Fighting Hunger Worldwide

Taking it to scale: Post-Harvest Loss Eradication in Uganda 2014 – 2015

Project Implementation Report

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Contents

Introduction

Although there is enough food to feed the world's 7 billion people, some 800 million people around the world are trapped in a life of poverty and hunger. In recent years, global food production has reached a record high, but one-third of all food produced for human consumption is lost or wasted. Post-harvest food loss is one of the largest contributing factors to food insecurity, under-nutrition, and hunger across the developing world, directly impacting the lives of millions of poor, smallholder farming families. In many developing countries, due to inadequate handling and storage practices at the household level, within the first three months after harvest, farmers lose up to 40 percent of their harvest to insects, pests, mould, and moisture. According to the UN Food and Agriculture Organization (FAO), Sub-Saharan Africa alone loses 20 million metric tons of food each year, valued at over US$4 billion (2011).

Achieving zero hunger by 2030 will require a dramatic reduction in the amount food that is lost or wasted. By preventing post-harvest losses in food systems, the availability of food can be increased worldwide without requiring additional resources or placing additional burden on the environment.

Food losses happen at every stage of the supply chain, as commodities become damaged, spoiled or lost while harvested, handled, processed, stored, and transported. These losses are most significant in developing countries. Post-harvest losses have significant nutritional, health, and financial impacts for both consumers and farmers, disproportionately affecting women, who are largely responsible for managing post-harvest drying, cleaning, and storage. For rural families, many of whom already live on the edge of hunger, lost food means lost land, water, fertilizer, and income for those who can least afford it. Lost food also traps farmers in a cycle of subsistence, depriving them the opportunity to grow and strengthen their businesses.

Although food losses are being recorded at every stage in the supply chain, from production through to retail and consumption levels, the area where the greatest percentage of crop losses are recorded are pre-farm gate, where poor harvest practices, including inadequate drying, processing, and storage of crops occurs. Post-harvest management at farm level is the critical "first link" in the supply chain. Current inefficiencies in this stage not only negatively impact household food security and income generation potential for smallholder farmers, but also represent a key limiting factor on available volumes of food for consumption and trade in food-deficit countries.

In 2014/2015 in Uganda, the World Food Programme (WFP) started the Zero Food Loss Initiative to reduce post-harvest food losses in SSA. The design and execution of the post-harvest loss eradication project was heavily influenced by WFP's expertise in logistics and supply chain management. Key to the success of the project was WFP taking an overall "value chain approach", which recognized the complexities and challenges for farmers to achieve safe handling, and then proper food storage, yet at the same time incorporating the food quality standards that farmers must reach to enable their participation in markets and at both the local and regional level.

The initial field trials were made possible with strong financial support from the United States Agency for International Development (USAID) and valuable assistance on the design of the monitoring and evaluation phases from the Massachusetts Institute of Technology (MIT) and Makerere University of Uganda (MU).

The results from WFP's project in Uganda are overwhelmingly positive. The unique combination of post-harvest management training, coupled with airtight storage equipment, enables farmers to eradicate their post-harvest losses. Participating farmers using traditional storage methods previously lost up to 60 percent within the first months after harvest. Through new post-harvest handling and storage methods and modern equipment, they reduced their loss levels to less than 2 percent. In just one harvest, farmers are able to pay off their investments, and on average can double their incomes. The impact of the project is particularly significant for women, who now need to spend less time on the food supply aspects for their families, and have more time to pursue other income-generating activities. More income means more food on the table for farming families and more children of farmers in school.

Background

Although food loss represents an enormous problem, the exact scale of loss varies greatly between reports and regions. Annual post-harvest food losses in SSA exceed 30 percent of total crop production, representing more than USD$4 billion in value every year (FAO, 2011). The African Post Harvest Losses Information Systems (APHLIS) calculates the annual food losses in SSA to be lower, at around 13.5 percent of total crop production (Bett & Nguyo, 2007). Research conducted by WFP between 2012-2014 shows areas in both west and east Africa with average post-harvest losses above 40 percent (Costa, 2014). The variance of loss is contingent on a number of factors including the period the commodity is held at the household level.

Food losses are a clear indication of a poorly functioning and inefficient food system (Bokusheva et al., 2012). The key to overcoming these inefficiencies is to apply a complete, end to end, supply chain focus, addressing all of the shortcomings in each of the interdependent functions, rather than optimizing individual links in the chain. Over recent decades, focus has primarily been on increasing food production. About 95 percent of all research investments over the past 30 years have focused on increasing productivity and only five percent directed towards reducing losses following harvest (ILO, 2012).

The premise of the Zero Food Loss Initiative is that a sustainable solution to global food shortages requires a balanced focus of preserving existing food production and combining traditional practices with new technology to increase productivity yields of low-income farmers.

Improving farm management practices following harvest will yield an even greater increase in food availability. Not only will it lead to millions of tons of additional food for consumption annually, it will achieve this without incurring the additional labour, land, materials, resources, and biofuel expansion required with increased production.

BUILDING ON EXISTING RESEARCH

On average, two substantive reports on maize losses (the predominant agricultural crop in Uganda) have been submitted each year since 2000. Despite these investigative papers on the recurring problem of food losses, implementation seems to have been limited. WFP sought to move beyond theoretical discussions and desk studies and provide a large-scale practical illustration of post-harvest handling practices applied in a developing country.

Building on the success of post-harvest management trials conducted from 2012 to 2014 in west and east Africa, WFP invited the Government of Uganda, NGOs, private sector partners and 16,600 low-income farming families to work towards the Zero Hunger Challenge set by the UN Secretary-General "to turn the vision of an end to hunger into a reality". Implementing a clearly defined, highly measureable, four-stage approach to support low-income farming families, the 2014/15 Zero Food Loss Initiative in Uganda produced the following lessons:

- Post-harvest losses can be reduced. Regardless of the previous rates of post-harvest losses, the crop type and the timeframe in which it is stored, evidence proves that crop losses in SSA can be reduced by 90-100 percent with improved management and farming equipment.

- Crop Contamination can be minimized. New handling and storage technologies have proven to be significantly more effective than traditional farming practices at controlling damaging pest activity and poisonous crop contamination, in particular aflatoxins.

- Family Nutrition can be improved. Increased food availability and reduced crop contamination is directly linked to improved family nutrition and health.

- Household Incomes can be increased. A staggering 97.9 percent of surveyed farmers achieved a financial gain by utilizing new storage technologies. Farmers are able to increase their incomes as they are able to sell higher-quality grain at most convenient time with almost no additional work.

- Gender Equality can be boosted. Strong evidence shows that women farmers using the new storage units enjoy more free time, freedom to leave their home and pursue other activities, increased food security (as silos are locked), higher personal incomes and reduced daily labour.

- Farmer Productivity can be improved. By preserving a much higher percentage of their harvested crop, farmers can use more of their land available to produce additional crops (therefore increasing regional food security).

- Youth Education can be encouraged. Previously food insecure farmers state that their priority is to increase income so as to provide a better education for their children. Improved post-harvest management supports them in this goal.

In food-insecure regions, grain loss at farm level affects both the availability of food for consumption, as well as smallholders' livelihoods. The coping mechanism employed by most farmers to minimize post-harvest losses is to sell their crops right after harvest. This allows them to cover immediate post-harvest expenses and loans but at the same time leads them to accept low prices for their crops. In the following weeks and months, these very farmers are forced to buy grain for their own consumption from the retail market at considerably higher prices, ultimately creating a cycle of poverty. Improved household storage units not only increase the available amount of grain (ref. Figure 1), they allow farmers to exercise greater control over the timing of crop sales for more favourable prices (ref. Figures 2 and 3), yielding a difference between farm-gate prices during harvest time and the following months of as much as 300 percent (ref. Figure 4).

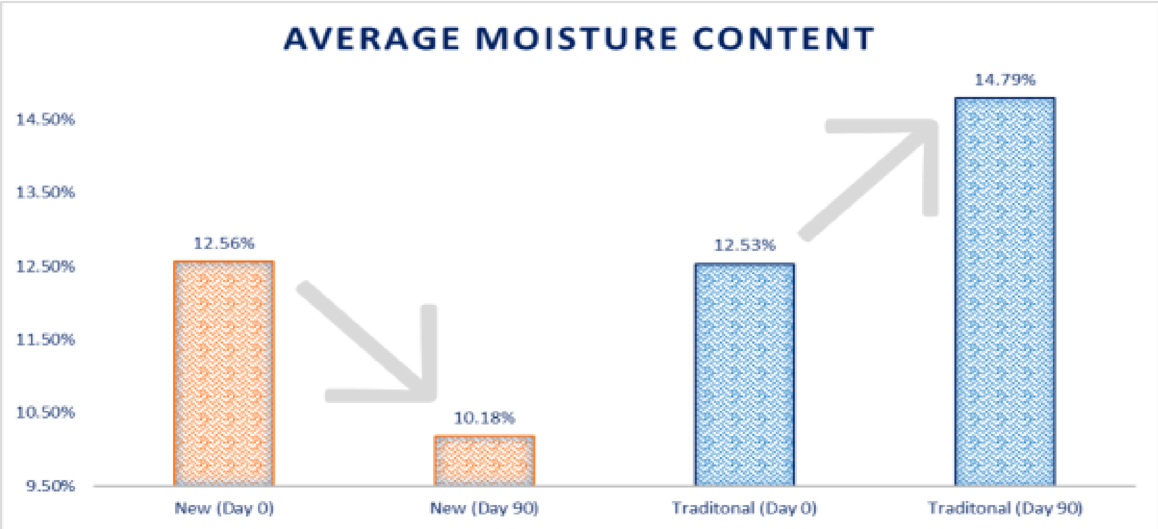

Figure 1: Periodic measurement of moisture content within stored crops (these changes assume greater importance when considered along with the Figure 6).

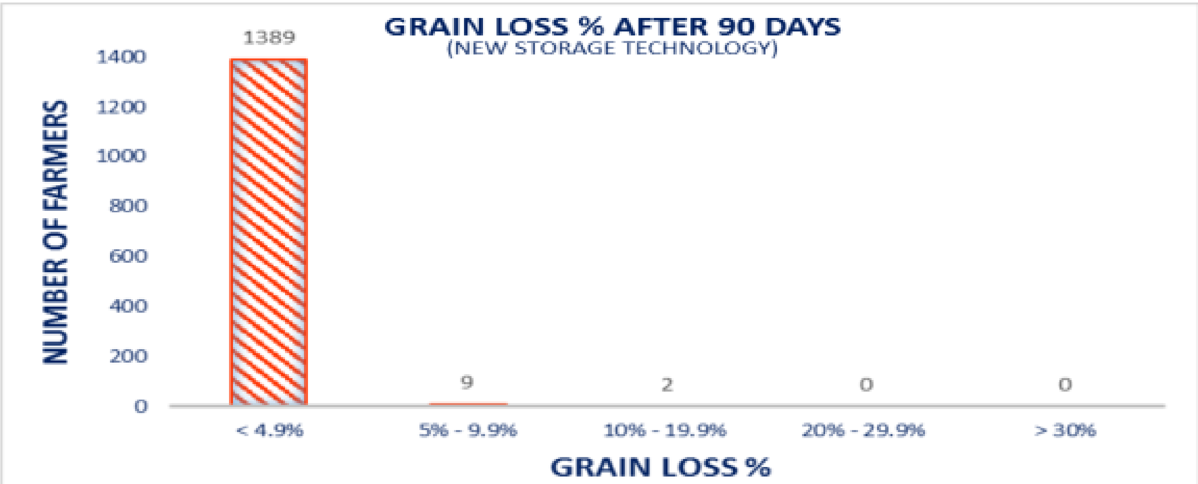

Figure 2: >99 percent of all participating farmers experienced less than 10 percent loss of crop after 90 days using the new storage technology. (Total loss average is now below 1 percent).

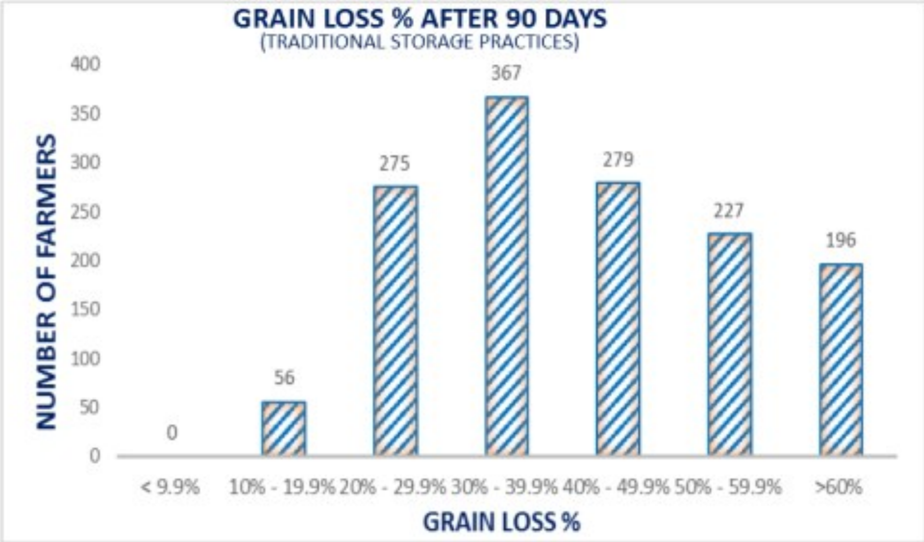

Figure 3: None of the participating farmers experienced less than 10 percent loss of crop after 90 days of using traditional storage practices. (Total average loss was lower than 41 percent).

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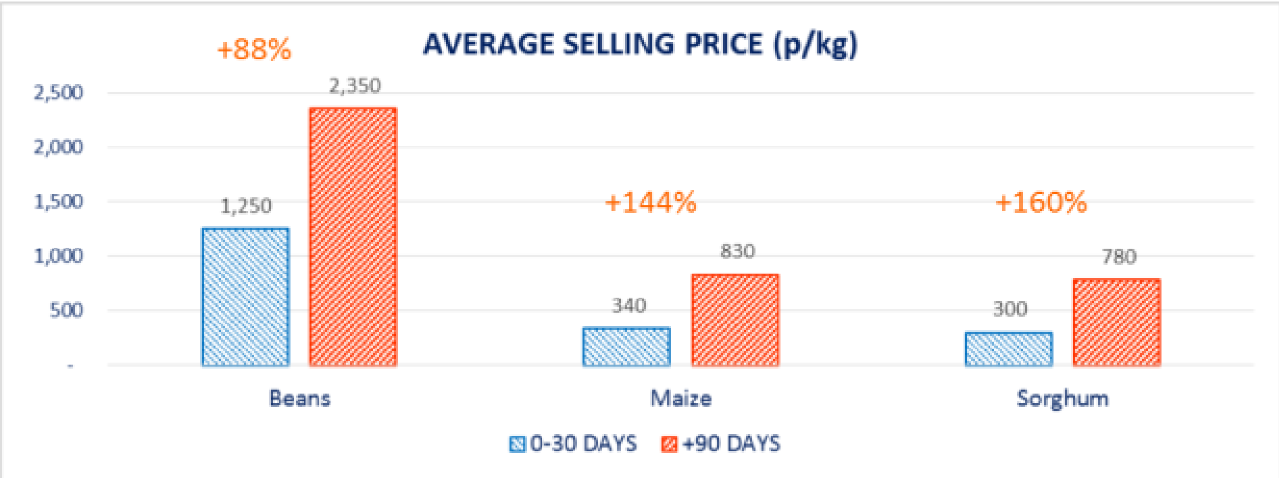

Figure 4: Farmers' increased sales due to the reduction in post-harvest losses

The possibility for farmers to sell their crops at a more favourable price has a positive effect on other low-income households as well. With local food supply no longer limited to harvest periods, price peaks on local markets are likely to decline. By adopting new storage techniques, farmers will contribute to less variable prices (Gitonga et al., 2012), more affordable food for poor households and in the longer-term, and a greater consistency of food available in the region.

Selection

Uganda provides ideal growing conditions for a wide variety of crops. Despite its rich, fertile soil, consistent median temperature, plentiful sunshine and bimodal rainfall enabling multiple harvests every year, the country still suffers major agricultural output challenges. Low productivity levels; high post-harvest losses due to insect pests, diseases, and ineffective storage; the inability to achieve international quality standards; inadequate infrastructure for marketing, storage, and distribution of crops are ongoing concerns. Engaging 16,600 farming families across multiple farming regions, the initiative aimed to address the UN Zero Hunger Challenge by demonstrating that 100 percent access to adequate food all year round and zero loss of food can be achieved in Uganda. The project also complements an important UN inter-agency project between FAO, the International Fund for Agricultural Development (IFAD) and WFP to mainstream food loss reduction initiatives.

Appreciation

The WFP Country Office of Uganda gratefully acknowledges the support and proactive participation of United States Agency for International Development (USAID), Massachusetts Institute of Technology (MIT) and Makerere University (MU) in this project, as well

as numerous Government Ministries, NGO implementing partners—Soroti Rural Development Agency (SORUDA), Office of Relief and Development Support (ORDS), Cooperazione e Sviluppo (CESVI), Agency for Technical Cooperation and Development (ACTED), Food for the Hungry (FH), Action Against Hunger (ACF), SNV Netherlands Development Organisation (SNV), Samaritan’s Purse (SP), and Millennium Villages Project (MVP)—and various private sector manufacturers, distributors, and project enablers who contributed to the success of this initiative.

The integrity of the initiative, as well as the framework for accurately capturing and assessing the outcomes, was greatly enhanced with the proactive involvement of MIT. The analytical expertise of the voluntary members of the MIT Humanitarian Response Lab, led by its director Jarrod Goentzel, tremendously contributed to the breadth, depth, and relevance of information gathered from the farming communities.

WFP's Zero Food Loss Initiative in Uganda

Strategic Intent

Employing proven concepts from successful research trials conducted in west and east Africa in 2012 – 2014, and leveraging over 30 years of experience from the successful *Postcosecha* projects in Latin America, WFP set a bold target of engaging 16,600 smallholder farmers, working together with numerous partners from the Ugandan Government, local and international NGOs and Ugandan private sector businesses to overcome numerous implementation challenges.

Efforts in recent years to improve post-harvest storage in Uganda have concentrated primarily on convincing farmers to collectively store and aggregate their crops. Less emphasis has been placed on improving post-harvest handling techniques and on-farm storage facilities.

By combining practical experience with a desk review on the subject of post-harvest handling and farm and community level grain storage, WFP sought to:

- Validate recommended procedures at scale,
- Provide clear policy recommendations (and procedural instructions) for similar implementations in neighbouring countries, and
- Increase global awareness on the levels of food loss in SSA.

Of particular importance was guiding information sourced from FAO, the World Bank (WB), the U.S. Department of Agriculture (USDA), the African Development Bank (AfDB), IFAD, the Swiss Agency for International Development Cooperation (SDC), the European Union Delegation (EU) and the International Maize & Wheat Improvement Centre (CIMMYT).

Project Design

- Attention focused initially on Uganda;
- Multiple farming districts in different regions;
- Enforce a strict eligibility prerequisite through the mandatory participation of farmers in a training workshop prior to purchasing new storage and post-harvest handling equipment;
- Commence Farmer Training Workshops in August 2014 and complete the training by December 2014;
- Manufacture and distribute of all improved post-harvest storage and drying equipment from October 2014 to December 2014;
- Commence the monitoring and Evaluation in January 2015 and complete it by April 2015;
- Partner with the Ugandan Government representatives at both central and district levels;
- Partner with local and international NGOs, UN agencies and private sector businesses at both central and district levels;
- Partner with reputable learning institutions to best capture the outcomes of the post-harvest loss reduction activities;
- Align with existing WFP programmes wherever possible;
- Involve a minimum of 16,000 low-income farming families;
- Include four interdependent stages with clear, measureable performance targets; Training, Equipping, Field Support and M&E;
- Circulate an evaluation paper at the conclusion of project activities.

Zero Food Loss Objectives

Prior to commencing the project, WFP (in collaboration with major donors) designed clear, measureable performance targets to achieve the following objectives in Uganda:

- Reduce grain damage and crop weight loss by more than 70 percent for all participating farmers (compared to traditional farming methods).
- Clearly demonstrate that insects and other pests can be prevented from reaching harvested crops when using the new technologies.
- Show that pests already present within the grain at the time of storage will die quickly and be unable to multiply and cause escalating crop losses.
- Prove that the equipment is easy to use and has no negative effect on the caloric value of the stored grain.

- Provide empirically based evidence to validate or dismiss the proposition that improved post-harvest management practices can contribute to reducing post-harvest losses.
- Provide empirically based evidence to validate or dismiss the proposition that utilizing new technologies for drying, processing and storing crops will result in significant quantitative and qualitative gains in the crops produced by smallholder farmers.
- Provide empirically based evidence to validate or dismiss the proposition that quantitative and qualitative gains for smallholder farmers will be the catalyst for improved household finance and amelioration of gender inequality issues for all participating households.
- Increase the ability of low-income farmers to decide what percentage of their harvest to retain for family consumption and the best time to sell surplus grain.
- Increase the capacity of low-income farmers to connect with medium-scale traders and quality-oriented markets, thereby increasing the total marketable grain quantities, individual financial returns and community food security.

Post-Harvest Challenges

Causes of Post-Harvest Losses

All crops are naturally subject to biological deterioration, but the rate of deterioration is highly influenced by factors ranging from individual farming practices to the chain of interdependent activities between harvest and delivery of food to consumers. In developing countries like Uganda, naturally occurring pests (primarily insects) are the main cause of this deterioration, causing a substantial loss of the yearly crop production. Due to poor storage structures and conditions, severe losses in quality and quantity of stored food occur. Precise quantitative assessment of losses has been proven difficult due to the high variability in infestation from year to year; however, studies in recent decades have clearly illustrated the significant impact of insect infestation (Joughin, 2012).

High levels of recorded food losses experienced by Ugandan farmers (and considerably low levels of production) are mirrored annually throughout the neighboring countries. In Kenya, total losses due to pest infestation of maize have been estimated at 57 percent (Sallam, 2008), while this figure reaches 92 percent in Zimbabwe (Pinstrup-Andersen, 2010). Grains and cereal crops, pulses such as cowpeas, which are key crops in many west African countries, are also extremely vulnerable to a variety of insects, with infestation levels reaching 90 percent on the farm (Mutiro, Giga & Chetsanga, 1992), in markets and village stores (Van Alebeek, 1996), and up to 100 percent after a few months' storage (Lienard & Seck, 1994).

Unfortunately, most low-income farmers are extremely limited in their strategies to cope with storage losses caused by pests. Damage by insects, rodents and birds represent the largest natural causes for crop losses, however poor handling practices are also a major contributing factor. In 2011 the World Bank, in association with FAO and NRI, released an important industry study in which they described this continuum as a value chain, where a variety of functions are performed, including harvesting, assembling, drying, threshing, storage, transportation, and marketing. Inefficient post-harvest handling and management practices across this value chain expose crops to contamination by microorganisms, chemicals, excessive moisture, fluctuating temperature extremes, and mechanical damage. These all greatly contribute to food losses (Zorya et al., 2011).

Damage and spilling of crops during the initial transportation process is a common occurrence. Further damage to the grain will often occur during the threshing process, where beating of the grain causes cracking or breaking of the protective outer shell, providing an entry point for insects and moulds during storage. Insufficient drying of crops prior to storage is another major problem. Retaining a high moisture content will result in the grain increasing in temperature, due to respiration, which will also occur with increased insect and/or fungal activity. This heating leads to moisture condensation within the stored mass of grain, which in-turn creates favorable environment for additional fungal growth and insect infestation (Imura & Sinha, 1989).

Finally, during what is arguably the most important stage of the postharvest value chain, household storage, deterioration of the grain quality occurs rapidly. Traditional granaries (ref. Illustration A), cribs, and open air holding units may provide natural ventilation for further drying of crops, but they provide little protection from insects, rodents, and birds. Also, using the same timber storage facilities year after year, where insects hibernate and continue to feed on wooden structures creates a continuous chain of infestation.

Illustration A: Traditional granary

Effects of post-harvest losses on farmers

Insufficient education on effective post-harvest management practices, lack of access to modern storage technologies, credit constraints (including high cost of capital), unreliable information on grain prices, and urgent needs for cash lead most farmers to sell immediately after harvest. Early sales reduce farmers' profits, diminishing their ability and motivation to invest in productivity-increasing technologies. Nonetheless, very little attention is given to improving post-harvest effectiveness of household crop storage facilities. Sub-Saharan farmers are continually frustrated with food losses resulting from their inability to combat naturally occurring pests and a lack of education regarding improved post-harvest handling practices.

Illustration B: Traditional Gunny bag

Four Stages of the Zero Food Loss Initiative

Following successful outcomes of WFP's Action Research Trials in 2013/14, the decision was made to follow the same four procedural stages with an increased number of farming families, but with slightly modified implementation practices based on information gathered from farming communities involved in the initial trials. Between August and December 2014, WFP conducted the first stage, which consisted of 346 post-harvest management education workshops. Overall, 16,600 smallholder farmers participated in the training, 62 percent of whom were women. The first two stages of the initiative were considered preparatory, where farmers received capacity development support and were supplied with their newly purchased handling and storage equipment to assist with the upcoming harvest. The third stage of the project was a follow-up "refresher" training and consisted of practical demonstrations on farms, field support for crop preparation and guidance regarding the correct positioning of the new equipment. The fourth stage of the initiative, conducted between January and April 2015, consisted of field monitoring and surveying of participating farmers to assess the outcomes and impact of applying the training concepts and new equipment in the three to four months after the harvest.

Stage 1: Capacity Development (Farmer Education)

Capacity development is critical to achieving a lasting change. One component of reducing food loss involves farmer education to provide general guidance on improved post-harvest handling. Training workshops were one-day (8 hours) education programmes held in different regions throughout the country. The majority of participating farmers were selected from registered farmers' organizations, many of whom had existing relationships with WFP's Purchase for Progress (P4P) initiative. These workshops were designed to address inappropriate post-harvest practices; poor crop drying systems (leading to grain rotting and fungal infestation); poor storage facilities (resulting in qualitative and quantitative losses from insect and weather spoilage); and food safety issues. Of great benefit to the learning process was the decision to produce all of the training manuals and conduct training workshops in local languages. Although administratively languages. Although administratively challenging, it removed the potential language barriers and provided a brochure that farmers could take home and share with family members and those unable to attend. An important motivational aspect of each training workshop was increasing farmers' awareness on the benefits of adopting suggested changes. Recognizing difficulties inherent in encouraging behavior change, WFP provided clear illustrations relating to the financial, health and food security reasons for farmers to consider when weighing up their options of employing the new farming practices.

Illustration C: Stage 1— Capacity development

The capacity development training workshops aimed to increase farmers' awareness of what "post-harvest loss" is and how to best avoid the major biological and environmental factors. Each workshop was divided into six learning modules, of which the following four procedural stages were given the most time:

HARVESTING

- Commencing at the right time to avoid losses;
- The susceptibility of crops to pest attacks after reaching physiological maturity;
- The impact of weather conditions at the time of harvest.

DRYING

- Minimizing damage by reducing the moisture content below the level required for mold to grow during storage;
- Methods for farmers to accurately measure the moisture content of their grain;
- Limiting Aflatoxin contamination; never exposing grain to the soil during drying; using tarpaulins to reduce the risk of contamination and to provide cover when exposed to damp weather;
- Keeping animals away from harvested crops.

THRESHING

- Precautions to avoid damage to grain during threshing/shelling;
- Options available for threshing grain;
- Optimal ways to clean grain before storage;
- Note: un-threshed crops are often stored in open cribs, but for the purpose of this trial, all crops were threshed prior to storage.

ON-FARM STORAGE

- Optimizing the efficiency of post-harvest storage at the household level by improving on traditional granaries using timber and soil or polyethylene bag stacked inside the house (ref. Figures 6 and 7);
- Introducing hermetic storage units or new storage technologies to protect crops from insects, rodents, birds, rain, temperature fluctuations;
- Effective methods of controlling moisture and temperature fluctuations for problem-free storage.

Stage 2: New Technology Farming Equipment

A critical complement to educating farmers on improved farming practices was ensuring supply of proven hermetic storage equipment discussed during the workshops, available for purchase. After testing numerous technologies during the research trials, the final range of equipment options (as well as the price subsidization offered to low-income families) was reduced for the project. All training workshops included practical demonstrations of the new handling and storage equipment and while no obligation was placed on farmers to purchase the new equipment, over 90 percent of workshop participants ordered one of the new farming technologies. All hermetic storage options also came with accompanying drying tarpaulin(s).

HERMETIC STORAGE OPTION A — SMALL (<100kg): Super Grain Bag.
Multi-layer polyethylene storage bags, which create a highly effective, hermetic storage environment for most crops. Water resistant and completely airtight. Each bag is placed inside a traditional storage bag for an additional layer of protection.
Price: US$2.50

HERMETIC STORAGE OPTION B — MEDIUM (250kg): Plastic Silo.
Plastic PVC storage units. A modified version of locally produced liquid storage containers, which create a highly durable grain storage facility. Minor adjustments to the sealing mechanisms help create the required hermetic storage environment.
Price: US$38.00

HERMETIC STORAGE OPTION C — MEDIUM (< 540kg): Metal Silo.

HERMETIC STORAGE OPTION D — LARGE (<1200kg): Metal Silo.

Constructed from galvanized iron, these robust storage units provided outstanding protection for all selected crops. Water resistant and hermetic, when positioned correctly they create an effective long-term, non-living storage environment.
Price: US$130.00 | US$180.00

STORAGE OPTION 1

STORAGE OPTION 2

STORAGE OPTION 3

Illustration D

What is hermetic storage?

When a sealed container does not allow oxygen and water from the atmosphere to reach the internally stored grain, the build-up of carbon dioxide will eventually reach a level of toxicity where it is impossible for insects and moulds to survive. Such a storage structure is referred to as being hermetic. Oxygen leakage back into the closed system substantially reduces the effectiveness of the high carbon dioxide atmosphere, and careful management during the project was required to prevent or repair punctures and tears occurring to containers during storage or transportation.

In the case of the metal silos, the process of removing oxygen was achieved more quickly by placing lit candles on a porcelain or metal plate inside the silo before closing.

The candles would burn until all of the remaining oxygen had been consumed, swiftly creating an uninhabitable environment for insect pests. There was no de-oxygenation process applied to the plastic silos or super-grain bags. Oxygen depletion occurred naturally, but over a longer period of time, which allowed for minor damage to grain to occur during the first days of storage.

DISCOURAGING FUMIGANTS

A very strong message was communicated to all participating farmers, discouraging the use of chemical fumigants. The use of phosphine fumigation (common throughout SSA) introduces another form of harmful poisoning and chemical contamination even as it attempts to limit pest infestation. Such practice becomes unnecessary when hermetic storage units are correctly sealed. Within an oxygen-deprived environment, all insect pests and living organisms are unable to survive. Also, because in many African countries the use of fumigants is prohibited, this was viewed as an additional benefit to participating families.

PRICE SUBSIDIZATION

WFP's post-harvest eradication programme is intended to cover a five-year period within each country, during which sustainable improvements in supply chain efficiencies (starting with farm management techniques and post-harvest storage) are implemented. To achieve this, a strong demand must be created among food-insecure smallholder farmers and households lacking commercial opportunities and requiring support before adopting improved post-harvest methods to reduce their losses.

This platform of support, which intentionally involves private sector businesses early in the process, has been modelled on a similar implementation in Central America, which achieved success by offering low-income farming families an initial price subsidy on the cost of their new equipment. Gradually, as "word-of-mouth" regarding the success of the new equipment becomes stronger, the subsidization offer was reduced to zero (Fischler, 2011). The subsidy model was documented as being a key factor in implementing and then increasing the production and dissemination of the new storage equipment. The project commenced in Uganda with a 70 percent subsidy offering. This amount will be reduced to 50 percent in the second year, 30 percent in the third and fourth, and no subsidies by the fifth year of the project.

EMPTY TESTING

DEOXYGENATION OF FULL SILO

Illustration E: Hermeticity testing of storage metal units

Stage 3: Field Support (refresher training)

As the ultimate success of the project depends heavily on each farmer applying the recently learned improved farming procedures and effectively utilizing the newly acquired farming equipment, it was necessary to reinforce the key training messages in the months following each workshop. Given the advice of experts indicating an average person retains as little as 20 to 30 percent of what they learn during training, and the lengthy period of time (for some farmers as much as 10 weeks) between the workshop and the commencement of harvest, WFP targeted farmers who were trained earlier in the training cycle for refresher sessions. A series of meetings were scheduled in the sub-districts and villages of all of the selected farming regions. Using detailed records collected during each training workshop, NGO training partners were able to identify the exact equipment purchased by farmers in each district and invite those with the same equipment to small gatherings (10 – 15 farmers) for an on-farm demonstration. During each demonstration, the key instructions on positioning and optimal utilization of the new equipment were repeated, as well as a refresher discussion on the top 10 post-harvest messages from the training workshop.

The response from farmers to this secondary training invitation was very positive and over 50 percent of all farmers involved in the workshops also received refresher training. There can be little doubt the huge improvements recorded between traditional and new farming practices (ref: Figures 2, 3, 4, 5 and 6) would not have been possible without the solid foundation of education provided.

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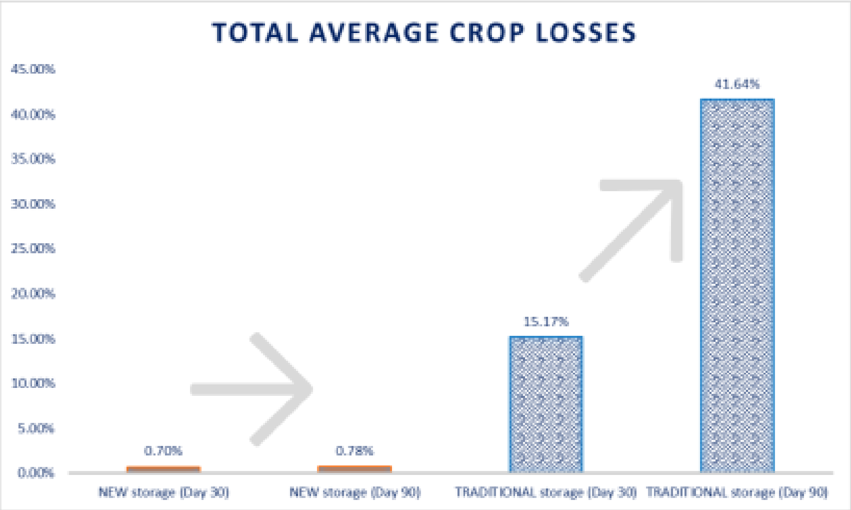


Figure 5: Periodic measurement of the average crop loss (percent) recorded by 1,400 low-income farmers

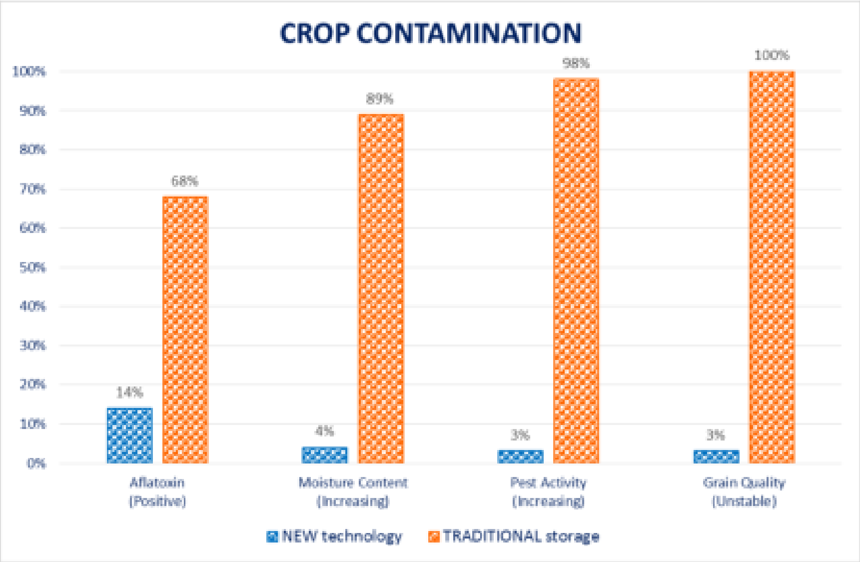


Figure 6: Monitoring various storage environment over the course of 90 days enabled the Special Operation to compare Ugandan outcomes against studies conducted in other developing countries. The above graph shows strong linkages between moisture content, grain quality and aflatoxin levels within a storage environment.

Stage 4: Monitoring and Evaluation

The Zero Food Loss Initiative encompassed a broader scope of focus than the action research trials, where the dominant aim was on measuring the qualitative and quantitative impact on harvested crops with changing farming practices. Credit for the expanded evaluation metrics is attributed to MIT, whose participation in preparatory discussions with WFP and USAID, led to a more comprehensive assessment of the project.

The overarching objective of the monitoring and evaluation stage was to ensure a balanced representation of small and medium-size farming households and the inclusion of new storage technologies, major crop varieties, and every sub-district within the selected farming regions. The aim was to conduct multiple, detailed evaluation interviews with eight percent of smallholder farmers involved in the training workshops. The actual number achieved was 8.5 percent (1,400 households).

In association with MIT, two detailed questionnaires/surveys were elaborated and uploaded onto electronic tablets for efficiency and data entry accuracy in the field. All surveys were conducted individually with farmers on a voluntary basis at the location where the traditional and new household storage units were positioned. To ensure that the evaluation process was accurately completed in two stages and over an extended period, a representative sample of harvested crops needed to be stored for at least three months using both traditional and new storage practices. The WFP project team understood such a request would require a large change to standard procedures for most farmers, as crops are traditionally sold as soon as possible following harvest. To alleviate any potential concerns of worried farmers about the degradation of their crop over a three-month period, the minimum retention sample in the traditional storage was reduced to 5 kg and a payment was made to each farmer for this retention sample.

The first series of surveys were conducted in the weeks following the 30-day milestone, where farmers involved had held their grain in storage for over 30 days. The first survey consisted of a series of questions within four major themes:

- Farmer familiarization: Name? Gender? Farm location? Number of people in the household? Size of owned as well as rented land? Size of arable land? Reason for selecting the purchased equipment? Method of payment? Main source of household income? Expectation of more or less available time as a result of the new equipment? Expectation of more or less security as a result of the new equipment? The biggest advantage expected from the new equipment? Main use of money from additional income derived from the new equipment? Family consumption details over the prior seven days?
- Crop information (**traditional** storage unit): Type of storage units used? Crops stored in traditional storage units? Quantities stored in traditional storage units? Date of storage? Moisture content at the time of storage? Percentage of damaged grain after 30 days of storage? Major causes of damaged grain? Moisture content recorded after 30 days of storage?
- Crop information (**new** storage unit): Type of new storage unit purchased? Crop selected for storage in new storage unit? Quantity of grain stored in new storage unit? Date of storage? Moisture content at the time of storage? Percentage of damaged grain after 30 days of storage? Major causes of damaged grain? Moisture content recorded after 30 days of storage?
- Crop sales; Amount of grain sold within the first 30 days? Reason for selling within the first 30 days? Price received for grain sold within the first 30 days (traditional storage)? Price received for grain sold within the first 30 days (new storage)? Main buyer of grain?

The second series of surveys were conducted following 90 days of storage. They focused more on the outcomes for farmers employing the new equipment and consisted of a series of questions within four major themes:

- Farmer validation; Name? Gender? Location? Number of individuals in the household?
- Crop information (**traditional** storage unit): Type of storage units used? Crops stored in traditional storage units? Quantities stored in traditional storage units? Date of storage? Percentage of damaged grain after 90 days? Major causes of damaged grain? Moisture content recorded after 90 days?
- Crop information (**new** storage unit): Type of new storage unit purchased? Crop selected for storage in new storage unit? Quantity of grain stored in new storage unit? Date of storage? Percentage of damaged grain after 90 days? Major causes of damaged grain? Moisture content recorded after 90 days?

- *Outcomes:* More or less available time as a result of the new equipment? Reduction or increase in daily work? More or less security as a result of the new equipment? Crop sales (traditional / new) in the first 90 days? Reason for selling during the first 90 days? Price received for grain sold within the first 90 days (traditional storage)? Price received for grain sold within the first 90 days (new storage)? Main buyer of grain? Has there been a financial advantage in storing the crop longer? Has there been other advantages of owning the new equipment? Do you have more/less control over your family's consumption with the new equipment? Main use of money from additional income derived from the new equipment? Would the same results have been achieved without the training? Has anyone in your village shown interest in buying the same new technology? Would you recommend this equipment to your neighbours? Would you pay the full price for the equipment? Would you need to borrow money (if so, how would you borrow it?).

EVIDENCE AND MAGNITUDE OF POST-HARVEST LOSS

Stage four enabled a detailed comparative assessment of the grain damage and weight loss in stored crops as a result of naturally occurring biological deterioration and human inefficiency across four farming regions, using multiple storage options and varying storage durations (30/90 days). Insect densities, percent of grain damage, percent of grain moisture content, dust production (an outcome of extensive tunneling into the grain by insects) and weight loss all escalated within traditional storage environments over the duration of the study period. Diametrically opposing results were recorded in all areas of measurement within the new storage technologies, where almost no degradation was recorded between the 30 day and the 90 day evaluations.

QUANTITY LOSSES

All of the 1,400 surveyed farmers estimated quantity losses in the traditional storage units as greater than 10 percent, either as weight of edible mass lost or the volume of food that became discarded due to apparent damage or spoilage. Figure 3 provides an aggregation of the losses. Most farmers recorded loss estimates of between 30-40 percent, with 194 families recording loss estimates above 60 percent after 90 days.
Of the same 1,400 farming families surveyed, only 11 families estimated quantity losses in the new storage units greater than 10 percent. Figure 2 shows the majority of the farmers (99.2 percent) recorded loss estimates of below five percent after 90 days. Figure 5 shows the increased levels of crop loss within the second and third months of storage, there was less crop loss within the new technology units compared to the traditional storage units.

QUALITY LOSSES

The majority of participating farmers reported quality losses in traditional storage units, as a result of increased pest activity, elevated moisture content and aflatoxin contamination. Figure 6 emphasizes the strong linkages between these three variables when the environment of a storage unit cannot be controlled. It supports the hypothesis of a connection between poor post-harvest handling and storage with increased quality issues and health dangers to low-income farmers and the communities in which the crops are consumed.

COST BENEFITS OF ADOPTING NEW TECHNOLOGY

Figure 19 reveals the strong perception (97.9 percent) amongst all participating farming families of the financial gain to their household of having the improved storage protection and ability to hold crops for a longer time, either for consumption or sale. The actual cost benefit for each farmer varied depending on the type of new storage technology selected, the type of crop stored, the timing of when part of the crop was sold and the price received for each kilogram sold.

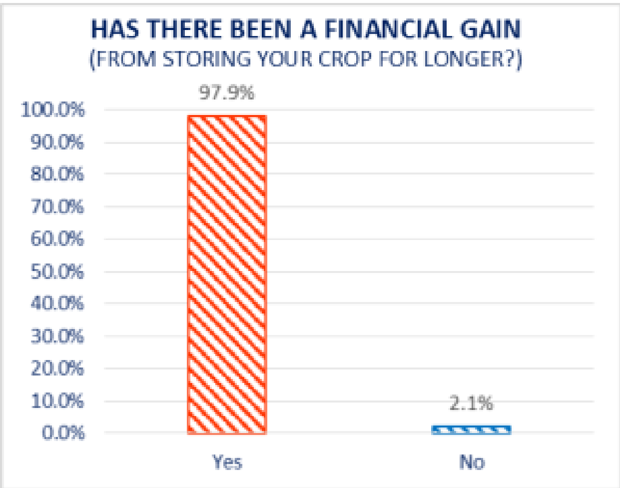


Figure 7: Financial gain due to the use of new storage equipment

Figure 4 indicates that an average farmer more than doubled their household income if they were trading maize or sorghum, with the increase reaching almost 90 percent for those selling beans. Extrapolating these figures across all of the different storage units, almost all farmers earned enough additional income to completely repay the investment cost of their new equipment after the first harvest. Even for the un-subsidized equipment, the worst scenario was a repayment time of one year (after two harvests). A substantial number of farmers surveyed (94.6 percent) stated they would be willing to pay full price for their new equipment (ref. Figure 8).

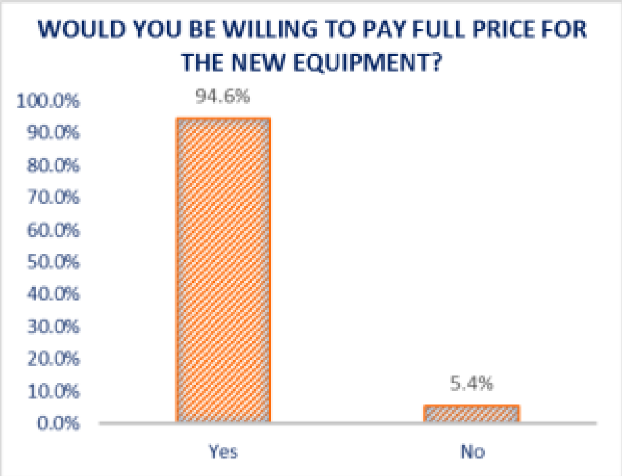


Figure 8: Farmers' willingness to pay for the improved storage

Large Metal Silo **cost**: Unit Price UGX540,000 (USD180)/ Cap. Storage 1,200kg/ Crop Maize

Large Metal Silo **return**: 1,200 x UGX490 extra p/kg = UGX588,000 potential extra income.

FOOD SAFETY

Improving post-harvest handling capacity of smallholder farmers not only has the potential to increase crop preservation and food volumes for consumption and trade, and household incomes. It also has the potential to positively impact health and well-being. Mycotoxin contamination poses a serious problem in SSA, with implications affecting human and animal health, as well as the economy. Mycotoxins are a toxic, poisonous chemical compounds that contaminate grain and agricultural crops (Darwish et al., 2014) when handled incorrectly.

Figure 6 demonstrates the increased health dangers of traditional storage units compared to new storage technologies. Due to the inability of traditional storage methods to control the ambient environment or pest activity within the storage unit, the moisture content of grain continues to increase (ref. Figure 1). Increased pest activity causes aflatoxin spores to spread, raising the potential for small pockets of contamination to spread completely through an entire storage environment (ref. Figure 6). Alternatively, in cases where a low percentage of stored grain has been contaminated within the new storage technology, the likelihood of spreading is reduced due to the stable temperature and absence of insect pests.

Laboratory capacity in Uganda's capital, Kampala, was inadequate to conduct testing beyond the accepted defect benchmark; however, professional testing equipment differentiating between grain samples with a positive presence of aflatoxins (>20ppb) and that with a negative presence of aflatoxins (<20ppb) were available (ref. Figure 6).

WHAT ARE AFLATOXINS?

Aflatoxins are the most common and naturally occurring mycotoxins. Aflatoxins are considered to be among the most carcinogenic substances known (Hudler, 1998) and present a very serious health risk to people and animals of all ages (Lawley, 2013). They are extremely difficult to identify by farmers as they have minimal smell, feel or taste and laboratory testing is normally required to discover its presence (IFPRI, 2010). The World Health Organization states that aflatoxins directly contribute to liver cancer, impaired immune function, stunted growth in children and are the third leading cause of cancer deaths globally (WHO, 2008). The problem of grain contamination, and the resulting poisoning, has become so widespread throughout Africa, particularly in the East African region, that it is now considered an epidemic (USAID & DANYA, 2013). Particularly prominent in maize (the largest crop produced in SSA), aflatoxin contamination occurs when crops come into contact with soil or debris during harvesting, threshing, and drying. Contamination of crops can also occur after grain has been placed into storage, due to pest infestation and poor storage conditions that lead to accelerated growth rates of the fungi.

Aflatoxin is a highly potent liver toxin and has been declared by the USA Food and Drug Administration (FDA) to be at a defect action level for grain products when above 20 parts per billion (ppb). Although analytical chemists are capable of conducting laboratory tests measuring 1ppb (which is the equivalent of measuring one second every 32 years (Yoe, 2015), for the purpose of project field testing, the FDA level of 20 ppb was the accepted benchmark.

Aflatoxin is produced by a fungus called *Aspergillus flavus*, a common fungus growing in soil and on dead plant debris. During the training workshops, farmers were given detailed instructions on ways of reducing the potential of aflatoxin contamination of their crops during harvesting, transportation, cleaning and drying. Particular attention was paid to the importance of sufficiently drying crops before storage. Crops dried and maintained at a level of ≤13 percent moisture content and protected from insect and rodent activity should not be affected.

The aflatoxin testing procedure consisted of removing samples of grain from random areas within both new and traditional storage units after a period of 90 days had passed. Each sample was placed (untouched by human hands) into clearly marked satchels and brought to a central location where testing was conducted. The study focused on the correlation between storage units with positive (unacceptable) levels of aflatoxin contamination, storage units with increased insect activity, and storage units with increasing moisture content readings.

Figure 9 reveals a definite link between these variables. Consistently, grain samples containing negative evidence of aflatoxin contamination were the same as those recording little or no insect activity and stable/ decreasing moisture content levels (and vice versa).

These findings support the study of Beti et al (1995) indicating aflatoxin levels in infested maize increases significantly with increased weevil activity (which carry aflatoxin spores both internally and externally).

These findings also highlighted additional benefits for low-income farmers, beyond reduced crop and income loss, of adopting improved post-harvest management practices, with potential positive impacts for those who consume this higher quality food.

CONTROLLING AFLATOXINS (THROUGH IMPROVED FARM MANAGEMENT)

With no known procedures for eliminating aflatoxins after they are produced, it is critical to limit or avoid concentrations through improved post-harvest management. Participating farmers were shown ways to limit the presence of poisonous aflatoxins in their crops and how contamination can be controlled with careful pre and post harvesting handling. Pre-harvest instructions focused on land preparation; the correct timing of planting and harvesting to reduce a plants susceptibility to aflatoxins; sanitizing of equipment; removal of broken grain, foreign material, and residual dust; as well as guidance on controlling moisture content; and avoiding direct crop contact with exposed soil.

Farmers were shown the importance of correctly drying their crops prior to storage (drying temperature, drying time, depth of layering, frequency of aeration and optimum moisture content prior to storage) to reduce the chance of fungal growth and ways of creating low humidity storage conditions to maintain the optimal storage environment. The traditional practice of stockpiling dried crops either directly on the floor, in baskets, or in polypropylene sacks on the floor of their houses (due to a fear of theft) was strongly advised against, regardless of the duration of storage, as was the use of chemical fumigants within any of the storage units.

Through these studies, empirical affirmation was given in support of improved preparatory practices of farmers (through education), combined with more effective post-harvest handling and storage equipment, greatly reducing aflatoxin contamination levels within stored crops (Ref. Figure 6).

Illustration E: Aflatoxin testing in the field: Using processional equipment to test reactions between antibodies and aflatoxin in stored crop samples. The tests indicated where aflatoxin levels had exceeded the defect action level of 20 ppb.

SOCIAL AND ECONOMIC BENEFITS

Even before being linked to commercial markets, this surplus provides tangible social and financial gains for all participating families. These gains are reflected most notably in the areas of improved food security (ref. Figure 5), improved health and well-being (ref. Figures 6, 17 and 20), increased income-generating potential (ref. Figures 4 and 7) and numerous benefits for women farmers (ref. Figures 7, 9, 10, and 11).

Figure 9

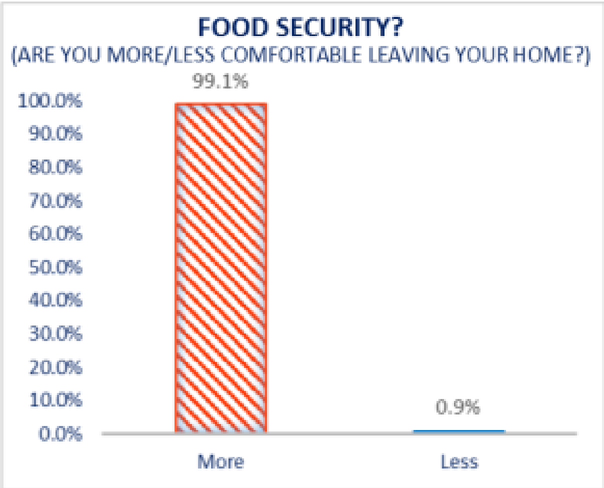


Figure 10

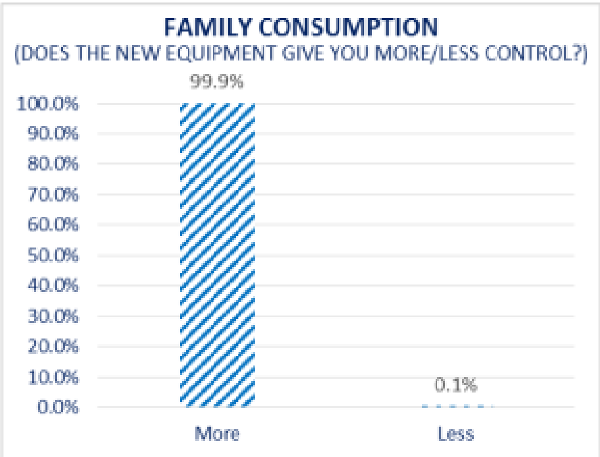


Figure 11

GENDER EQUALITY

Achieving gender equality is a crucial development objective throughout the world. In SSA women contribute up to 80 percent of the labour for food production, for both household consumption and for sale (Saito, 1994). However, their labour is often invisible, unpaid, and undervalued. Women also represent the majority of smallholder farmers and manage a large part of the farming activities on a daily basis (ibidem). Although men provide assistance with clearing the land, women traditionally undertake the bulk of the remaining farming activities; planting, weeding, harvesting, drying, and storing. While men and women generally face the same external constraints, they have an unequal access to productive assets and opportunities, such as land rights and education, technologies, labour, capital, support services, and credit. This disparity results in productivity differentials to the detriment of women (UNEP, 2007).

The State of Food and Agriculture 2010-2011 report issued by the FAO in 2011 declared "if women had the same access to productive resources as men, they could increase yields on their farms by 20 to 30 percent. This could raise total agricultural output in developing countries by 2.5 to 4 percent, potentially reducing the number of hungry people in the world by 12 to 17 percent" (FAO, 2011).

Through this Special Operation, WFP made a deliberate attempt to address these inequalities by including women in all aspects of the project (62 percent of participants were women). The final evaluation surveys revealed concrete benefits for women farmers, including:

- Increased Spare time: 98.3 percent of the women surveyed reported having additional free time after utilizing the new storage unit. (Ref. Figure 9)
- Increased Security: 99.1 percent of the women surveyed reported having increased freedom to leave their home and pursue other activities, due to the improved security of their stored food, as the new storage units could be locked. (Ref. Figure 10)
- Reduced Labour: Participating women consistently reported a reduction in their daily work duties, because the new storage units eliminated the arduous task of cleaning and shelling cereals before each meal. Instead of requiring hours of labour, this task now took minutes to withdraw the required amount of grain from the food storage unit. (Ref. Figure 9).
- Increased Prices: 97.9 percent of the women surveyed reported their family having achieved a financial advantage by using the new storage units and having greater control over the timing of sales. The average increase in prices across the three major crops was between 53 and 91 percent, but many families sold for prices two to three times higher to those of their neighbours who had not purchased the new storage units. (Ref. Figures 4 and 7).

Major Implementation Challenges

To successfully achieve the Zero Food Loss Initiative objectives, numerous operational challenges needed to be addressed. Through diligent support of the NGO training partners, the determination shown by the private sector equipment manufacturers and distributors, and the capable management of the WFP Ugandan Country Office, the following obstacles were all overcome:

Capacity Development & Support of Low-Income Farmers:

- Mobilization and selection of farmers
- Selection of experienced training partners
- Training of the workshop facilitators
- Identification of suitable training venues
- Access to electricity to run the workshop projectors
- Development of the PHL training material
- Translation of all training material into nine different local languages
- Scheduling of refresher trainings prior to harvest (and getting farmers to attend)
- Dealing with higher attendance of farmers compared to the planned number
- Keeping the numbers of farmers participating in each training session to 50, to encourage a genuine workshop and sharing of ideas, rather than a classroom environment.

Equipping of Low Income Farmers:

- Identifying skilled local artisans
- Training of local artisans on the manufacturing of hermetic storage units
- Finalizing the designs of the various storage options
- Demand-planning and achieving productions schedules
- Meeting agreed quality specifications
- Distribution of new storage units from manufacturers to individual farms
- Collection of farmer payments for new equipment

The process of overcoming these challenges has provided a very important foundation for replicating similar or larger implementations in other developing regions over the coming years.

Illustration F: Manufacturing and distribution challenges

Impact Assessment

An accurate assessment of WFP's post-harvest loss reduction activities required measuring the financial impact on participating households, but also the performance of the new equipment compared to that of traditional storage units and practices. Ultimately, the decision by smallholder farmers in SSA to adopt new post-harvest management practices and invest funds in a new storage technology will depend on their understanding of the positive impact of making such investments. The information gathered from the series of surveys undertaken illustrates that benefits go beyond increasing available food for consumption. Improved household storage can contribute to improving household finance, family health, and food security.

Measuring qualitative losses (where a diminution of caloric and nutritive value has occurred, or the loss of acceptability or edibility to potential consumers) is far more difficult than measuring quantitative losses of grain, pulses, and legumes. Despite a general perception of a higher priority in developing countries for reducing quantitative losses, in the case of Uganda, farmers are strongly encouraged to reach the East African Standard of quality (EAC, 2011). Therefore, WFP's testing of grain samples attempted to also include issues of consumer dissatisfaction with produce quality, linked to higher rates of post-harvest losses and crop value (i.e. blemished/damaged grain, insect or vermin damaged grain, discolored kernels, mouldy kernels, broken kernels, and foreign matter.

When calculating the impact of the new post-harvest management practices and storage technologies, a basic count and weigh method was applied. The 1,400 participating farming households all followed the same post-harvest handling procedures of transportation, threshing, drying, cleaning, and processing their crop, regardless of the applied method of storage. All participating farmers were required to retain a representative sample (5 kg) of their harvested crop and store it in their traditional storage unit, placing the balance of their crop into their recently purchased new-technology storage unit. The independent variables were the different storage environments on each farm and the dependent variable was the recorded volume of loss after >30 and >90 days of storage.

Testing for aflatoxin contamination was conducted by a separate team of evaluators to those facilitating the 30- and 90-day surveys. Following preliminary examinations, it was decided the level of training required to correctly use the laboratory testing equipment in the field and the degree of accuracy required to ensure the integrity of the captured data, exceeded the capacity of most of the field monitoring staff. As such, the aflatoxin readings were carried out independently and involved a reduced number of farms (Figure 6).

Results

The trial results were unequivocal. From the very first inspections the difference in crop preservation between the new technology and traditional storage units was apparent. The performance gap became greater with the increase of the duration of storage days. Of the 1,400 surveyed households, not one recorded a better storage result using the traditional handling and storage methods. For all participating farms, without exception, the theoretical benefits expected to be derived from employing new technologies for handling and storing crops were proven in the practical results achieved.

The new technology enabled farmers to record an overall average loss of grain of below 1 percent (after 90 days storage), compared to 41.64 percent (after 90 days storage) using traditional storage practices (ref. Illustration G and Figure 5).

Illustration G: Maize after 90 days in traditional and new technology storage

These results at scale - volume, income, food safety, and consumption gains for each individual family – have the potential to greatly impact local, national, and regional food security. The implications are considerable: creating a decentralized network of household grain storage facilities (where thousands, potentially millions, of tons of grain are securely stored), feeding into community collection centers in a controlled manner and linked to local and international markets, have the potential to open trade across Africa and greatly reduce food price volatility, especially for the poorest households. More resilient markets will also likely encourage farmers to increase production (Figure 12 shows 40 percent of farmers currently using less land than capacity), enhance their ability to take risks, and ensure food availability at affordable prices for the community.

Figures in the annex provide an overview of the impact of post-harvest loss reduction activities on a representative sample of all participating low-income families.

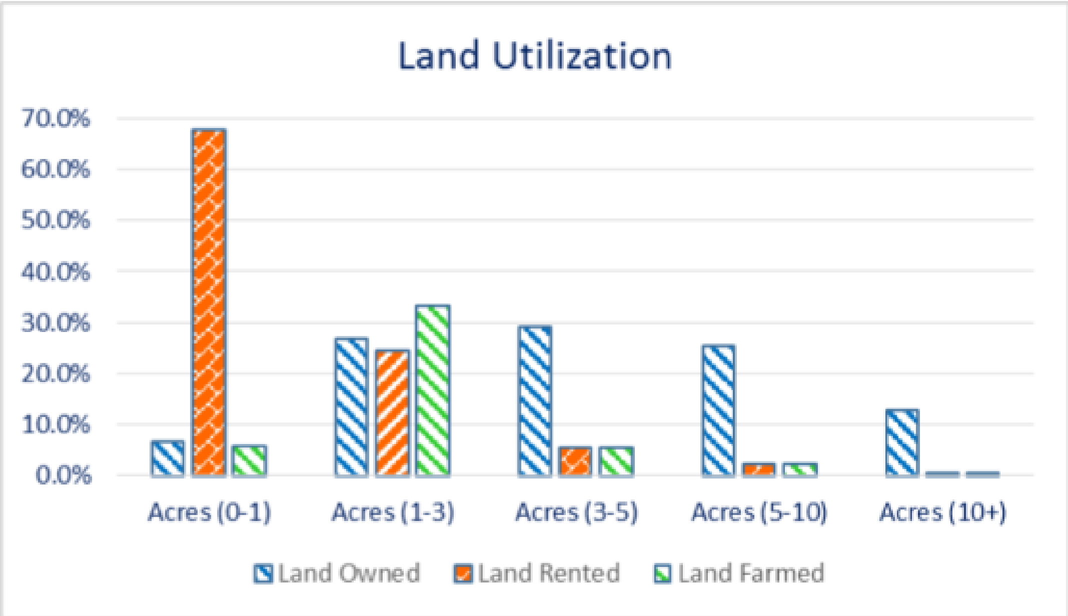


Figure 12: Land Utilization in Uganda. Over 40 percent of farmers utilize less land than owned or rented

Sustainability

Enduring food security and sustainable agricultural intensification depend on development strategies with resilience built in from the start (Conway, 2012). Considering that the ultimate determinant of success for any new agricultural initiative is its longevity after the initial period of support, enthusiasm, and external funding, WFP in conjunction with USAID, considered the most critical areas, which, if left unattended, would negatively impact the long-term success of these agricultural improvements. The most likely potential threats were considered to be:

- Farmers becoming dependent on continued price subsidization.
- Inability to engage Governments, the private sector and NGOs to work together to develop resilient and sustainable intensification.
- Inadequate inclusion of female farmers and youth.
- The ongoing capacity development of farming communities.
- The design and operational effectiveness of the new equipment.

Raising awareness of these dangers into the framework of the project ensured the decision making process within all operational stages remained attuned to the long-term sustainability of the initiative. A clear plan was established to gradually phase out subsidization of equipment to zero over the course of five years; the active involvement of district and central Government officials in the capacity development of farmers was a priority; local and international NGOs were assigned leading implementation responsibilities; private sector business partnerships were established for the manufacturing and distribution of equipment; women farmers' engagement was strongly encouraged (with 62 percent of all participants being women); youth employment was developed through the creation of artisan courses at training institutes and regional employment; and training workshops were aligned with equipment manufacturing to ensure private sector retailers understood the correlation between capacity development and effective use of equipment (leading to increased equipment sales). Despite varying levels of success achieved across all strategic areas, a strong foundation of partnerships was established in the first year, which bodes well for the ongoing resilience of the project, the country, and those involved.

Vitally important to sustainability is the environmental impact of the initiative. Reducing post-harvest losses has the potential to increase food availability, without additional investment in labor, land, materials, resources, and biofuel.

Marketing

Unless low-income farmers are linked with markets that recognize and reward improved grain quality, the supplementary benefit to low-income farmers of increasing household incomes will not be achieved, which would have important repercussions on the sustainability of the intervention. At the time of writing this report, smallholder farmers, working within farmers' organizations, were exploring alternative means of marketing their surplus. Among these new market opportunities were initiatives such as WFP's Purchase for Progress Programme (P4P), local village traders and larger national/international buying co-operatives, which had previously rejected grain from these farmers due to quality issues. (i.e., not meeting EAC grain quality assurance standards, or excessive aflatoxin contamination). Encouraging reports (supporting the results shown in Figure 6) since the conclusion of the project indicate a positive impact of new farming procedures enabling farmers to connect to markets and receive fair prices for their crops.

Private Sector Inclusion

Without strong private sector engagement, agricultural improvement initiatives are not sustainable. Without a strong domestic framework where businesses embrace the change, both for commercial gain and progress, momentum will quickly stall. Many private sector actors understand that without capacity development, user benefits will not be maximized and repeat sales will be impacted. As such, WFP sought to engage local businesses in the farmer training component of the implementation as well as the equipment manufacturing, distribution, and sales.

Private sector partnerships were formed with local artisans, training institutes, transport providers, and distributors. Wherever possible, work was awarded in the same districts in which the farmers were located. Not only was this intended to stimulate local business and youth employment, it was deemed vital for farmers to have access locally to equipment manufacturers rather than travel long distances to the capital city. Artisan training was organized for professional businesses, and technical training courses were introduced at district training institutes.

In addition to developing these relationships, more work is required to promote private sector leadership in capacity development (agricultural training), farmer financing options, crop marketing services, and important market linkages. The ultimate indication of success will be the continuation and expansion of these activities after the international support is withdrawn.

Illustration H: Private sector partners

Illustration I: Farmers collecting their newly purchased storage equipment

Conclusion

WFP Uganda's Zero Food Loss Initiative demonstrates an effective, scalable, and replicable model of significantly reducing post-harvest losses and delivering numerous benefits to low-income farmers and communities. It is by no means an all-encompassing agricultural initiative, but it has clearly demonstrated that regardless of the level of post-harvest losses, the negative effects of inadequate post-harvest management can be significantly reduced, if not eradicated.

Crop contamination can be reduced, family nutrition can be improved, household incomes can be increased, numerous gender inequality issues can be addressed, and farmers' productivity can be greatly improved. We have the knowledge and the tools to eradicate this problem; it is now a question of will.

***

WFP sincerely thanks USAID for their guidance and financial support and equally appreciate the valuable contribution to the success of the Special Operation provided by volunteers of MIT and MU.

Figure J: Participating Farming Families

Figure K: Simon J Costa, project manager WFP Uganda's Zero Food Loss Initiative

Annex

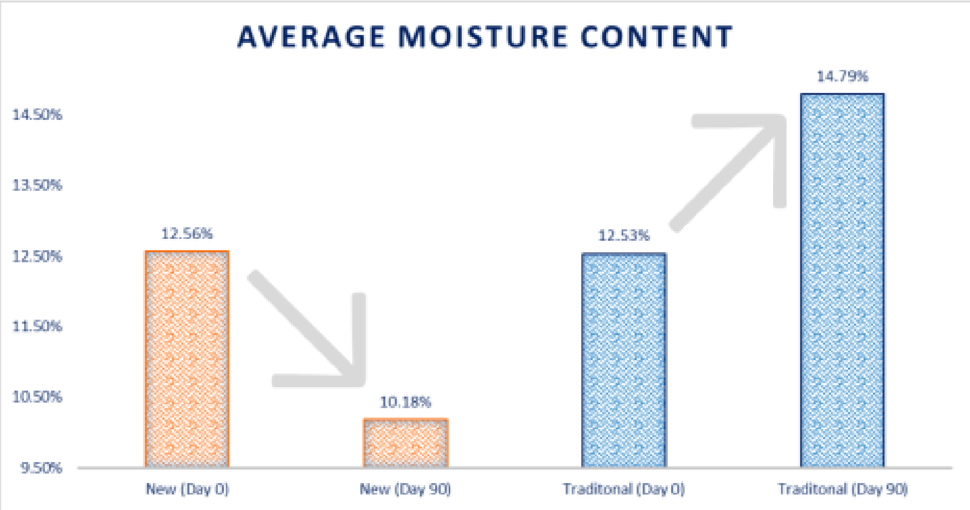


Figure 1: Periodic measurement of moisture content within stored crops (the significance of these changes to the internal environment can be better understood in Figure 6).

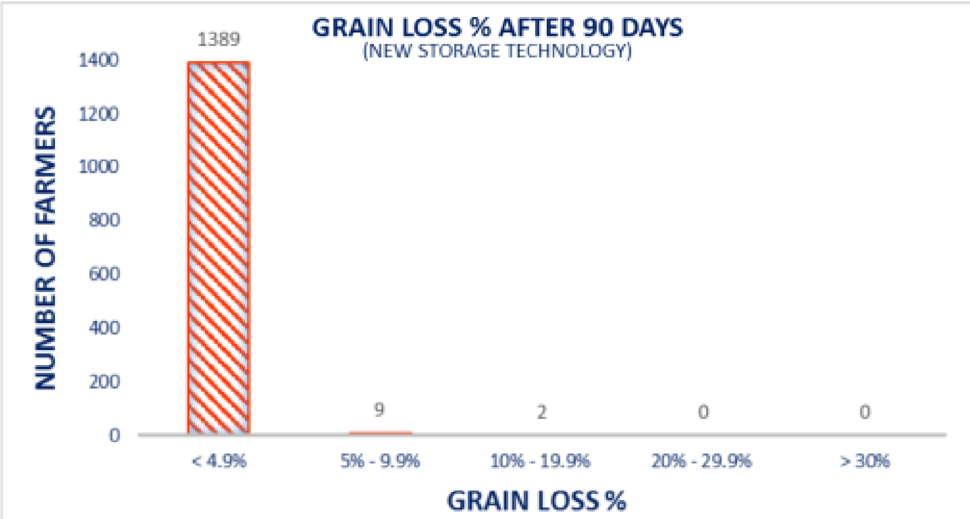


Figure 2: >99 percent of all participating farmers experienced less than 10 percent loss of crop after 90 days of using the NEW storage technology.

(Total average loss <1 percent)

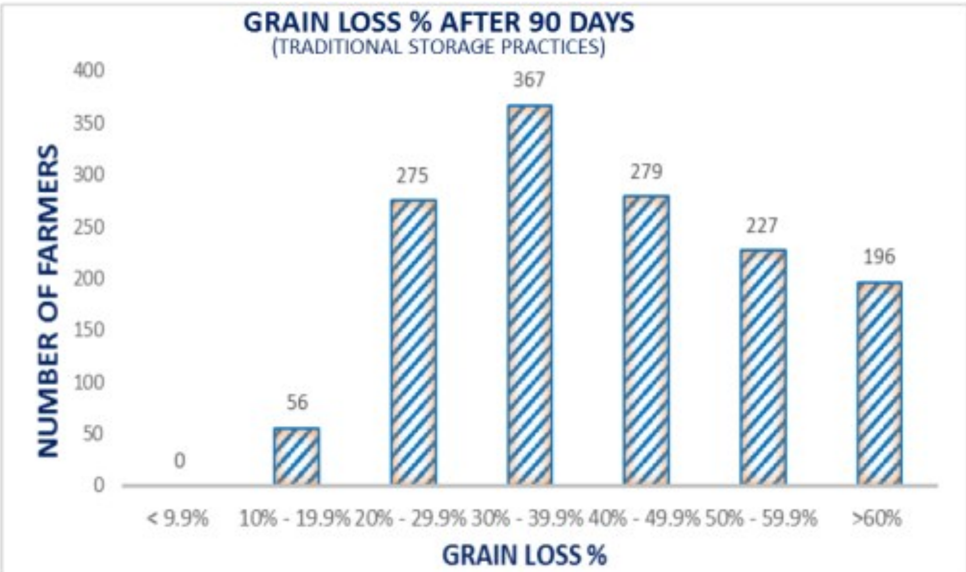


Figure 3: 0 percent of all participating farmers experienced less than 10 percent loss of crop after 90 days of using TRADITIONAL storing practices.

(Total average loss >41 percent)

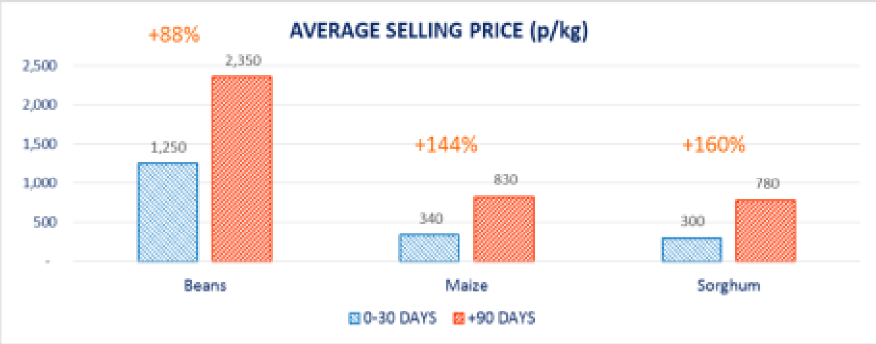


Figure 4: Average selling prices

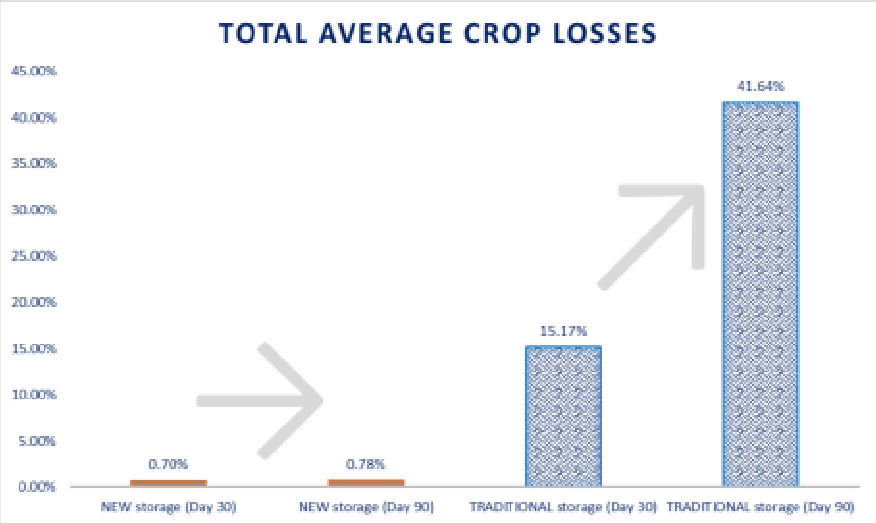


Figure 5: Periodic measurement of moisture content within stored crops (the significance of these changes to the internal environment can be better understood in Figure 6).

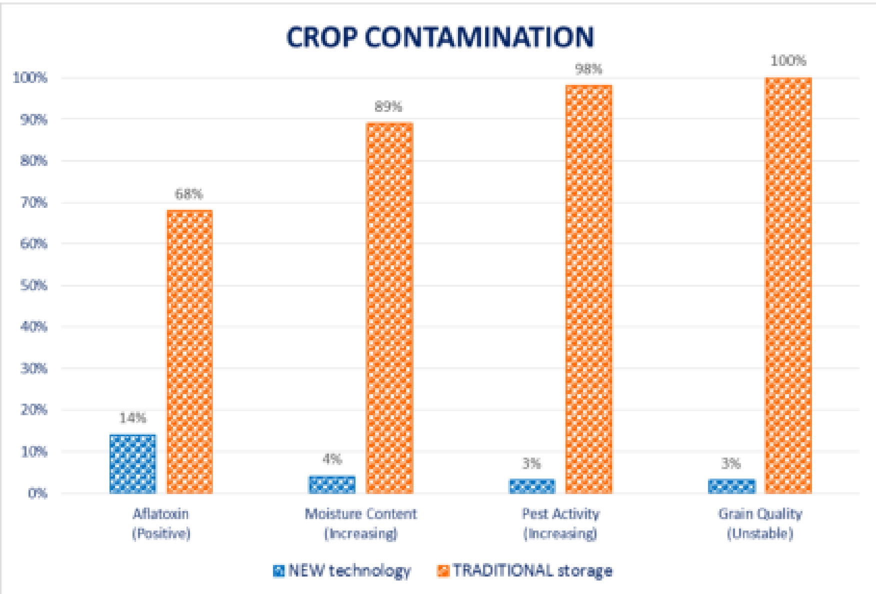


Figure 6: Monitoring the various storage environments (new and traditional) over a 90 day period enabled the Special Operation to compare Ugandan outcomes against studies completed previously in other developing countries. An important hypothesis being investigated was the correlation between poor post-harvest handling and storage practices and increased health dangers to the communities where crops are consumed.

The above results demonstrate when the ambient environment of a storage unit cannot be controlled and pest activity escalates, the moisture content of the stored grain, cereal or legume crop will continue to rise and the overall quality/stability of the stored crop will be impacted negatively. Increased pest activity not only leads to a loss in the quantity of consumable grain, but it can change the environment from minor levels of aflatoxin contamination to an environment with high levels of aflatoxin contamination.

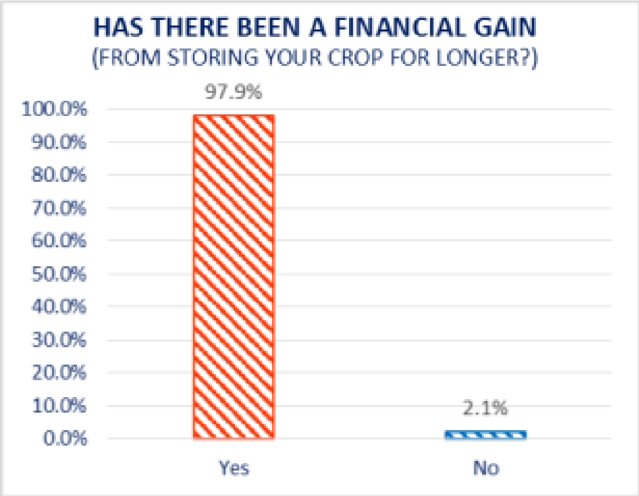


Figure 7

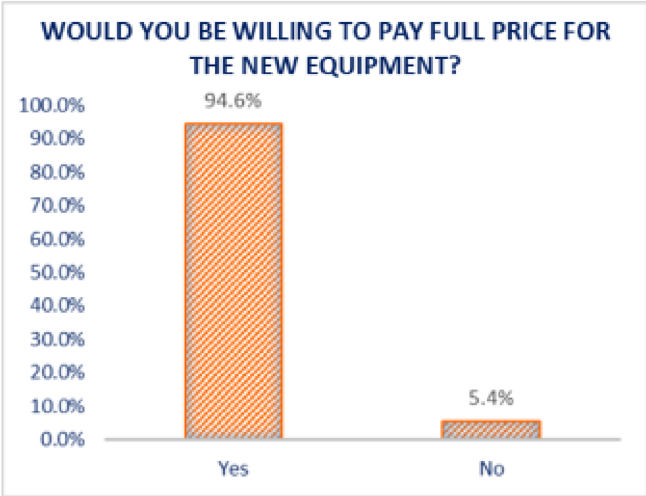


Figure 8

Figure 9

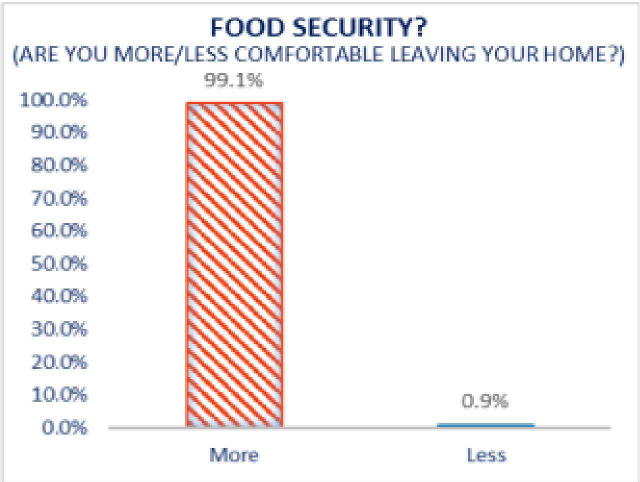


Figure 10

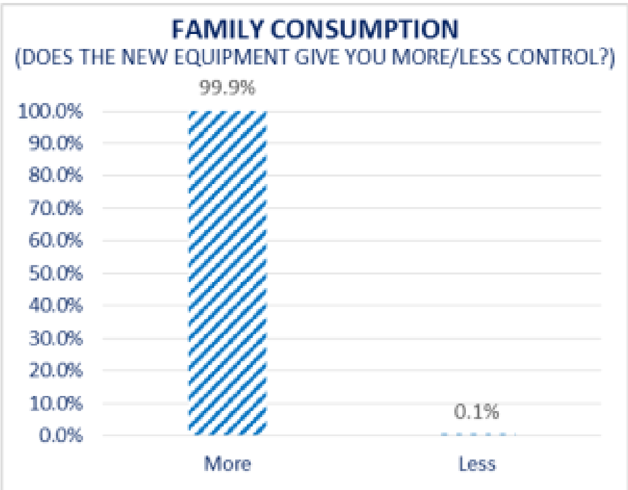


Figure 11

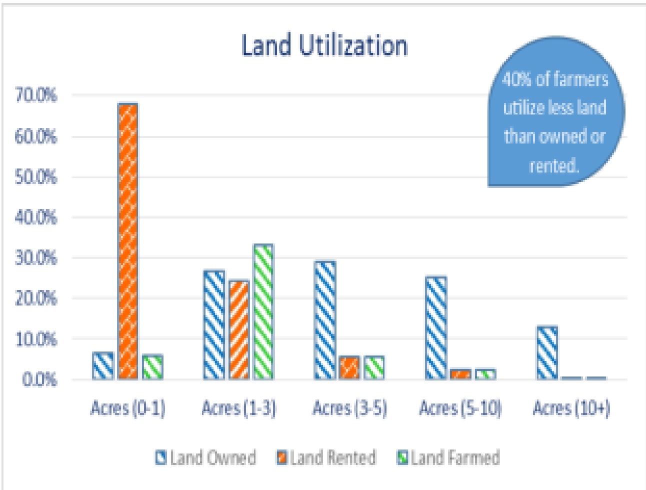


Figure 12

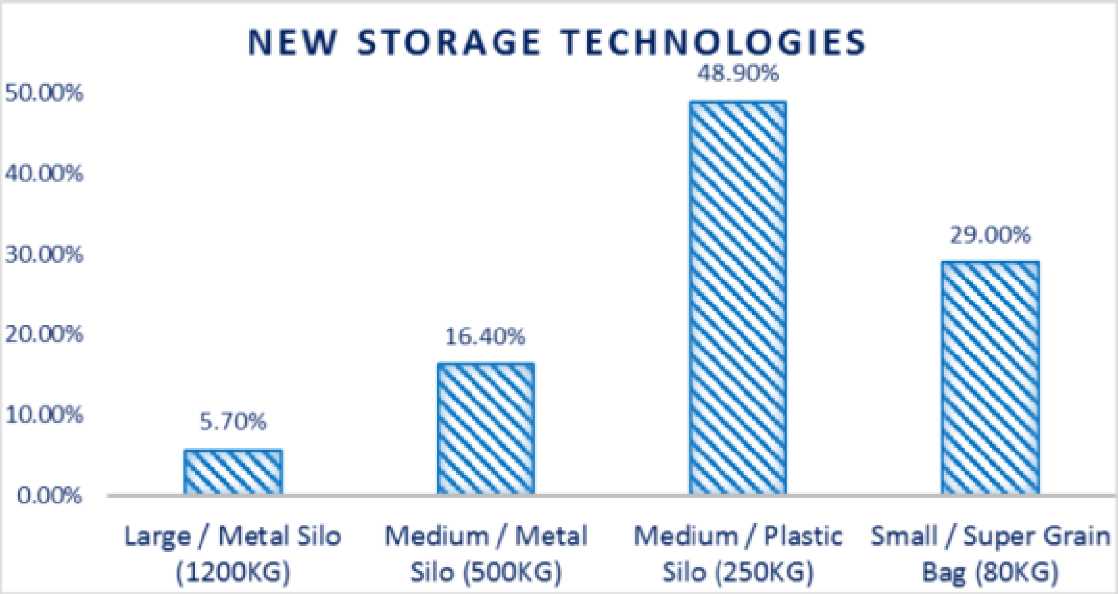


Figure 13

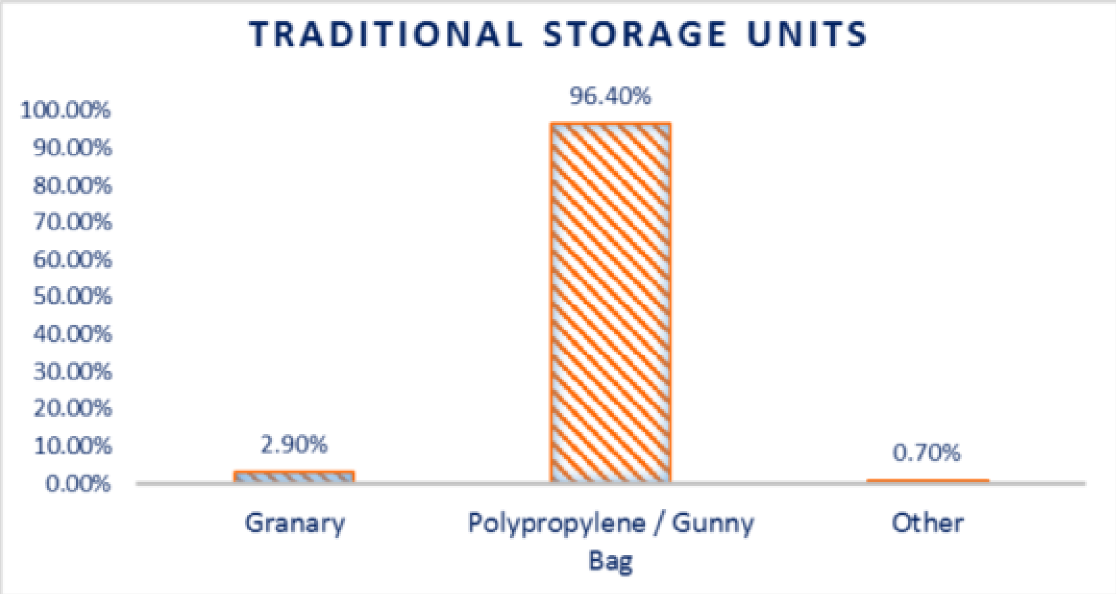


Figure 14

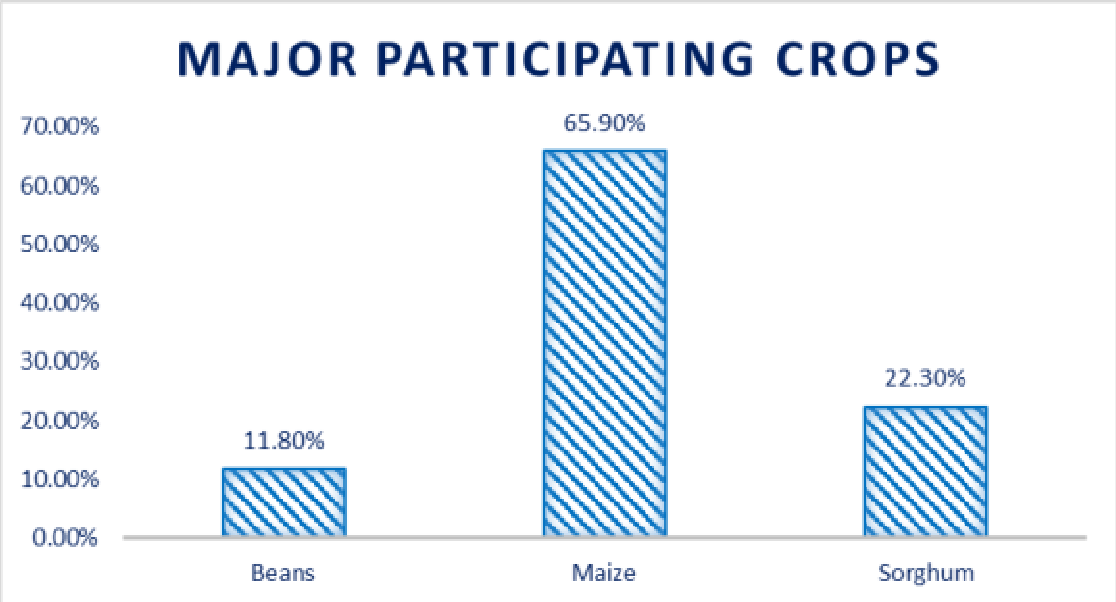
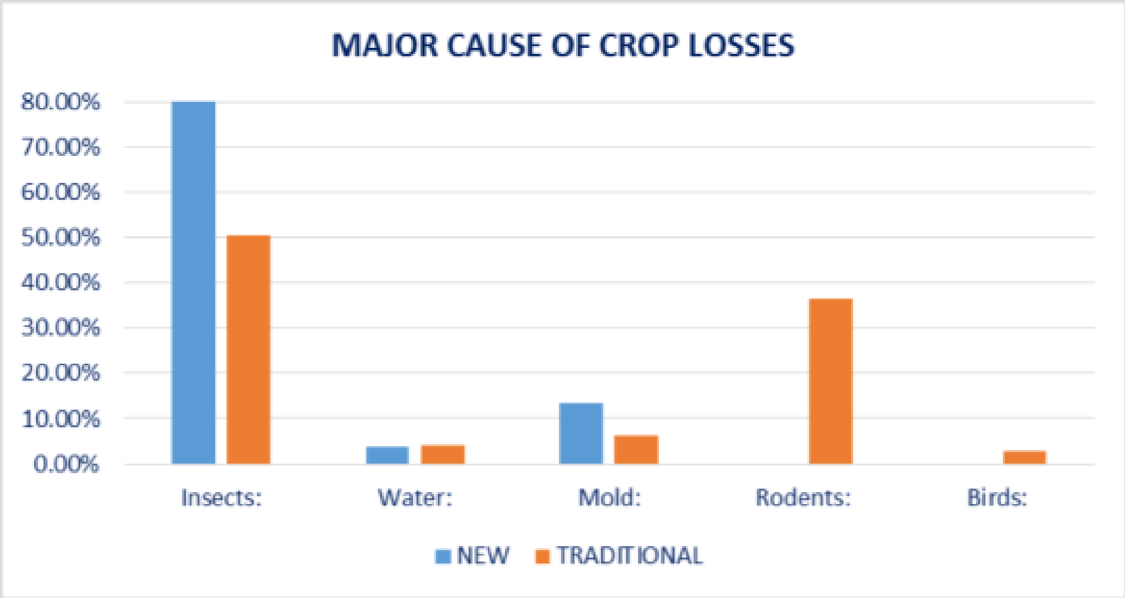


Figure 15



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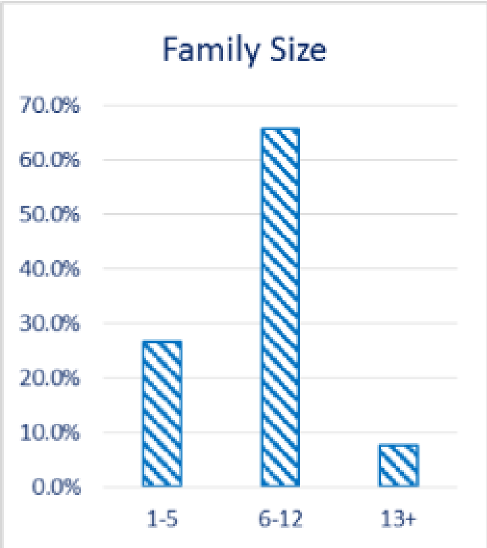

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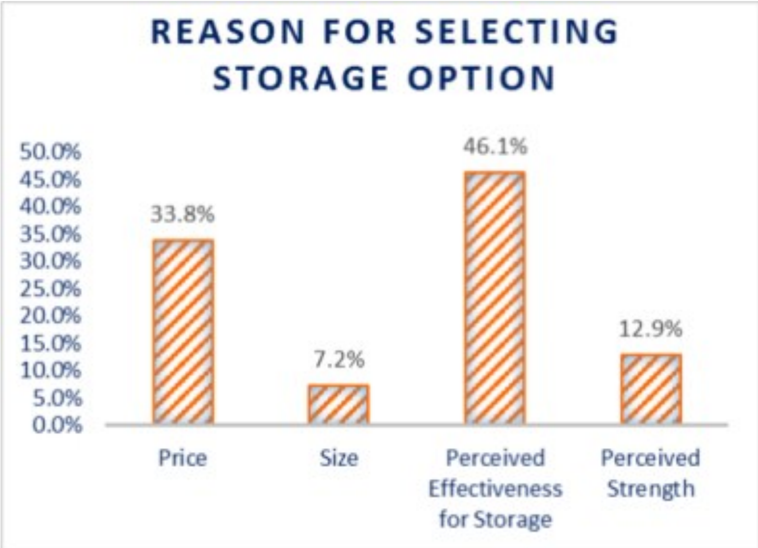

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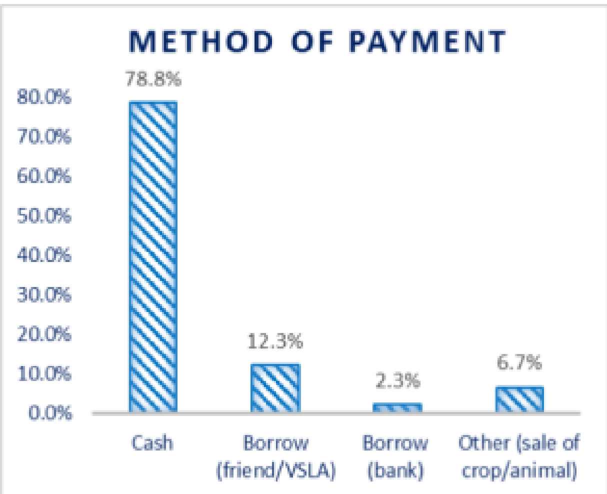

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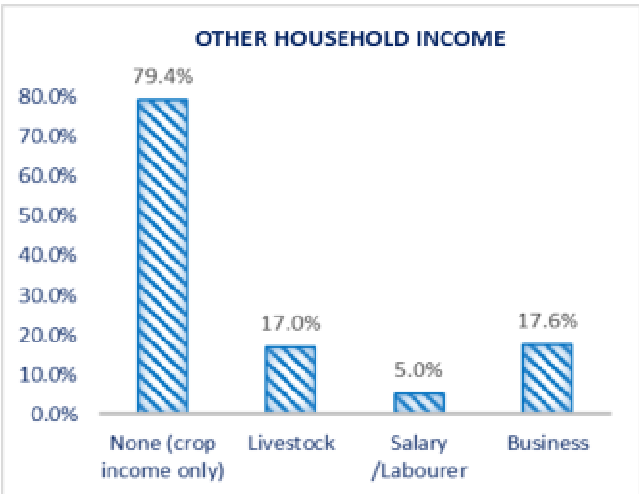

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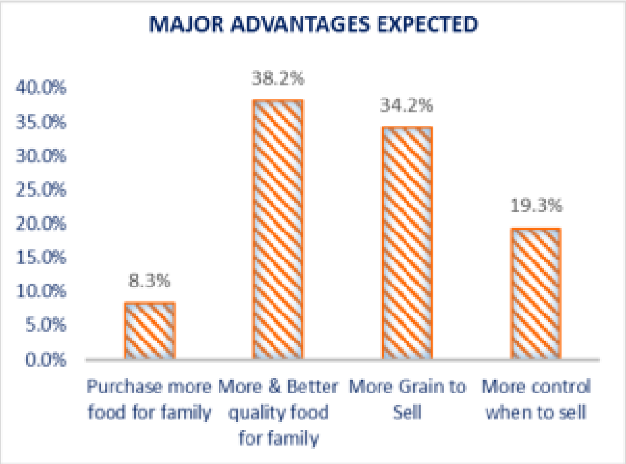

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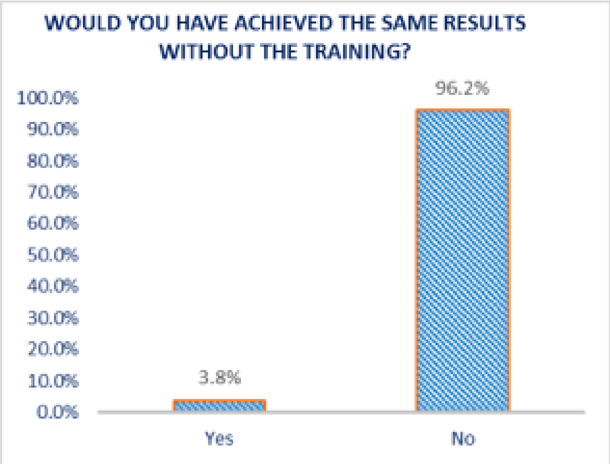

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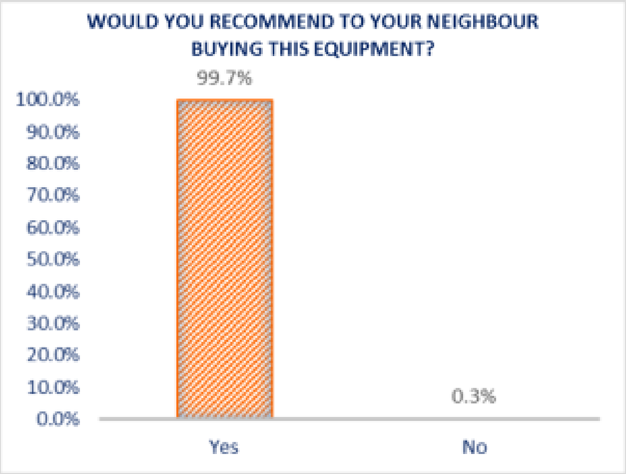

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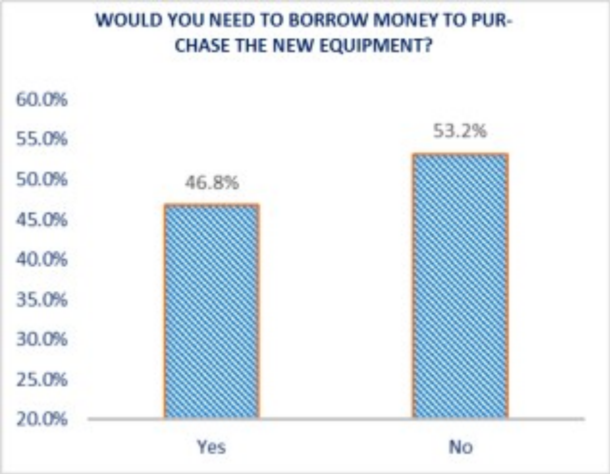

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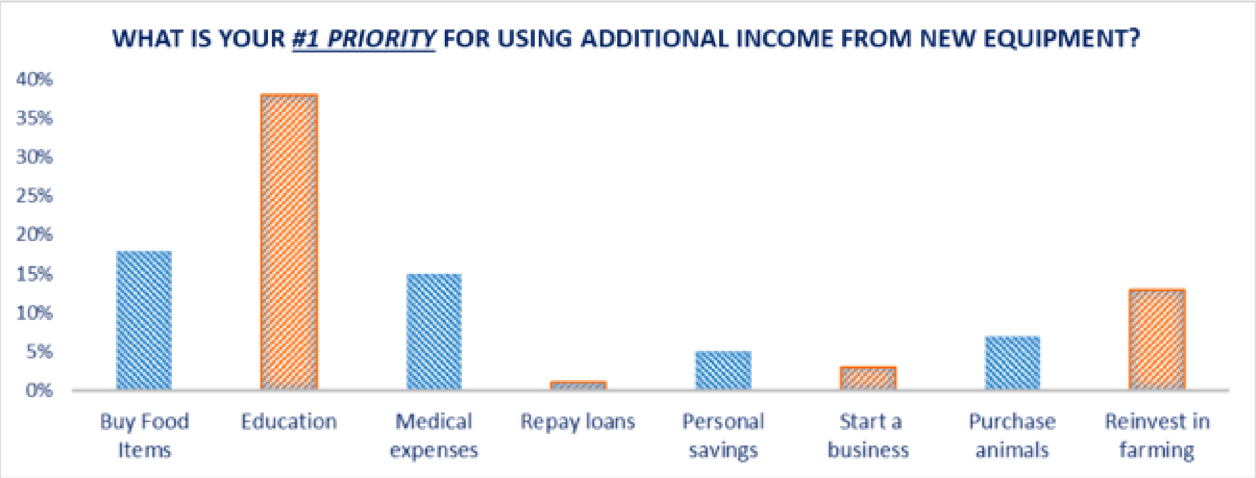

Figure 25

Acronyms

AfDB	African Development Bank
APHLIS	African Post-Harvest Losses Information Systems
CIMMYT	International Maize and Wheat Improvement Centre
EU	European Union
FAO	Food and Agriculture Organization
IFAD	International Fund for Agricultural Development
MIT	Massachusetts Institute of Technology
MU	Makerere University of Uganda
P4P	Purchase for Progress
SDC	Swiss Agency for International Development Cooperation
SSA	Sub-saharan Africa
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WB	World Bank
WFP	World Food Programme

Bibliography

Alebeek, F. V. (1996). Foraging behaviour of the egg parasitoid Uscana lariophaga: towards biological control of bruchid pests in stored cowpea in West Africa. Landbouwuniversiteit Wageningen (Wageningen Agricultural University).

Beti, J. A., Phillips, T. W., & Smalley, E. B. (1995). Effects of maize weevils (Coleoptera: Curculionidae) on production of aflatoxin B1 by Aspergillus flavus in stored corn. Journal of economic entomology, 88(6), 1776-1782.

Bett, C. & Nguyo, R. (2007). Post-harvest storage practices and techniques used by farmers in semi-arid eastern and central Kenya. In African Crop Science Conference Proceedings (Vol. 8, pp. 1023-1227).

Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., & Maternal and Child Nutrition Study Group. (2013). Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost?. The Lancet, 382(9890), 452-477.

Biello, D. (2009). Another Inconvenient Truth: The World's Growing Population Poses a Malthusian Dilemma. Scientific American. Retrieved on 2 October at http://www. scientificamerican. com/article. cfm.

Bokusheva, R., Finger, R., Fischler, M., Berlin, R., Marín, Y., Pérez, F., & Paiz, F. (2012). Factors determining the adoption and impact of a postharvest storage technology. Food Security, 4(2), 279-293.

Conway, G. (2012). How to create resilient agriculture. Appropriate Technology, 39(2), 12.

Costa, S. J. (2014). Reducing food losses in sub-Saharan Africa (improving post-harvest management and storage technologies of smallholder farmers.)—an 'action research'evaluation trial from Uganda and Burkina Faso. UN World Food Programme, Kampala, Uganda.

Darwish, W. S., Ikenaka, Y., Nakayama, S. M., & Ishizuka, M. (2014). An overview on mycotoxin contamination of foods in Africa. The Journal of Veterinary Medical Science, 76(6), 789.

De Onis, M., Blössner, M., & Borghi, E. (2012). Prevalence and trends of stunting among pre-school children, 1990–2020. Public Health Nutrition,15(01), 142-148.

EAC (2011); Maize Grain—Specification. East African Standard. Third Edition. Retrieved on 2 October at https://law.resource.org/pub/eac/ibr/eas.2.2011.html

Egger. P. (2013). Employment in Africa: Think agriculture! Why agriculture should be Africa's top priority. International Labour Organization. Retrieved on 2 September 2015 from http://www.ilo.org/global/about-the-ilo/newsroom/comment-analysis/WCMS_203469/lang--en/index.htm

FAO. (1995). Synthesis report of the African Region: Women, agriculture and rural development. In Report prepared under the auspices of FAO's Programme of Assistance in Support of Rural Women in Preparation for the Fourth World Conference of Women.

Fischler, M. (2011). Year Ex-Post Impact Study. Postcosecha Programme Central America. Bern, Zürich: Intercooperation und ETH.

Gitonga, Z. M., De Groote, H., Menale, K., & Tefera, T. (2012). Can metal silo technology offer solution to grain storage and food security problem in developing countries? An Impact evaluation from Kenya.

Grisley, W. (1997). Crop-Pest Yield Loss: A Diagnostic Study in the Kenya Highlands. International Journal of Pest Management 43 (2): 1 37- 1 42.

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., & Meybeck, A. (2011). Global food losses and food waste. Food and Agriculture Organization of the United Nations, Rome.

Hudler, G. W. (1998). Magical mushrooms, mystical molds. Princeton University Press.

IFPRI. (2010). Aflatoxins in Mali. Retrieved on 25 July 2015 from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127059

Imura, O., & Sinha, R. N. (1989). Principal component analyses of bagged wheat infested with Sitotroga cerealella (Lepidoptera: Gelechiidae) and Sitophilus oryzae (Coleoptera: Curculionidae). Ecological research, 4(2), 199-208.

Joughin, J. (2012). The Maize Industry in Uganda. United States Agency for International Development.

Kader, A. A. (2005). Post-harvest Technology Research Information Centre. University of California.

Kader, A.A. and R.S. Rolle. (2004). The Role of Post-harvest Management in Assuring the Quality and Safety Horticultural Crops. Food and Agriculture Organization. Agricultural Services Bulletin 152, 52 p.

Lawley, R. (2013). Aflatoxins. Food Safety Watch. Retrieved on 25 July 2015 from http://www.foodsafetywatch. org/factsheets/aflatoxins.

Lienard, V., & Seck, D. (1994). Review of control methods against Callosobruchus maculatus (F.)(Coleoptera: Bruchidae), a pest of grain cowpea (Vigna unguiculata (L.) Walp) in tropical Africa. Insect Science and its Application, 15(3), 301-311.

Mutiro, C. F., Giga, D. P., & Chetsanga, P. (1992). Post harvest damage in small farmers' stores. Zimbabwe J. Agric. Res, 30, 49-59.

Njie, D. (2011). Food Loss Reduction Strategy. Food and Agriculture Organization. Retrieved on 5 September 2015 from http://www.fao.org/fileadmin/user_upload/ags/publications/brochure_phl_low.pdf

Pinstrup-Andersen, P. (2010). The African Food System and Human Health and Nutrition: a conceptual and empirical overview. The African Food System and Its Interaction with Human Health and Nutrition, Cornell University Press, Ithaca.

Saito, K. A., Mekonnen, H., & Spurling, D. (1994). Raising the productivity of women farmers in Sub-Saharan Africa (Vol. 230). World Bank Publications.

Sallam, M. N. (2008). Insect damage: damage on post-harvest. AGSI/FAO: INPhO. Retrieved on 25 November 2015 from http://www.fao.org/inpho/content/compend/text/ch02-01. htm.

Stephens, E. C., & Barrett, C. B. (2011). Incomplete credit markets and commodity marketing behaviour. Journal of Agricultural Economics, 62(1), 1-24.

UN Food and Agriculture Organization. (2011). The State of Food and Agriculture 2010–2011: Women in Agriculture: Closing the Gender Gap for Development. Retrieved on 25 November 2015 from http://www.fao.org/docrep/013/i2050e/i2050e00.htm

UNEP. (2007). Women Farmers' Productivity in Sub-Saharan Africa. Retrieved on 22 October 2015 from http://www.unep.org/training/programmes/Instructor%20Version/Part_2/Activities/Human_Societies/Agriculture/Supplemental/Women-Farmers_Productivity_in_Sub_Saharan_Africa.pdf

USAID and Danya International. (2013) Aflatoxin: A Synthesis of the Research in Health, Agriculture and Trade. Feed the Future Office of Regional Economic Integration, East Africa Regional Mission, Nairobi, Africa.http://www.aflatoxinpartnership.org/~/media/Files/Projects/Aflatoxin%20microsite/PACA%20general%20documents/Aflatoxin%20 Desk%20Study%20Final%20Report%202012.pdf

World Food Logistics Organization. (2010). Identification of Appropriate Postharvest Technologies for improving Market Access and Incomes for Small Horticultural Farmers in Sub-Saharan Africa and South Asia. Alexandria VA, March.

World Food Programme. (2014). Who are the Hungry?. Retrieved on 10 October 2015 from: https://www.wfp.org/hunger/who-are

World Health Organization. (2008). World health statistics 2010. World Health Organization.

Yoe, C. (2015). Aflatoxin Risk Assessment "Red Book" Model Exercise. College of Notre Dame of Maryland. Retrieved on 10 October 2015 from http://documents.mx/documents/aflatoxin-risk-assessment-red-book-model-exercise-charles-yoe-phd-college-of-notre-dame-of-maryland.html

Zorya, S., Morgan, N., Diaz Rios, L., Hodges, R., Bennett, B., Stathers, T. & Lamb, J. (2011). Missing food: the case of post-harvest grain losses in sub-Saharan Africa.

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