HERMETIC STORAGE: SAVE MONEY, SAFE FOOD

An AflaSTOP Brief

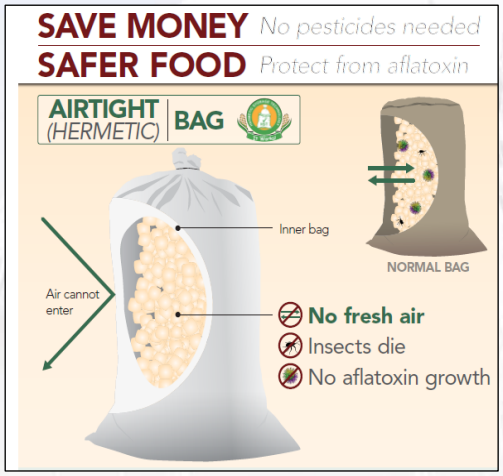
In the fight against aflatoxin contamination and its devastating effects on human health and food security, storage is a critical battleground.

Although grain is initially contaminated in the field, **aflatoxin can grow at alarming rates during storage**, rapidly increasing the concentration of toxin and exposure over time, as maize is incrementally taken out of storage for a family's own consumption or sold into the market for others to purchase. In fact, scientific research conducted by AflaSTOP in Kenya saw aflatoxin levels in maize in different areas grow by an average of 24 to 92 percent *per month* when stored in traditional polypropylene bags, commonly used by smallholder farmers in East Africa.[1]

Hermetic (i.e. airtight) storage devices arrest aflatoxin growth nearly entirely. This has been substantiated through research in both real-world and controlled settings. Complemented by recent advancements in commercially viable and locally available options for smallholder farmers, hermetic storage offers tangible hope in mitigating aflatoxin's blight.

This brief explores hermetic storage's important role with respect to aflatoxin, while also highlighting its relevance to other critical development concerns such as **reducing post-harvest losses** and **supporting commercial solutions**. It presents four evidence-based benefits of hermetic storage, building on the investments of USAID and the Bill and Melinda Gates Foundation in Kenya through the AflaSTOP program.

Figure 1: Excerpt from promotional flyer capturing the benefits of hermetic storage



- **It's effective:** hermetic storage arrests aflatoxin growth.
- **It's attractive:** hermetic storage prevents infestation and moisture loss, reducing post-harvest loss.
- **It's affordable:** cost-effective storage options exist.
- **It's accessible:** commercially available solutions are in the marketplace now.

AflaSTOP is leveraging scientifically rigorous research and human-centric design, grounded in marketplace realities, to support post-harvest storage solutions and to develop and commercialize new drying technologies in order to prevent and control the spread of aflatoxin in maize. It is implemented by ACDI/VOCA and Agribusiness Systems International, under the direction of Meridian Institute supporting the objectives of the Partnership for Aflatoxin Control in Africa (PACA), and funded through a Global Development Alliance between USAID and BMGF. For more info visit www.acdivoca.org/aflastop.

[1] *The Comparative Effects of Hermetic and Traditional Storage Devices on Grain: Key Findings from AflaSTOP's "Off-Farm", Controlled Tests in Eastern Kenya*. AflaSTOP, 2015.

Aflatoxin: the problem

Aflatoxin is a highly toxic substance caused by the growth of toxic strains of *Aspergillus* fungi, and is known to cause liver cancer, immune-system suppression, growth retardation, and death in both humans and domestic animals. It affects many important food crops in sub-Saharan Africa, including maize and groundnuts, and is present in products such as milk, meat, and eggs through contaminated animal feed. Mothers also pass the toxin on to their infants through breastmilk. Aflatoxin threatens efforts in Africa to achieve agricultural development, food security, and better health outcomes.

In addition to agro-ecological factors (e.g. warm and humid climates, drought that stresses crops at certain growth stages), other factors that contribute to contamination include harvesting immature grain, drying grains on the ground or delaying drying.

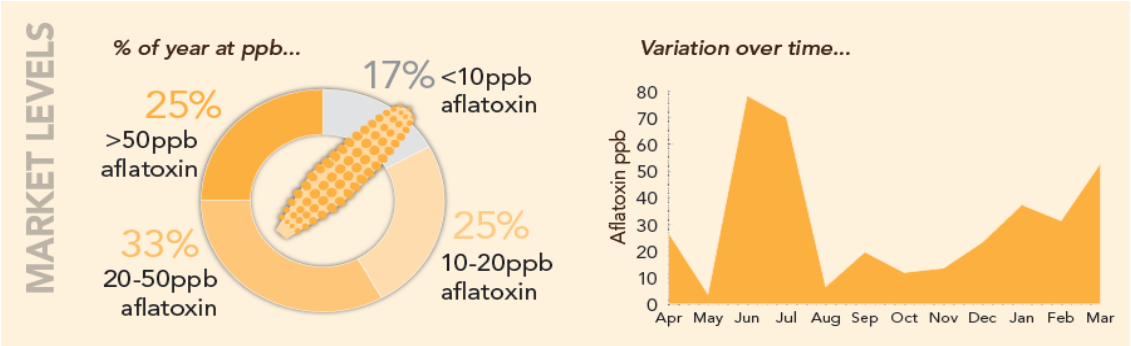
The key mitigation measure to have emerged in recent years is Aflasafe™, a bio-control applied to the soil that introduces non-toxic *Aspergillus* strains to out-compete local toxic strains. This is hugely important as contamination begins in the soil, but it is also costly, not currently widely available to most rural farmers, and requires widespread, regular use.

Post-harvest mitigation measures are therefore critical, because – regardless of conditions when maize enters storage in traditional polypropylene (PP) bags - by the time it is eaten months later, aflatoxin levels can increase tremendously. This is true even for maize harvested with minimal initial contamination levels and dried to a moisture content below the recommended 13.5 percent.

In certain areas of Kenya, aflatoxin is particularly prevalent. For example, in the areas where AflaSTOP sourced maize in 2014 (Makueni and Meru, Kenya), 75 percent of farmers tested through the project's research had maize contaminated above 10 ppb at harvest, the limit set as 'safe' by East African governments. The baseline level in one region was 500 ppb; in another region, it was 1,900 ppb[2]. These levels are incredibly high and well beyond 'safe', and they increase during the 4.5 months an average famer in Eastern Kenya stores maize each season.

When farmers run out of their own maize, they turn to their neighbors and the market for their main food supply. Yet maize purchased in the marketplace is also often contaminated, though levels changes over time, as shown in Figure 2 below. The high level of contamination in maize available on the market is likely linked to how long the local maize has been stored before farmers sell to traders.

Figure 2: Aflatoxin contamination of maize in Makueni, Kenya open-air markets, April 2015-March 2016



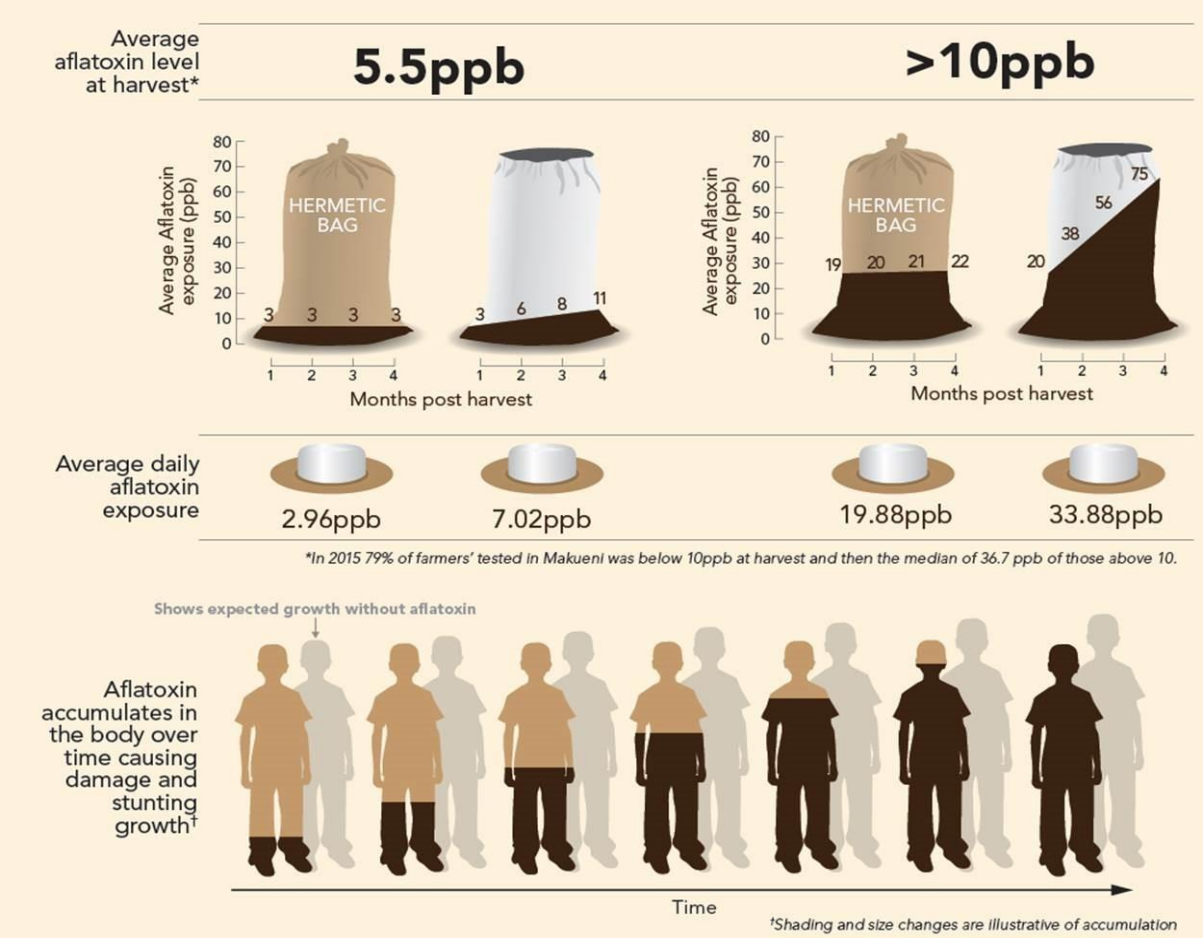
Source: AflaSTOP data.

[2] *Findings from On-Farm Acquisition of Maize Contaminated with Aflatoxin*, AflaSTOP, June 2014 and *The Comparative Effects of Hermetic and Traditional Storage Devices on Grain: Key Findings from AflaSTOP's "Off-Farm", Controlled Tests in Eastern Kenya*. AflaSTOP, 2015.

What does this mean for a typical smallholder household?

As illustrated in Figure 3, a family's exposure to aflatoxin increases with every meal of maize, as aflatoxin accumulates in the body over time. This daily exposure to toxin increasingly damages the body. Drawing on data collected by AflaSTOP in Eastern Kenya about consumption levels of maize, and comparing farmers whose maize started below 10ppb and those which started above 10ppb, an adult will have consumed between 800 - 3,600 ppb of aflatoxin over the course of six months, eating a mix of maize stored at their own household and purchased from the market. If the household portion had been stored in hermetic bags, they would only have consumed 600 - 2000ppb[3].

Figure 3: Aflatoxin exposure and its impact on humans



* Shading is illustrative of accumulation, as is the growth of the shadow boy

HERMETIC STORAGE: PART OF THE SOLUTION

Evidence clearly demonstrates the valuable role hermetic storage plays in arresting aflatoxin growth, reducing post-harvest losses, and supporting food security. This is explored through four arguments below.

1. It's effective: *hermetic storage arrests aflatoxin growth*.

With respect to aflatoxin, evidence from the largest aflatoxin storage trial to date of small-scale grain storage devices (90 kgs – 1,000 kgs) conclusively demonstrates that hermetic storage is effective at arresting aflatoxin growth. This held true in both a controlled 'off-farm' setting, where lab technicians

[3] Below 1000ppb over 6 months from all food sources (maize, milk, meat, etc.) would be considered acceptable, approximately.

took samples and bags were stored in locked, local stores, as well as in 'real-world' settings, where farmers stored at home, loading the bags and taking grain in and out as their needs dictated.

In these off-farm tests, three tested hermetic devices – a 90 kg capacity PICS bag, an artisan built metal silo, and Grain Pro's Grain Safe 1000kg capacity bag – reduced aflatoxin increases in storage to less than 5 percent per month, compared with PP bags, which increased 24 to 92 percent per month (depending on the region). There were no statistical differences for aflatoxin growth in the control bags between maize stored with a moisture level below 13.5 percent compared to maize stored between 13.5 to 15 percent moisture content. This indicates drying is not enough to address the problem. However, if maize was not dried to below 13.5 percent moisture content before placing into hermetic storage, other problems occurred. To address this problem AflaSTOP developed the EasyDry M500, profiled in a companion brief[4].

Importantly, in research conducted in Kenya, the majority of farmers did not need to be trained to use any of the devices effectively[5] and farmer practice was not detrimental to the devices' performance.

2. It's attractive: *hermetic storage prevents infestation and moisture loss, reducing post-harvest loss.*

The key reason farmers are buying hermetic bags is driven by their dislike of using pesticides on their main food source. The pesticide is needed to prevent insect infestation, and farmers tend to use more than is actually recommended. AflaSTOP farmers related stomach problems with consumption of pesticides. The proper use of hermetic storage eradicates insect infestation, which is a benefit farmers immediately see.

Even when farmers use insecticide it does not stop insect damage completely – hermetic storage does. Additionally, hermetic storage prevents natural moisture loss. This means that at the end of storage the farmer potentially has around 4.5 kgs per 90 kg bag of additional maize to eat or sell.

These upsides have an immediate and visible impact on a farmer's finances and food security. Thus, they are the true selling points in marketing hermetic bags to farmers and will drive a wide-scale shift in purchasing decisions by farmers away from traditional PP bags and insecticide to hermetic storage options. Arresting aflatoxin is an unseen benefit.

Figure 4: Promotional Flyer, Hermetic Storage

Building on these insights into consumer behaviors, AflaSTOP developed a flyer with private sector bag producers in Eastern Kenya to more effectively promote the additional aflatoxin benefits hermetic storage provides. The flyer in Figure 4 will be used by the Department of Agriculture extension officers in heavily affected Meru and Makueni and distributed to agro-dealers.

3. It's affordable: *cost-effective storage options exist.*

Currently, most farmers use insecticide and spend around $0.81 per bag per season. Hermetic bags are designed to last between 2 to 3 seasons with the cost per use between $0.80 to $1.25. The combined value of the reduction in the loss of weight (4.5kg) as referenced above more than makes up for the additional cost of the bag within the first season.

[4] To access this brief, visit www.easydry.org.

[5] *On-Farm Storage Results*, AflaSTOP. Publication forthcoming, 2017.

Once these messages are understood by the farmer, aided by marketing from manufactures and rural input shops that interface directly with the consumer, the investment is even more attractive. Nevertheless, farmers need to plan for such an investment, so marketing the bag needs to be done *prior to harvest* so farmers can sell some maize to cover the purchase price of the bag.

Table 1 summarizes these financial benefits. Not included? An estimation of the often significant health costs associated with lifelong, consistent aflatoxin exposure – such as cancer, stunting, susceptibility to diarrhea and other diseases – and their impact on income potential.

Table 1: Financial Benefits for Farmers: Hermetic Storage

Avg cost of hermetic bag per year	-$1.25
Savings through not buying insecticide	$0.81
Value of 1.8 kg of moisture loss	$0.72
Value of 2.7 kg of insect loss	$1.08
Total savings per 90kg bag	**$1.36**
Total savings per avg 4 bags stored	**$5.44**

4. It's accessible: *commercially available solutions are in East African markets*

Farmers can access hermetic bags in the market, and in nearly all of East Africa, hermetic storage options are sold by the private sector, supported by promotion from government, donors and NGOs. In Kenya, for example, which has over 10,000 potential agro dealer sales points, the annual market size for hermetic bags is estimated by AflaSTOP at over 6 million bags with a commercial value of $15 million dollars. Five commercial companies are currently selling into the market: AtoZ Group Tanzania (maker of AgroZ bags) with a production capacity of 5 million bags, Bell Industries Kenya (the exclusive distributor of PICS bags) with a production capacity of 2 million bags per year, and others including Elite Innovations (maker of Elite Bags), GrainPro (maker of GrainSafe and SuperGrainbag), and Vestergaard (maker of ZeroFly bags). AgResults, a multilaterally-funded program present in several countries is using pull mechanisms (i.e. results-based economic incentives) to drive private sector investment in neglected areas. AgResults' pull mechanism in Kenya provides an incentive to private sector companies to sell improved storage to smallholder farmers – currently all of the improved solutions are hermetic.

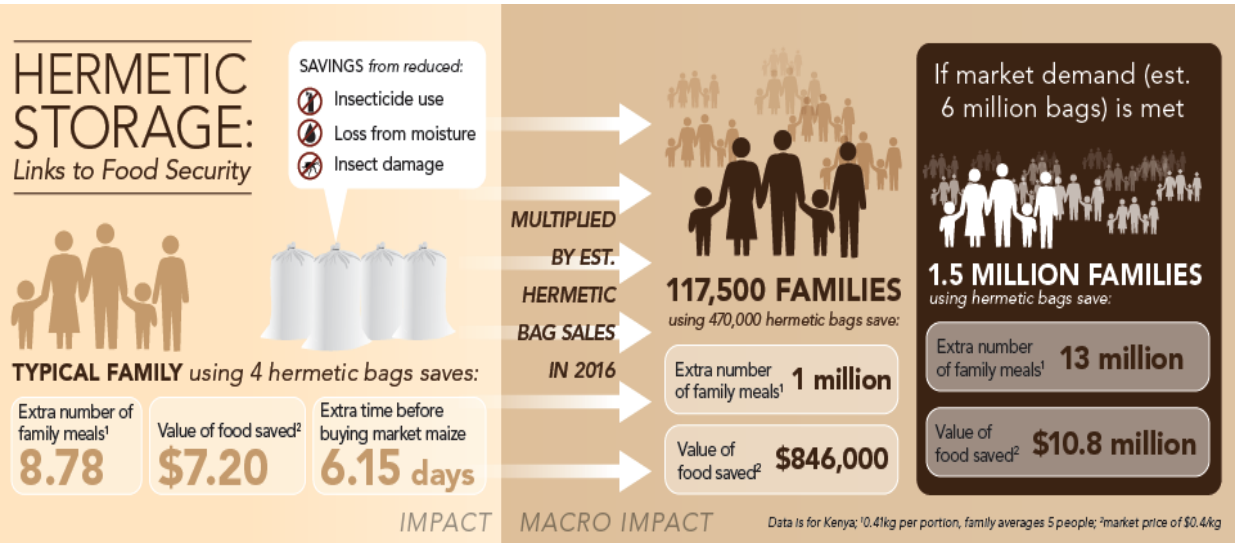
As with any product aimed at a largely poor, rural, and geographically dispersed population served by small, largely informal retail outlets – certain challenges exist to fully commercializing. Some of these include maintaining brand copyright, product quality and brand loyalty across multiple country contexts. Other obstacles include manufacturing capacities, inventory management and last mile distribution, education of retail outlets, financing, balancing public good versus private profit, and creating customer awareness. These issues will always exist to some degree, however, in these markets, they can either stump growth, or create opportunities for innovation in business models and technology that transform the meaning of 'what's possible.' Many of the companies manufacturing hermetic bags in Kenya have faced these issues head on: for example, bag distributors were surprised by the rapid rate of uptake for their product, and if suppliers do not have stock to service this demand through agro-dealers, momentum around and interest in a 'new' product will wane. As part of its efforts to support commercialization, AflaSTOP provided targeted marketing support to help refine messaging to farmers and improve awareness (and availability of promotional material) in retail shops as related to the value of hermetic storage. In addition, AflaSTOP provided capacity building support to Bell Industries to help alleviate stocking issues, which proved vitally important to improving sales in the winter 2016 season.

HERMETIC STORAGE AND FOOD SECURITY

Reductions in post-harvest losses have a direct impact on a family's food availability, as illustrated in Figure 5 below. For example, drawing from the data in Table 1 above, for a farming family of five in Makueni, Kenya, use of hermetic bags (assuming four 90kg bags of maize stored over 4.5 months, two seasons a year) translated to an additional 44 meal portions per season, or more than 8 meals for the entire family of five, because less was lost to insect damage and moisture loss. Given 2016 sales of hermetic bags by the main companies, it is estimated that 5.6 million portions – or over 1 million family meals were gained through the use of hermetic

storage in 2016 alone. Additionally, using hermetic bags delayed them having to go to market by 6.15 days and saved over a dollar per day ($7.20 total) in terms of not having to buy maize for this period - 35% of these sales were in areas with known aflatoxin problems.

Figure 5: Linking Hermetic Storage to Food Security: Tangible Benefits



UNANSWERED QUESTIONS

While hermetic storage has been around for thousands of years, it has only recently taken off in Africa, spearheaded by the emergence of the PICS bag, which were developed by Purdue University in order to address the massive infestation problems in cowpeas in West Africa. There is substantial evidence proving its efficacy now in a range of crops.

With regards to aflatoxin and hermetic storage, however, some areas require additional research:

- Untreated hermetic bags can be bored through from the outside by grain borers. In AflaSTOP's testing, 25 to 75 percent of the 90kg bags tested, were penetrated by insects in the first six months, but farmers are told that these bags will last 2 to 3 seasons. It is unclear how effective in controlling insects and aflatoxin the bags will be the second time around if they have been holed, and it is not clear what methods of 'mending' the holes will be effective solutions for smallholders.
- AflaSTOP's work demonstrated that while hermetic storage arrested aflatoxin, it did not influence fumonisin growth. A total of 75 percent of maize sourced from Kenyan farmers was above the legal limit for fumonisin of 1 part per million. This is an additional area of concern for health that should be explored.

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