and check moisture before storing. Third, clean and sort: remove damaged, mouldy, and infested grain. Fourth, store safely: use a sealed, clean, rodent-proof store matched to quantity and duration. Fifth, monitor: check moisture, insects, and mould during storage and act early. Sixth, sell wisely: compare price, storage cost, and cash need before deciding when to sell.

Tables

Table 1. Storage options and their main mechanisms. If continued overleaf, the continuation is headed Table 1 (continued) and repeats the column headings.

Storage option	How it works	Main advantage	Main limitation
Hermetic bag	Airtight liner, oxygen depletion	Low loss, no pesticide, affordable	Must dry first, liner can tear
Metal silo	Airtight metal, rodent-proof	Durable, large quantity, low loss	High upfront cost, needs fabrication
Improved crib	Raised, ventilated, rodent guard	Affordable, local materials	Less airtight, shorter protection
Woven bag + pesticide	Chemical protectant	Low upfront cost	Residue risk, resistance
Cold + hermetic	Low temperature + sealing	Very low loss, quality	Needs electricity, high cost

Table 2. A balanced indicator set for post-harvest loss reduction. If continued overleaf, the continuation is headed Table 2 (continued) and repeats the column headings.

Dimension	Indicator	Practical measurement
Loss	Weight loss by stage	Weighing, records
Quality	Moisture, aflatoxin, damage	Moisture meter, sorting, test
Income	Price, gross margin, sales timing	Cost, price, sales records
Health	Aflatoxin exposure, residues	Test, farmer recall
Gender and labour	Workload by gender, adoption	Household survey
Adoption	Use, reuse, persistence	Panel records

7. Future Research and Policy Priorities

Future research should report loss, quality, aflatoxin, cost, labour, and income together, rather than loss alone. Long-term, multi-season studies are needed because pest pressure, prices, and weather vary, and a technology that pays in one season may not pay in another. Research on low-cost moisture measurement, solar drying, and affordable hermetic storage for small quantities is more valuable for smallholders than further development of large, capital-intensive systems (Bradford et al., 2018; De Groote et al., 2013). Research on aflatoxin testing that is affordable, rapid, and trusted at cooperative level is urgent. Policy should support loss reduction through extension on drying and storage, standards and premiums for safe grain, warehouse receipt and inventory credit systems, and regulation of stored-grain pesticides. Public investment in drying infrastructure, cooperative storage, and market information can make storage profitable for farmers who currently must sell at harvest.

8. Conclusion

Post-harvest loss reduction is not only about bins and bags. It is about drying first, storing safely, monitoring during storage, and selling wisely, supported by markets, finance, and extension that make storage pay. When grain is dried to

safe moisture, cleaned and sorted, stored in a sealed, rodent-proof container, and monitored, losses can be cut sharply, quality and safety can be preserved, and income can rise. When grain is stored wet, in an unsealed container, without monitoring, even the best store will fail. The priority is practical: measure loss, dry first, store safely, monitor, and learn from each season.

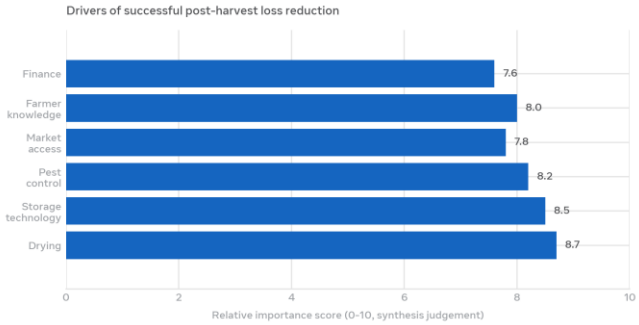

Figure 2. Drivers of successful post-harvest loss reduction, based on synthesis judgement from the cited evidence. Drying and storage technology are central.

The practical implication is that post-harvest investment should be sequenced, not bought as a single package. A farmer who first learns to test moisture, dry on a clean surface, and sort damaged grain will get more value from a hermetic bag than a farmer who buys the bag but stores wet grain. A cooperative that first builds trust in weighing, grading, and record-keeping will get more value from a warehouse than one that builds the warehouse first. Extension, therefore, should teach the sequence, drying, cleaning, sorting, storing, monitoring, selling, and help farmers practise it on a small quantity before they commit a whole harvest. That small, low-risk trial, repeated over two seasons, is often what turns a demonstration into durable adoption.

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Conflict of Interest

The authors declare no conflict of interest.

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