

Assessment of maize postharvest losses in the Middle Belt of Ghana

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Abstract

A United States Agency for International Development-funded Feed the Future Innovation Lab for the Reduction of Postharvest Loss was established in Manhattan KS, U.S.A. in 2014. This Lab is administered through Kansas State University, but includes researchers from many institutions. One of the focus areas within this broad project is reducing maize postharvest losses in Ghana. As the initial step in the process, an assessment trip was made to evaluate where most postharvest losses are occurring and to identify currently available or easily modified tactics or tools that could be applied to help alleviate these losses. Most of the maize production in Ghana is in the Middle Belt and Northern Ghana. The Middle Belt has two maize production seasons, namely, the major season and minor season. These seasons cover the periods April-August/September and September-December, respectively. In Northern Ghana, the maize production season is June-October (but maize is left in the field to dry until late November/December). The most serious problem facing smallholder farmers in the Middle Belt is difficulty drying their major season maize. The window for drying is only approximately four weeks in August and September. In the Middle Belt postharvest losses are primarily due to mold and aflatoxin, and due to insect pests in Northern Ghana. Major stored product insects reported to cause damage include *Sitophilus zeamais*, *Rhyzopertha dominica*, and *Sitotroga cerealella*, with some parts of the country reporting damage by *Prostephanus truncatus*. Phosphine fumigation and application of pirimiphos-methyl were the primary insecticides used, but there was considerable variation in how they are used and little data regarding actual efficacy. Quantifying where most postharvest losses occur and developing control strategies that can be integrated into the local systems will ultimately help reduce storage losses and increase food security in Ghana.

Keywords: stored product, postharvest loss reduction, storage pests, integrated pest management, aflatoxin

1. Introduction

Maize is the most cultivated crop in Ghana, and up to 1,023,000 ha are used for maize production (Statistics Research and Information Department of the Ministry of Food and Agriculture, 2012). Storage of maize on the cob is usually in traditional grain silos but shelled maize is put into jute or polypropylene sacks with or without chemical protection (Sugri et al., 2014). In sub-Saharan Africa, postharvest losses due to stored-product arthropods have been estimated at 20% (Obeng-Ofori, 2008). Therefore, it is important to mitigate these and other postharvest losses to ensure food security in Ghana. With funding from USAID, a Feed the Future Innovation Lab for the Reduction of Postharvest Loss (PHL-IL) has been established.

This Lab is administered through Kansas State University, but includes researchers from many institutions. The institutions and professionals that comprise the PHL-IL Ghana Project Team (GPT) are: Oklahoma State University, Stillwater, OK; Kansas State University, Manhattan, KS; Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana; USDA-ARS Center for Grain and Animal Health Research (CGAHR), Manhattan, KS; University of Kentucky, Princeton, KY; Fort Valley State University, Fort Valley GA; and Vestergaard Frandsen SA, Lausanne Switzerland. Current key cooperators in Ghana include Pens Food Bank Enterprise, Ejura; Masara N'Arziki Farmers' Association, Tamale; and Agri Commercial Services, Wenchi.

In 2014, the first year of the 5-year project, the GPT assessed current grain handling and pest management tactics, stored-product insect activity and post-harvest maize losses on-farm and in small-, medium-, and large-scale storage warehouses in Ghana with the ultimate goal of identifying researchable areas in postharvest loss (PHL) that are perceived “critical control points” where breakthroughs in research and development could lead to significant improvements in food security. Information was also sought from the Ministry of Food and Agriculture (MoFA), Universities, Council for Scientific and Industrial Research (CSIR), MoFA district offices, Ghana Grains Council, and other important stakeholders in the maize value chain in order to identify needs, priorities, promising “on the shelf” technologies, and successful tactics already in use in Ghana but which are not yet widely adopted or need further refinement. The first maize PHL assessment was conducted during the period May 19-30, 2014 and focused on the Middle Belt of Ghana. The second PHL assessment that focused on key maize growing areas in Northern Ghana was conducted during the period December 5-19, 2014.

In 2015 and 2016, the Ghana Project aims to conduct research on topics identified as researchable areas in postharvest loss where breakthroughs in research and development could lead to significant mitigation of PHL in maize. In 2017 and 2018, the Ghana Project aims to conduct educational and training meetings in the Middle Belt and Northern Ghana to share proven practices and information learned during assessments and research activities to reduce PHL of grains at the household and village level. The target audience will include farmers, aggregators, local NGO's, warehouse owners and/or managers and other stakeholders including women's groups that are part of the market process.

2. Maize postharvest loss assessment in the Middle Belt of Ghana

A 2-week in-country assessment of PHL in the Ghana maize value chain was conducted in the Middle Belt of the country by ten professionals in postharvest engineering technology and stored-products protection from the GPT. The GPT visited stakeholders in Accra and traveled to the

major maize growing region of Ghana, the Middle Belt (Table 1). The major centers of maize production and marketing in the Middle Belt, namely, Nkoranza, Wenchi, Ejura, Bonyon and Techiman were visited. During visits to these areas, the GPT acquired knowledge on postharvest losses that occur along the value chain. Stages of the maize postharvest system such as harvesting, pre-drying in the field, threshing (shelling), drying, cleaning, bagging, and storage were assessed. Additionally, the capacity and operations of grain storage systems in these regions and maize losses that occur in them were assessed. The GPT observed current grain handling and pest management tactics, stored-product insect activity, drying systems and post-harvest grain losses in on-farm storages and small-, medium- and large-scale storage warehouses in Ghana. The ultimate goal was to identify researchable areas in PHL where breakthroughs in research and development could lead to significant improvements in grain quality and food security. All important stakeholders in the maize value chain, such as smallholder farmers, government and quasi-governmental agencies, the private sector, non-governmental institutions, research institutions, universities, etc. were visited as part of the PHL assessment (Table 1).

3. Findings from the postharvest loss assessment

3.1. Maize postharvest losses

In the Middle Belt, Pens Food Bank Enterprise estimates major season PHL of maize due to field losses (over-maturity, harvesting, heaping), shelling or threshing, drying, storage losses (molds) and storage losses (insects) at 5, 1.5, 0.5, 15 and 8%, respectively (a total of 30% loss). The major season covers the period April-August/September. Most of the major season losses are due to drying challenges resulting from the short dry spell prior to the minor growing season, poor handling of the maize in the field and drying of the corn ears on bare ground or on less than suitable surfaces. Additionally, shelling is often done in the field creating conditions attractive to insect infestation and proliferation. During the minor season, these losses are estimated at 6, 1, 0.2, 2 and 10%, respectively (a total of 19.2% loss). Most of the minor season losses are due to insect pest-related problems caused by delayed harvesting. The minor season covers the period September-December.

Generally, maize farmers cite insect pests, delayed threshing and marketing of their maize and poor storage facilities as critical constraints to maintaining crop quality after harvest. Many farmers emphasize that maize loss through insect pest damage is significant. Farmers exhibited some knowledge of insect problems of maize and key pests they identified included maize weevils [*Sitophilus zeamais* (Motsch.): Coleoptera: Curculionidae], rice weevils [*Sitophilus oryzae* (L.): Coleoptera: Curculionidae], larger grain borer [*Prostephanus truncatus* (Horn): Coleoptera: Bostrichidae], lesser grain borer [*Rhyzopertha dominica* (F.): Coleoptera: Bostrichidae], red flour beetle [*Tribolium castaneum* (Herbst): Coleoptera: Bostrichidae], Angoumois grain moth [*Sitotroga cerealella* (Olivier): Lepidoptera: Gelechiidae], termites [*Microtermes* spp: Isoptera: Microtermitidae] and corn earworm [*Helicoverpa zea* (Boddie): Lepidoptera: Noctuidae]. Field infestation is high especially during the minor season when maize stays longer in the field as farmers take advantage of the relatively long and dry spell to leave their maize longer in the field to dry properly but this leads to increased insect pest infestation that is transferred into storage.

Table 1 Dates and locations, people, groups, or organizations (entities, projects) visited during the maize postharvest loss assessment in the Middle Belt of Ghana during the period May 19-30, 2014.

Date	People/Locations/Groups/Organizations/Entities/Projects Visited
May 19, 2014	USAID Office of Economic Management, MOFA-Agric Mechanization, Ministry of Food and Agriculture (MOFA) - Policy, University of Ghana - College of Agriculture, Ghana Grains Council
May 20, 2014	World Food Program, Winneba Seed Storage Warehouse, Winneba MIDA Assisted Warehouse, Wienco, National Food Buffer Stock Company (NAFCO)
May 21, 2014	Kwame Nkrumah University of Science and Technology (KNUST) - Faculty members in Entomology, Plant Pathology, Animal Science and Extension; Asuoyeboah Seed Warehouse
May 22, 2014	Yedent Agro Processing Ventures Limited, Kwame Boateng Maize Drying Center
May 23, 2014	MOFA Nkoranza, A MIDA Assisted Warehouse (Mr. Manso), Nkoranza Farmers Group
May 26, 2014	Pens Food Bank Warehouse, Alliance Farms, Ejura Farms
May 27, 2014	Mbaana Farmers Groups 1 and 2, Digyawu Farmers Groups 1 and 2, MOFA Ejura, Ejura Market
May 28, 2014	Nkyensie Farmers Groups 1 and 2, Santaso Farmers Groups 1 and 2, Sekyedumase Farmers Group, Maize Warehouse and Processing Facility
May 29, 2014	KNUST -Postharvest faculty group in Agricultural Engineering, Council for Scientific and Industrial Research – Crops Research Institute (CSIR-CRI), Kumasi
May 30, 2014	Exit Meeting with USAID Office of Economic Management

3.2. Warehouse storage

The amount of maize stored in warehouses in Ghana is rapidly increasing. A number of private and public sector organizations that own many of these warehouses operate as Postharvest Service Centers whose key goal is to improve agricultural production and food quality and reduce PHL. However, it is important to point out that many warehouses, such as those owned and/or operated by the Warehouse Receipt System (WRS), Agricultural Development and Value Chain Enhancement, and Millennium Development Authority, are not adequately patronized by farmers due to lack of trust. The immense success of Masara N'Arziki Farmers Association (MAFA) which comprises approximately 10,000-11,000 farmers in Northern Ghana and the failure of the WRS to establish to date can be explained by the production-related packages such as agricultural inputs and pre-harvest, harvest, and post-harvest services provided by the former. The provision of inputs and services earns MAFA a lot of trust from farmers. Because of this trust, Wienco

(Ghana) Limited warehouses, used by MAFA, are well utilized. There are approximately 40-50 nucleus farmer-based warehouses in Northern Ghana that are also well patronized due to the aforementioned reasons.

Postharvest losses of maize occur at multiple points during warehouse storage in Ghana, but based on information obtained during the assessment trip there are two major sources of loss, namely, losses due to storage of high moisture maize resulting in mold and aflatoxin, and losses due to insect pests and rodents. The significance of these two major loss types varies with season, geographic location within the country, and management practices, but both can produce estimated losses of 30% or more. Losses during handling and processing were also reported. There are technologies and tactics available that could greatly reduce losses during storage, but research is needed to determine which could be most effectively applied under current conditions in Ghana and how they need to be modified. Warehouse storage in Ghana is also highly variable and in developing and/or implementing new technologies and tactics it is important to make them scalable and/or targeted to specific storage conditions. Technologies and tactics should also ideally be implemented incrementally, producing the most improvement with the least cost initially while also putting the practitioner in a position to take advantage of the improved storage capacity with additional tactics to increase storage protection further. For example, needs and management tactics at the farmer level and at the aggregator level may be similar, but the specific method of implementation needs to be different. Fortunately, a number of technologies and tactics that are currently available that show promise to be adaptable to conditions in Ghana were identified.

The preservation of maize stored in warehouses could be improved by utilizing the considerable amount of research information and knowledge on development of pest management programs for the food industry that is currently available. Thus, there is great potential for the adoption of economically feasible and culturally acceptable improved storage methods for proper grain management in warehouses.

3.3. Aflatoxins in maize

Mitigation of aflatoxin begins in the field production stage. Reducing aflatoxin prior to harvest is critical in maintaining safe levels throughout the maize value chain. Total aflatoxin levels in samples of stored maize from Ejura-Sekyedumasi, North Kwahu and Nkoranza were found to be 120.5 ppb, 153.2 ppb, and 134.2 ppb, respectively (Akrobortu et al, 2008). Average levels were 12.0 ppb (SD 2.7), 15.3 ppb (SD 7.4), and 13.4 ppb (SD 6.9), respectively (Akrobortu et al, 2008). These values were collected over the years 1990-99 and exceeded safe levels for human consumption in several individual years. Samples for the study were also taken only from the minor season harvest which usually has less mold problems. As such, major season aflatoxin could be much higher. Ghana Bureau of Standards considers 15 ppb acceptable levels of aflatoxin in maize and raw shelled groundnuts. The US Food and Drug Administration considers acceptable levels as 20 ppb in maize, groundnuts and groundnut products.

A significant effort to reduce aflatoxin in Nigeria, Kenya and some surrounding countries is being done with the use of AflaSafe™ applied to fields. Aflasafe is comprised of a cocktail of atoxigenic strains of *A. flavus* that outcompete and exclude the toxigenic strains of the fungus that produce variable amounts of aflatoxin. Aflasafe is a field treatment and currently costs approximately US\$15 /ha. Initial development of an Aflasafe product was done in Nigeria and is a transferred technology initially developed by USDA-ARS from the U.S.A. Data indicates

aflatoxin reduction is around 70% and higher and currently an Aflasafe production plant operates at the International Institute of Tropical Agriculture in Ibadan, Nigeria. Field trials are currently being conducted by Dr. R. T. Awuah at KNUST, Kumasi, Ghana for the production of Aflasafe tailor-made for Ghana for the reduction of aflatoxin in groundnuts.

3.4. Farm level management operations

3.4.1. Harvest

Major season moisture content at harvest can be very high depending on ambient conditions. Maize harvest is defined as pulling ears from stalks and typically piling the ears until shelling can be done. In some cases moisture content was reported to be as high as 32% but more often in the mid to high 20% range, which dictates an equilibrium relative humidity within the pile above 95% and is favorable for mold growth.

3.4.2. Threshing (shelling)

Most farmers use mechanical threshers that shell either whole or de-husked ears. The threshers are contracted and this sometimes creates delays waiting for the thresher to arrive. Many farmers who de-husk before threshing will remove molded kernels from the ears. With whole ear threshers, no de-husking is done and moldy kernel exclusion is not possible. Threshed grain in this case is sometimes examined and individual moldy kernels are hand-removed. Farmers either discard moldy grain into fields, feed it to animals, or occasionally burn it. Discarding kernels into fields inoculates the field with additional spores. As mechanical harvesters have become more prevalent over hand threshing, damaged and broken kernels appear to have increased during the high-moisture major season. These broken kernels are more prone to mold and insect infestations. A key factor exacerbating the aflatoxin problem is the long delay between harvesting and threshing, which postpones drying and incubates mold production.

3.4.3. Drying

Drying of shelled maize by farmers is commonly done by solar drying of grain on tarps. Drying on tarps requires several days, usually up to 5 days, during the major season. However, due to heavy precipitation during the major season, there is a need to constantly protect grain being dried from sporadic rain and this adds to labor requirements and the cost of drying. Several studies have already identified this as a major problem contributing to mold and aflatoxin development. Artificial drying is less common due to the prohibitively high cost. Grain aggregators will sometimes buy higher moisture grain from farmers and dry at commercial facilities but costs are high for diesel or electric drying (up to GHS 10 / 140-kg bag) (US\$ 1 ≈ GHS 3).

Two solar drying greenhouses (solar dryers), one made of fiberglass and the other Plexiglas, were visited at Nkoranza and Sekyedumase and seem to be very effective for drying. The Sekyedumase unit dries about 1.2 MT from 25% moisture content to 16% in 2 days on multi-layered racks; a moisture meter is used to monitor moisture during rack drying. The Sekyedumase dryer is run by a farmer based organization (FBO) comprised of approximately 30 farmers. The solar drying system seems to be very successful although purchase of the solar dryer would be very difficult for a small group. The dryer was purchased by Pens Food Bank as a demonstration project. An added benefit of this dryer is that insect disinfestation occurs due to the high temperatures ($\geq 50^{\circ}\text{C}$) achieved. There seems to be great potential for significantly improving these solar dryers, which would reduce the drying cost, increase throughput and enable

its use for multiple crops through design alterations. The cost of solar drying using the Sekyedumase solar dryer is estimated at GHS 3 / 140-kg bag. Solar dryers could have a large positive impact in relation to the aflatoxin problem by drying grain relatively quickly. This technology could be adaptable to the farm level, made portable and financed through FBOs.

3.4.4. Storage

The majority of people responsible for longer term storage at the warehouse level indicated they target a moisture content of 12% or lower for maize. Spot measurements were taken at several warehouse and market locations and these showed the moisture content to be well below 12% and typically around 10.5%. All of these measurements were believed to be on minor season maize which should be well dried.

3.5. Potential research ideas identified

3.5.1. Moisture meters

Moisture meters will be a significant tool for facilitating better drying management and maintaining safe moisture levels. Grain aggregators who purchase maize from farmers often use the same moisture measurement methods as farmers at the farm gate. However, moisture content must also be assessed by modern methods when maize is delivered to a warehouse or seed storage facility. An instrument developed at USDA-ARS in Manhattan KS was used at site visits to measure moisture levels in bags at various locations. The instrument was designed for both bag and bulk measurement and has a 0.5 m probe that can be inserted into the grain bulk. The meter actually measures the temperature (T) and relative humidity (RH) of the air surrounding the grain and uses these values to calculate the equilibrium moisture content (EMC) of the grain. EMC relationships have been used extensively for grain drying models for many years and are well established. The design of the meter can also allow the user to monitor several sensor points within a grain bulk. Sensors can be attached by telephone wire and used to monitor points over several meters using the same hand-held reader. Measurements require the probe to remain in the grain bulk for at least a minute to get accurate readings and should only be used for bag or bulk grain measurement. The meter can also be used for measuring ambient T and RH weather data. A single instrument was left with Pens Food Bank to obtain some feedback on its performance.

3.5.2. Solar drying to control moisture content

The two solar dryers seen during the PHL assessment seem to be very successful and could significantly mitigate the drying and aflatoxin problems. Considering the economy of the region, the lack of infrastructure, and problems associated with obtaining access to fields during the rainy season, improved solar drying appears to have the best potential for drying maize in the field. This is true for both Northern Ghana and the Middle Belt of Ghana.

3.5.3. Specific training and workshops on phosphine fumigation

The lack of attention given to proper fumigation is cause for concern. In addition, many of the general workers we encountered had limited communication skills in English, which is another cause for safety concerns. Training and education needs are substantial, but government agencies have limited funding, few personnel, and little capacity to conduct such training. The general feeling was that MoFA needs to be involved but not to rely on them alone. Training on usage of application of phosphine is essential, and perhaps the phosphine registrants and suppliers in

Ghana could assist with training efforts. There are many points in the application process where worker safety is being compromised.

3.5.4. Evaluation of the ZeroFly[®] storage bags and PICS bags for maize storage

The Vestergaard Frandsen ZeroFly[®] Storage Bags could be utilized to improve maize storage in Ghana. ZeroFly bags are deltamethrin incorporated bags that have been shown to be highly effective at mitigating insect-related postharvest losses in Uganda and Burkina Faso (Costa, 2014). Each of these bags currently costs US\$ 1.20. ZeroFly bags trials need to be conducted in Ghana as well to provide empirically based evidence of their effectiveness in mitigating insect pest infestations.

3.5.5. Utilization of small metal and plastic silos for storing grain

There are at least several companies that offer small storage bins, and farmers cooperatives are interested in the concept. Pens Food Bank has steel bins with a capacity of 150 or 200 maxi-bags (15 and 20 MT, respectively). These bins are already being sold, but adoption appears to be limited perhaps due to cost, which is between GHS 6,000 and 8,000 for the 15-MT bins. However, there are smaller metal silos (540-1,200 kg) that sell for GHS 600-750 (Costa, 2014), that can be evaluated for use in Ghana. Likewise, there are 100-150-kg plastic silos selling for GHS 60-110 (Costa, 2014), that also need to be evaluated.

3.5.6. Baseline assessments of insect pest populations

Insect pests were prevalent at virtually every location visited during the assessment trip. The maize weevil was a predominant pest but others including the larger grain borer, red flour beetle, and Angoumois grain moth were present as well. There is little information on prevalence of insects in the rainy season versus the dry season, or differences between Northern Ghana and the Middle Belt. Estimates of peak populations, seasonal history and potential for number of generations within a calendar year or storage season would be of great benefit for improving pest management programs. Monitoring programs could easily be conducted using standard sticky, dome or pitfall traps. Although this method would catch a diverse range of insect species besides stored product pests, it is unlikely that pheromone traps could be utilized unless additional funding is secured for the purchase and monitoring of such traps. Other monitoring options include traps baited with maize to attract stored product insects, but experimental designs must be carefully done so as to protect the baited traps from animal pests.

3.5.7. Baseline assessments of aflatoxin levels in maize

Baseline data need to be obtained on aflatoxin levels in stored maize in the Middle Belt after harvest in the major and minor seasons. These data also need to be obtained for the single maize production season in Northern Ghana. Grain samples collected for the baseline study of insect populations could also be analyzed for mold growth and mycotoxin production.

4. Conclusions

Tools and tactics to significantly mitigate PHL of maize in Ghana are known and are in use in Ghana and/or elsewhere. Therefore, focus needs to be on successfully scaling up these tools and tactics to significantly mitigate maize postharvest losses in Ghana.

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