Smallholder Grain Storage in Sub-Saharan Africa

A Case Study on Hermetic Storage Technology Commercialization in Kenya

February 2016

Postharvest grain loss significantly constrains household food security across sub-Saharan Africa, and hermetic technologies offer small-scale farming families effective, cost-efficient, insecticide-free methods for on-farm storage. There are a range of suitable technologies capable of abating losses, but evidence suggests that for various reasons, low volume hermetic bags are preferred to larger scale technologies such as metal silos. Several hermetic bag products are currently available in the Kenyan market, which is rapidly evolving to meet growing demand from small-scale farmers. A case study of the leading brand illustrates the opportunities and challenges to commercializing the technology; including raising market awareness, easing rural logistical constraints, and facilitating access to value chain finance at the manufacturer, distributor, and local dealer levels.

Overview of the Challenge

Across sub-Saharan Africa, staple grain crops provide the foundation for household food security through both income generation and direct consumption by small farming households. The continent produces more than 112 million tons of grain per year, and the grain sub-sector accounts for approximately 37 percent of incomes.1

A widely recognized constraint along grain value chains across the continent is postharvest loss, and minimizing such losses could play an important role in reducing production volumes needed to feed a growing population.2 The scope of the postharvest loss problem in Africa therefore has significant implications for food security, economic growth, and environmental degradation.

Postharvest losses are often narrowly considered as a loss of volume harvested, and this is indeed a concern. Loss estimates vary widely by country, and source; however, the African Postharvest Losses Information System estimates conservatively that volume losses across Africa range from 10-20 percent. In 2013, postharvest losses as a percent of total annual production were estimated to be almost 18 percent for maize, 12 percent for rice, 12 percent for sorghum, and nearly 10 percent for millet.3

Postharvest losses can also be more widely characterized as a deterioration of the grain condition, which leads to loss of nutritional value, monetary value (lower unit prices paid), and access to particular market segments. While loss of nutritional value is paramount given the importance of staple grains to household diets, it is less straightforward to quantify continent-wide. Similarly, assigning a monetary value to the loss of market access has proven difficult. Nonetheless, volume losses alone have been estimated at $4 billion per year across the continent, thus illustrating the economic imperative of addressing these issues.4

While postharvest losses occur during various functional processes from farm to market including threshing/shelling, drying, storage, and transport, this paper focuses on postharvest losses of whole grains during storage after harvest; particularly the causes of and strategies for abating those losses.

Hermetic storage is a proven technology for reducing on-farm and off-farm storage losses, yet

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3 http://www.aphlis.net
4 Hodges et al (2011). “Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use”
limited uptake of such technologies in Africa can be explained by more than technical factors.

First, farmers and other market actors often tolerate postharvest losses because systemic incentives to address the problem are lacking. Until output markets consistently reward producers for improved quality, they will be reluctant to invest in new technologies. Second, system-wide uptake of improved technologies will depend on various contextual factors including but not limited to cost/benefit; market actor knowledge; socioeconomic preferences; enterprise-level capacity; rural infrastructure and logistics; financial services; distribution and transport services; and the wider institutional environment. A market system perspective is necessary to facilitate the commercialization of proven technologies to reduce postharvest losses.

**Overview of Postharvest Storage Losses**

Thieves, and environmental disasters such as fires or floods notwithstanding, postharvest grain losses during storage can be primarily attributed to two main natural drivers – the relative humidity in many sub-Saharan African countries that fosters mold formation; and damage from pests such as weevils, grain borers, birds, and rodents.\(^5\)

While climate change induced temperature, humidity, and rainfall variability does exacerbate postharvest challenges,\(^6\) it should be emphasized that insect pest infestation accounts for 20-50 percent of losses.\(^7\) Traditional on-farm grain storage methods fail to alter the ambient environment and are therefore highly susceptible to molds and attacks from pests, such as insects.

The risk and magnitude of losses increase the longer grain is stored, reducing the potential for producers to take advantage of market price fluctuations after harvest. Farming households that may otherwise be net grain producers are forced to sell their grain shortly after harvest when prices are lowest to pre-empt losses, and repurchase grain in the lean season when grain prices are highest.

Access to safe, affordable grain storage technology therefore provides small-scale farming families the option of storing grain for household consumption year round, or selling when market prices are more favorable. Efficient on-farm storage provides the flexibility to optimize grain retention with income generation and holding on to maize as a household asset with an immediate market in case of emergency or alternative investment opportunities.

**Comparison of Grain Storage Technologies**

There are several methods for managing insect infestations in grain storage systems, including insecticides and fumigants, inert dusts, biological agents, and various hermetic storage technologies.\(^8\) This paper summarizes the on-farm storage methods currently being utilized, or showing promise as safe, cost-effective solutions for small-scale producers in sub-Saharan Africa; in particular, the focus is on maize, the primary staple grain in East Africa.

The traditional method for on-farm storage typically includes mud and thatch stores or simple gunny sacks. Insecticide treatment methods have become increasingly more common to protect against insects, particularly Actellic super – a combination of 1.6 percent Pirimiphos-methyl and 0.3 percent Permethrin,\(^9\) which is ubiquitous in Kenya and Tanzania. This method requires insecticide applied to dried maize, then reapplied approximately every three months depending on the local prominence of the maize weevil and large grain borer, the main scourges of stored maize in East Africa.

Hermetic storage technology is an alternative, often pesticide-free method that eliminates

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insects and molds by depleting oxygen levels and producing carbon dioxide within the storage unit.

The hermetic technology essentially uses natural respiration processes coupled with the impermeability of containers to alter the ambient environment where pests otherwise would thrive. An air-tight enclosure effectively suffocates insects by forcing them to use up the available oxygen. Hermetic principles may be applied to hard containers or flexible materials, such as bags.

Examples of hermetic storage technology applied to a container include metal silos or plastic drums soldered air tight to keep oxygen out. These may be of varying sizes from small scale to very large scale depending on the capacity of a producer or aggregator. A recent study of maize storage in small-scale metal silos found a near complete elimination of losses from insects, saving an average of 150-200 kilograms of grain, an increase of 1.8-2.4 months of storage duration, and a complete reduction in insecticide costs.\(^1\)

Hermetic storage technology using flexible materials include bags that feature high density polyethylene. Well-known hermetic storage bag products include the Purdue Improved Crop Storage (PICS) bag, the GrainPro SuperGrain bag, and the IRRI Superbag. In Kenya, following locally-led promotion of the technology, at least five brands of hermetic bags are now available on the local market. Each of these bags applies the same hermetic principles, but differs in design.

The PICS brand bag utilizes a triple layer bag system where two air-tight polyethylene bags are placed inside a protective sack. The GrainPro bag utilizes a double layer system where an ultra-hermetic gas-tight polyethylene bag is placed inside a protective sack. A new brand, the AgroZ® Bag is composed of two distinct bags, the polypropylene woven outer bag and a multilayer inner liner that is coextruded with barrier layers preventing the passage of oxygen, carbon dioxide, and water vapor. The IRRI Superbag also utilizes a double layer system where the super bag is used as a liner inside an existing storage bag.

While the IRRI Superbag was designed for rice, it is said to be suitable for a range of crops, including maize. The PICS bag was initially developed for cowpea in West Africa, but has since expanded its application to maize, millet, sorghum, and coffee in East Africa. The GrainPro bag is marketed for a wide range of grains including maize, rice, sorghum, and wheat, as well as other commodities such as cocoa, coffee, and soybeans.

In terms of comparative efficacy, evidence suggests that the varied hermetic storage technologies offer similar benefits. In a four month experiment comparing PICS and GrainPro brand bags, researchers found that “preservation of the grain was equally good in both types of bags.”\(^1\)

Additional studies have concluded that it is technically feasible to control insects without insecticide in Africa by using either hermetic metal silos or hermetic bags.\(^2\)

Such studies offer an important indicator that the commercialization of various suitable hermetic storage technologies is important to expand access for small-scale producers and aggregators. Where awareness and demand for the technology can be raised, supplier competition will prove an important driver of improved supply chain efficiencies and reduced retail costs for farmers.

Nonetheless, each of the varied hermetic storage technologies available possess characteristics that will influence their uptake. The first important characteristic to consider is cost. In Kenya, an analysis of alternative maize storage technologies shows that a common insecticide treatment method costs approximately $30/ton, and the GrainPro Superbag costs approximately $52/ton; a 0.36 ton metal silo will cost approximately $316/ton.\(^3\) As the capacity of the metal silo increases, although the overall cost increases, economy of scale drives the unit costs down. A metal silo with 0.72 ton capacity costs $216/ton, while a 1.8 ton capacity silo costs $171/ton.

Unfortunately, small-scale farmers are often unable to access the capital necessary to invest even in the smallest metal silos, let alone to seize economy of scale with the larger scale silos.

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\(^1\) Gitonga, Z. et al (2013). “Impact of metal silos on households’ maize storage losses, and food security”


Therefore from a direct cost perspective, hermetic bags are more attractive than hermetic silos for small-scale producers.

Additional socioeconomic factors suggest hermetic bags are preferred to hermetic silos for on-farm storage at the small-scale producer level. First, in areas where natural disasters (floods, fires, etc.) are common, or where conflict is prevalent, bags provide the added benefit of mobility whereas silos are sedentary. Second, theft may be a common occurrence, and bags enable farming families to hide their grain. And third, the culture of reciprocity often places social pressure on successful farming families to give away their surplus grain to family and/or community members who have a grain deficit in lean periods. Many farming families prefer to conceal their surplus grain to avoid this pressure and save grain for future consumption or sale.

A Case Study in Kenya

Maize is a particularly important staple food crop in East Africa that accounts for 50 percent of caloric intake, and at least 70 percent of seeds are sourced from the previous harvest.\(^{14}\) In Kenya, total annual maize production fluctuates between 2.9 million and 3.4 million tons valued at up to $1 billion, but net imports of 350,000 tons cost the country more than $130 million per year.\(^{15}\) Thus, the Kenyan government sees achieving maize self-sufficiency and re-emerging as a regional net-exporter as main priorities.

With average farm sizes under 4 acres nationwide, and average per hectare maize yields declining from 2.2 metric tons in the 1990s to 1.74 metric tons in 2012, farmers must optimize land to achieve the highest possible returns.\(^{16}\) But postharvest maize losses are particularly acute in Kenya, with estimates ranging from 20 to 36 percent, drastically reducing the volume of maize available for consumption and trade.\(^{17}\)

Reducing on-farm postharvest losses is one important component of optimizing scarce resources, and is therefore likely to have high returns at the farm and the national supply level. At the national level, reduced postharvest losses will support maize self-sufficiency. At the farm-level, reducing losses will free land that can be allocated to higher value agricultural products like fruits, vegetables, and dairy.

**Commercializing Hermetic Storage Technologies**

Recognizing this imperative, Fintrac began addressing postharvest challenges in Kenya from 2013 through both the Feed the Future Partnering for Innovation (FTF-P4I) project and the USAID Kenya Agricultural Value Chain Enterprises (KAVES) project. Leveraging past lessons learned, these initiatives focused on commercializing modern, low-cost hermetic storage technologies suitable for small-scale on-farm use.

The market for postharvest storage technologies was nascent, yet rapidly evolving with new products and providers entering regularly. Rather than selecting the technology, brand, and provider that was presumed to emerge as the market leader, a range of commercial pilots were initiated to enable market dynamics to take hold.

Early stage market access was facilitated for a number of hermetic technologies including small-scale metal silos, the PICS brand bag, the GrainPro brand bag, and the AgroZ Bag. Each product was examined for technical efficiency, cost effectiveness, and cultural preference. Additionally, project teams sought to identify which commercial partners would emerge as committed, entrepreneurial, and adaptive to changing market conditions.

The KAVES team field tested the GrainPro brand bags and facilitated farmer demonstrations with local distributor Kenya Promotions & Marketing Company, local non-governmental organization Farm Concern International, and the Africa Farm and Markets Network to raise market awareness. The product has proved technically effective, but farmer uptake has thus far been limited. As the inner and outer layers of the product need to be purchased separately, the costs are higher than competing products.

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\(^{14}\) Yakubu, A. (2012). “Reducing losses to maize stored on farms in East Africa using hermetic storage”

\(^{15}\) FAO (2014). “Food Loss Assessments: Causes and Solutions”

\(^{16}\) USAID KAVES (2015). “Policy Brief on the Maize Value Chain”

\(^{17}\) USAID KAVES (2014). “Maize Value Chain Analysis”
For small-scale metal silos, KAVES conducted field trials, and trained 65 rural artisans in silo fabrication. Again, the technology proved to be technically efficient, but the price for farmers and farmer groups has been prohibitive. Additionally, farming families prefer the relative mobility and discretion that grain storage bags provide. For these reasons, small-scale metal silos currently face several cost and distribution challenges limiting the scale of uptake among farming families.

AtoZ Textile Mills, Ltd, based in Arusha, Tanzania, recently introduced a new hermetic bag product into the Kenya market under the AgroZ® brand name. KAVES is currently testing 300 bags in small-scale producer areas. Although too soon to determine the success this product may achieve, early indications suggest AgroZ is a committed and capable manufacturer with significant regional distribution networks.

The most significant commercial momentum at the small-scale farmer level in Kenya to date has been observed with the PICS brand bags. The technology was initially developed through support from USAID’s Collaborative Research Support Program with Purdue University in Cameroon from 1987-2002 to reduce postharvest losses of cowpea, and then received support from the Bill and Melinda Gates Foundation in 2007 to expand crop applicability and regional focus. By 2013, Kenya had not been explicitly included as a target country through these efforts, but then came the FTF-P4I project, funded under the US Government’s Feed the Future initiative, and implemented by Fintrac.

In September 2013, FTF-P4I provided a 12 month grant to Purdue University in partnership with Bell Industries to introduce and expand access to the storage bags for small-scale farming families in Kenya. Purdue identified and provided exclusive national license rights to Bell Industries, as local private sector distributor. Under this model, Bell leads production, marketing, and distribution, and maintains profits from sales, less the small annual licensing fee paid to Purdue. The FTF-P4I funding provided distributor training and resources for initial farmer demonstrations in key markets.

Meanwhile, KAVES embarked on an independent field trial to test 2,500 bags with small-scale farmers across 22 counties and document the technical efficacy and the benefit/cost of PICS brand bags compared to insecticide treatment methods. The results confirmed that the PICS brand was technically efficient in small-scale farming communities targeted for support. Maize grain dried to appropriate moisture levels (13.5-14 percent) showed constant moisture and no live insect infestation after six months of storage.

A financial analysis illustrates the cost efficiency of hermetic storage bags compared to the status quo storage method. Table 1 lays out the initial costs of storing maize through the common insecticide treatment method compared to PICS brand bags.

<table>
<thead>
<tr>
<th>Costs (KES)**</th>
<th>Insecticide treated bag</th>
<th>PICS brand bag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag</td>
<td>40</td>
<td>250</td>
</tr>
<tr>
<td>Actellic dust</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Dust application labor</td>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>Bagging labor</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>213</strong></td>
<td><strong>300</strong></td>
</tr>
</tbody>
</table>

* USAID-KAVES, PICS field trial results (unpublished)  
** 100 KES ~ $1 USD

When comparing initial costs alone, one may understand why farmers would be reluctant to adopt this new technology. The cost of the bag system itself is over six times the cost of the traditional gunny sack, and even when chemical treatment and labor costs are considered, the pesticide method is 25 percent less expensive.

However, initial costs alone fail to account for the repeated costs associated with insecticide application and the useful lifespan of hermetic storage bags. The chemical treatment effectively abates losses through the first three months of storage, but its effectiveness wanes thereafter, requiring reapplication. An analysis of net benefits of each technology at different storage durations throughout the year tells a more complete story. Table 2 illustrates that the status quo method of chemical treatment is not economically rational at any point over a 12-month period.

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18 PICS Newsletter, Volume 1, Issue 1, 2015
The cost of reapplying insecticide treatment (chemical costs + labor costs) every three months exceeds the average marginal price increases of maize at three month intervals. Thus, in an average year farmers could sell their maize at harvest and then purchase maize in the market throughout the year; they would be better off than storing their maize with insecticide treatment. So, the insecticide treatment method should be viewed as an inefficient insurance policy against market shocks.

Hermetic storage bags provide this insurance at a lower cost, and deliver tangible returns throughout the year. The only costs to consider are the purchase price of the bag and initial bagging labor. The PICS brand bag for example can exceed the benefits of the insecticide treatment at six months of storage, and begin delivering net benefits to the farmer at nine months. The benefits of the technology continue to increase through the three-year lifespan of the product if perforation of the bag is avoided.

**Facilitating Market Awareness and Demand**

The investment horizon perceived by a small-scale farmer is often shorter term than rational economic analysis would suggest. Farmers observe higher initial costs and are reluctant to change their practice, failing to see the longer term benefits. This is understandable for farmers operating in uncertain and risky environments.

Fintrac recognized that a market awareness and behavior change campaign was necessary to demonstrate the longer term comparative advantages of the hermetic storage bags. Therefore, KAVES expanded the demonstration model beyond the limited time period and geography under the one year pilot phase funded by FTF-P4I. Efforts focused on building the capacity of the distributor to embed extension agents in their business capable of demonstrating hermetic storage benefits to farming communities. KAVES provided the logistical support for field officers of several product distributors to access small-scale farming communities and conduct demonstration events. From 2014-2015, demonstrations were delivered to over 300 rural extensionists and over 5,000 lead farmers to expand awareness.

Distributors very quickly learned that once farmers understood how hermetic storage worked, and observed the comparative benefits (including financial returns and labor efficiency), the market demand for the bags spread so rapidly that it outpaced the capacity of distributors to fill orders.

### Rural Supply Chain Challenges and Solutions

Despite rapid end market demand growth, the most significant constraints to commercializing hermetic storage bags in Kenya were rural logistics and value chain finance. The high costs of transportation to rural production areas meant that already thin margins on hermetic bags at the national distributor level were squeezed further. To bring costs down, a more efficient distribution system was needed rather than direct to the consumer. Distributors needed to develop relationships with a network of rural dealers/stockists that would enable them to reach widely dispersed small-scale farmers more efficiently.

With extensive knowledge and networks in maize production areas, KAVES was in a unique position to facilitate access for distributors of hermetic storage bags to agro-dealers within those communities. Distributor-led rural demonstration events in farming communities served the dual purpose of raising awareness among end users, and enabled the distributor to rapidly identify hundreds of rural dealers who were interested in stocking the technology.
Additionally, access to finance at the manufacturer, distributor, and stockist levels limited commercial actor capacity to meet farmer demand. With regard to the PICS brand bag, a local manufacturer was selected by the exclusive distributor for their quality control capacity, but their unwillingness to finance inventory purchases for the distributor limited growth potential. Meanwhile, the distributor extended a 60-day line of credit to their stockists to purchase retail inventory. Without a similar line of credit from their manufacturer, the distributor was faced with a significant cash crunch, as well as exposure to repayment risk from their stockists. Where receivables from stockists were in excess of 60 days past due, the distributor faced significant challenges purchasing additional inventory from their manufacturer to keep up with farmer demand.

To address these challenges, KAVES provided access to a working capital fund in the amount of $120,000 to finance inventory and on-lend to stockists. This initial infusion of capital enabled the distributor to meet orders from stockists, maintain momentum of technology uptake, and provide proof of concept for private financial markets. KAVES is currently working with a number of financial institutions to institutionalize the concept of a revolving credit fund for hermetic storage technology distribution.

Given continued demand growth, the exclusive distributor of the PICS brand bag recognized that vertical integration, specifically investing in in-house manufacturing, would reduce reliance on a single manufacturer and ultimately bring down costs of goods sold. Unfavorable credit terms (22 percent borrowing costs) forced the distributor to invest approximately $45,000 of their own capital on the equipment necessary to manufacture the PICS brand bags. Their first run of in-house manufacturing was completed in January 2016.

**Overview of Commercial Results**

While transactional data alone should not be considered indicative of broad-based systemic change, it does offer an important indicator for tracking the commercial momentum of a given technology in the market. In the case of the PICS brand product in the Kenyan market, exponential sales growth over a relatively short period of time clearly indicates robust demand for hermetic storage bags from farmers.

Initial sales targets for the FTF-P4I project were 17,500 units by 2014, reflecting the conservative expectations and limited commercial success prior to 2013. By the end of 2014, actual sales had exceeded targets by a multiple of 3.5, reaching 69,209 bags sold. One year later, sales had grown an additional 200 percent and reached 215,248 in 2015 alone, illustrating the exponential growth of the brand in the marketplace. Graph 1 illustrates the growth in average monthly sales of the PICS brand bags from November 2013 to January 2016.

**Graph 1: Average Monthly PICS brand bag sales**

![Graph 1: Average Monthly PICS brand bag sales](image)

By the end of January 2016, total unit sales of PICS bags reached 304,683 equaling 49.1 million Kenyan Shilling ($481,000), representing up to 27,421 metric tons of maize stored by small-scale farming families. Sales by suppliers of other hermetic storage bag brands are estimated to add another 10 percent to the total uptake of the technology to date, and are expected to gain an increasing market share in the future. This in itself indicates that hermetic bags have reached the commercialization tipping point where new products and actors are emerging regularly to respond to end market demand.

**Summary and Lessons Learned**

Hermetic storage technologies offer a clear value proposition at both the small-scale farming family level and the national level. At the farm level, reduced losses increase availability of food, and reduce the need to sell grain when prices are
lowest and/or purchase grain when prices are highest. At the aggregate level, reduced losses coupled with increased productivity reduces the demand for imported grain.

With the range of technically efficient hermetic storage technologies to address on-farm post-harvest storage losses, including metal silos and various hermetic bag products, hermetic bags possess several characteristics that make them preferable to silos at the small-scale farming family level, including cost effectiveness, labor efficiency, mobility, and discretion.

There had been limited commercial success of hermetic storage bags in the Kenyan market prior to support from the FTF-P4I and KAVES projects in 2013. Rapid commercialization of the technology is now evident through actual product sales and the evolution of the competitive landscape. There are indications that the PICS brand bag has established early momentum as the market share leader, but new providers and products are entering the fray regularly.

Key challenges for private sector distributors of hermetic storage bag products will include 1) expanding market demand to the population level through nationwide consumer awareness campaigns, 2) establishing efficient rural distribution networks, and 3) obtaining working capital credit through financial service providers and/or innovative value chain arrangements.

There are no quick wins when it comes to hermetic storage technology innovation and commercialization in Africa. Ultimately, success relies on a private sector led process of testing, learning, and adapting. But development partners can play an important role in jump starting the technology commercialization process through initial technical, logistical, and concessionary financing support to private sector actors committed and capable of serving the small-scale farmer market.

If you have any questions about the information presented here, please contact info@fintrac.com