A Report on Assessment of Maize Postharvest Losses in the Middle Belt of Ghana

May 19-30, 2014

A Summary Report Prepared by

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Overview

A two-week in-country assessment of postharvest losses (PHL) in the Ghana maize value chain was conducted in the Middle Belt of the country by ten experts in post-harvest engineering technology and stored-products protection from four different U.S. Land-Grant Universities (Oklahoma State University, Kansas State University, Fort Valley State University, and University of Kentucky); the USDA-ARS Center for Grain and Animal Health Research (CGAHR); Kwame Nkrumah University of Science and Technology (KNUST); and Vestergaard Frandsen (Switzerland) – referred to hereafter as 'Team'. The assessment covered the period May 19-30, 2014 (in country).

The Team visited stakeholders in Accra and traveled to the major maize growing region of Ghana, the Middle Belt (Figures 1-6). The major centers of maize production and marketing in the Middle Belt, namely, Nkoranza, Wenchi, Ejura, Bonyon, and Techiman were visited (see mapsofworld.com/Ghana). During visits to these areas, the Team acquired knowledge on postharvest losses (PHL) 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 Team 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 that are perceived "critical control points" 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 (smallholder farmers, government and parastatal entities, the private sector, non-governmental institutions, research institutions, universities, etc.) were visited as part of the PHL assessment. Specific activities of the Team are listed in Table 1.

Major findings of the PHL assessment of maize value chain the Middle Belt were:

- There are multiple tactics in use for monitoring insects and grain moisture at both the on-farm storage level as well as in warehouses. Many of these are not effective or reliable.
- Farmers are not patronizing warehouse storage systems.
- Farmers are resistant to investing in new technology to produce quality grain when there is no economic reward for increased input and management costs.
- The Team identified a potential working model that could assist farmers adopt new technologies while addressing the microfinance issue on a small scale – this model is currently being used by Farmer Based Organizations (FBOs) and delivering positive results.
- Aflatoxin related issues may be exacerbated by current practices (including heaping maize ears pending shelling for long periods (>1 week) and the lack of proper drying facilities during harvest).

- Current mitigation practices for aflatoxin issues may be inadequate and in some cases may increase soil fungal levels and aflatoxin levels in animal-based food products. While people are aware that moldy grain poses health risks, they don't associate soil with aflatoxin, which can be both a pre-harvest and post-harvest problem.
- Current local and on the shelf technologies exist that may address identified problems while capitalizing on private sector partnerships.
- We have identified potential partners for engagement and for assisting us in data collection.
- Training is needed on stored-product pest identification and correct pesticide use.
- There is lack of shelling, drying, and storage facilities in close proximity to communities.
- Contacts to conduct research have been established.

The following areas were identified as researchable areas in postharvest loss where breakthroughs in research and development could lead to significant mitigation of PHL in the maize value chain in the Middle Belt:

- Collect baseline data on grain moisture levels, insect infestations, aflatoxin levels, and physical losses during harvesting for both the major and minor seasons.
- Investigate means of refining the solar tent dryer, moisture meter, and on-farm storage methods.
- Assess the impact of timing of harvest on moisture levels.
- Collect data on insect pest species and population dynamics of those species for on-farm storage and in warehouses.
- Measure the efficacy of current monitoring tactics for moisture and insect infestation and compare this to improved monitoring methods.
- Test currently used and commercially available bagging systems.
- Evaluate the potential use of a solar tent dryer as a means of managing stored-product insect pests and reducing aflatoxin levels.
- Investigate modifications to the design of the solar tent dryer to improve ventilation for seed production systems.

Introduction

The motivation of the Feed the Future Innovation Lab for Reduction of Postharvest Loss in Ghana (hereafter referred to as the Ghana Project) is mitigating PHL in the maize value chain in the key production and processing areas. The major cereal grain produced in Ghana is maize, and it is considered the most important cereal accounting for 74% of the total cereal production (MoFA 2005). Total annual maize production in Ghana is estimated at 2.1 million MT and consumption is 1.7 million MT. 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 two seasons cover the periods April-August/September and September-

December, respectively. In the Northern region, 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 in drying their major season maize. The window for drying is only four weeks (August to September). This is not a problem in the north where they can leave their maize in the field until late November/December for it to completely dry before it is harvested. However, this exacerbates insect related problems. In the Middle Belt where there are two rainy seasons, leaving maize in the field for long is not an option because the minor season rains also do not allow for proper drying. Because of the drying challenges in the Middle Belt, there are a lot of mold- and aflatoxin-related problems associated with maize harvest, especically during the major season. Aflatoxin incidence is also associated with insect infestation. In the Middle Belt, PHL in the major season are mostly due to mold and aflatoxin whereas insects are the major cause of losses in the minor season.

Annual grain PHL of up to 50% along the value chain were reported by contacts made in Ghana. Improving food security through a reduction of PHL is imperative for meeting current Ghana Ministry of Food and Agriculture (MoFA) development objectives since losses reduce real income for all consumers, divert essential income out of farmers' pockets, and undermine overall food availability. According to Evans Nsiah of Pens Food Bank Enterprise "Food production in Ghana has never been a problem, for almost 70% of the population within the maize growing areas do farming, but how to manage post-harvest is the greatest challenge." Information gathered during the PHL assessment trip suggests that on-farm maize PHL are approximately 30%. These losses are mainly due to piling of husked ears or ears on stalks on the ground in the field for long periods of time after harvest (pre-drying in the field); lack of proper drying of maize which results in molding and increase in aflatoxin levels; physical losses during harvesting, transportation, shelling, and bagging; and insect infestation. The inherent tropical climate that exists in Ghana exacerbates insect and mold problems. It is likely that significant mitigation of PHL in the maize value chain could be achieved if losses that occur between harvesting and drying to targeted moisture content of 12-13% could be minimized (timely drying). Many of the stakeholders we interacted with suggested that the highest losses occur during pre-drying in the field stage of the postharvest system of maize. This stage involves piling of husked ears or ears on stalks on the ground, in the field, for long periods of time after harvest while waiting for shellers to arrive.

Key challenges which are currently being faced by smallholder farmers and warehouses are the lack of appropriate technology for mitigating losses due to poor harvesting and postharvest handling, namely, lack of affordable and adequate numbers of mechanized maize harvesters, dryers, shellers, cleaners, and moisture meters. Additionally, there is lack of know-how on using technologies already in place (proper pesticide application) and lack of storage infrastructure (stores, warehouses, miniaturized silos, and bag/bulk grain handlers).

A number of institutions and professionals comprise the Ghana Project Team, namely, Oklahoma State University, Dr. George Opit, Entomologist and Team Leader; Kansas State University, Dr. Shannon Washburn, Professor of Communications, and Dr. Venkaat Reddy, Project coordinator; Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, Dr. Enoch Osekre, Entomologist; USDA-ARS Center for Grain and Animal Health Research (CGAHR), Manhattan, KS, Drs. James Campbell and Frank Arthur, Entomologists and Dr. Paul Armstrong, Agricultural Engineer; University of Kentucky, Dr. Samuel McNeill, Agricultural Engineer; Fort Valley State University, Dr. G. Mbata, Entomologist; and Vestergaard Frandsen SA, Lausanne, Switzerland, Dr. Oana Baban and Isaac Ola Ayobami, Entomologists. Current key cooperators in Ghana include Pens Food Bank Enterprise, Ejura, Ghana, Mr. Evans Nsiah, Managing Director; Masara N'Arziki Farmers' Cooperative, Tamale, Ghana, Mr. Marc Kok, Managing Director; and Agri Commercial Services, Wenchi, Ghana, Mr. Kwabena Adu-Gyamfi, Managing DirectorRefer to biosketches of the referenced individuals in Appendix A.

During the first year, the Ghana Project Team will assess current grain handling and pest management tactics, stored-product insect activity and post-harvest grain losses in small-, medium-, and large-scale storage warehouses in Ghana with the ultimate goal of identifying researchable areas in postharvest loss that are perceived "critical control points" where breakthroughs in research and development could lead to significant improvements in food security. Information will also be sought from 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 of two planned PHL assessment trips was conducted during the period May 19-30, 2014 and focused on the Middle Belt of Ghana. The major findings of the first PHL assessment are presented on pages 3-4 of the overview. The second assessment trip will focus on key maize growing areas in Northern Ghana, and is scheduled for December 5-19, 2014.

In the second and third year, 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 the maize value chain in the Middle Belt – refer to page 4 of the overview:

In the fourth and fifth year, the Ghana Project aims to conduct educational meetings in the North and Middle Belt to share proven practices and information learned during assessment 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 inherently compose local partners due to market forces. A bid to host the next International Working Conference on Stored Product

Protection in Africa will be submitted and the meeting will be held during year five. Support for attendance by Ghanaian cooperators will be provided and a symposium or workshop session focused on this project will be proposed.

After five years, the Ghana project hopes to achieve the following:

1. An assessment through documentation and field research, of current practices, constraints, and critical control points that will identify improved technologies and management options for PHL mitigation in warehouses.
2. New postharvest technologies and management options that have been verified and piloted to suit local conditions in small-, medium-, and large-scale storage warehouses. This will include improved, low cost grain moisture content monitoring, practical pest monitoring and management approaches and technologies, and improved maize drying and storage technologies.
3. Improved capacities and awareness of warehouse owners and/or managers engaged in grain storage regarding sources of PHL and remediation options.
4. Scale-out of successfully adopted technologies in other regions.
5. Data collection and field research will be disseminated to wider actors and policy-makers regarding warehouse losses and needs with proposed interventions and policy recommendations.
6. Capacity building through the training of:
    a. 3 MS graduate students. Emphasis will be placed on training at least 2 female graduate students.
    b. 15 professionals in 2 train-the-trainer workshops.
    c. 50 farmers, cooperative members, and agribusiness customers in 2 annual symposia.
    d. 1,350 smallholder farmers in 90 local Extension workshops.
7. Made available downloadable educational materials and videos/audio files on demand via cell phones, internet etc.
8. Seek additional funding to support related research that targets the mitigation of insect infestation and aflatoxin contamination in maize.
9. Measurable evidence and impact that post-harvest loss has been reduced because more smallholder/subsistence farmers, producer cooperatives and agribusiness enterprises are linked/integrated with market-based value chains from seed to end-user.
10. Measurable evidence and impact that food security has improved because more people, at more times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Description of the Ghana Middle Belt Maize Value Chain and Postharvest Losses that Occur Therein

A supply chain is defined as the network of retailers, distributors, transporters, storage facilities, and suppliers that participate in the sale, delivery, and production of a particular product (http://dictionary.reference.com/browse/supply+chain). A value chain on the other hand is a supply chain analyzed in terms of how much value is added during the various stages from, for example, purchase of raw materials to sale of the finished product (http://www.investopedia.com/terms/v/valuechain.asp). The figure below is a simplified illustration of the Ghana Middle Belt maize value chain and the types of losses that occur therein.

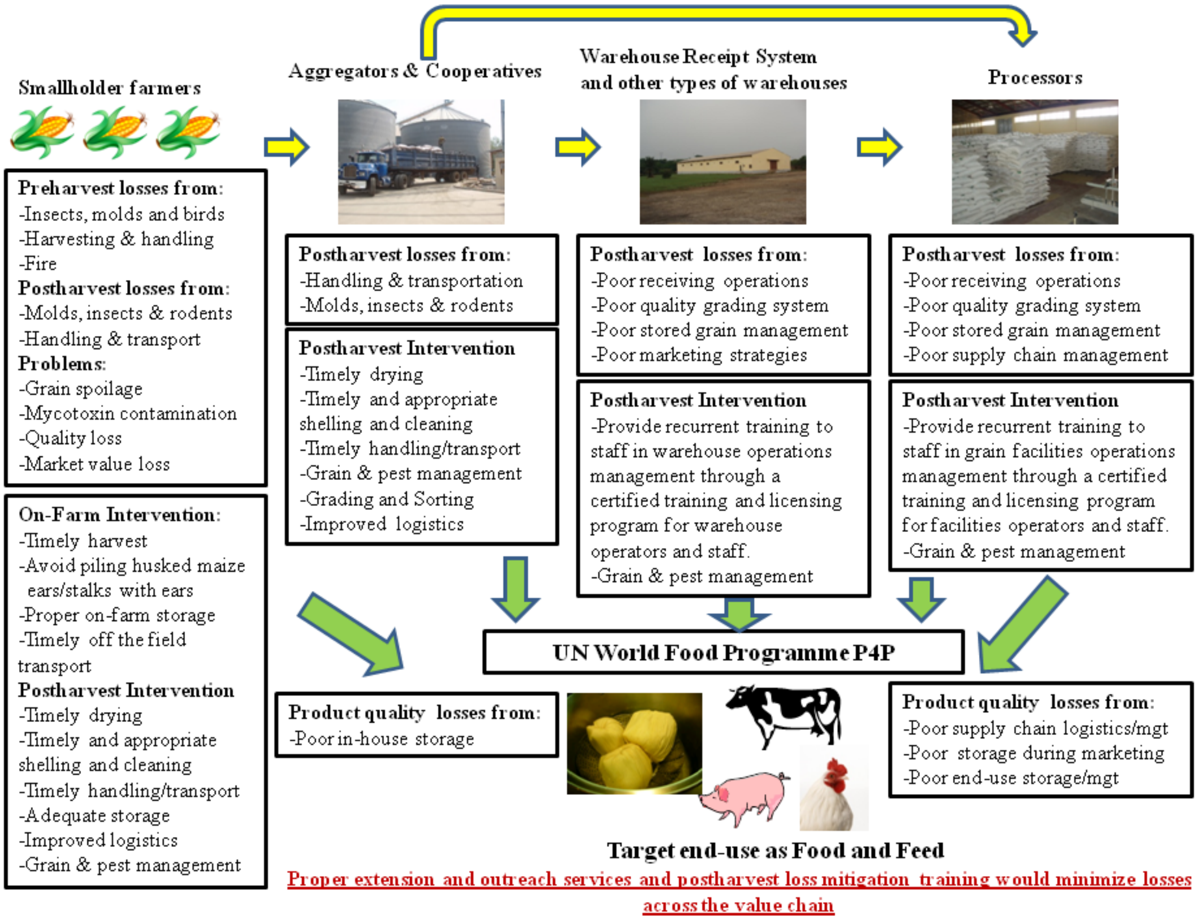

Figure 1. A diagrammatic representation of the Ghana Middle Belt maize value chain and the types of postharvest losses that occur therein.

Smallholder farmers typically produce grain on about 2 ha of land. Because of the lack of quality inputs of good seeds, fertilizers, machinery, crop management, they produce less than a quarter of potential yields achievable (e.g. less than 1.5 ton/ha for maize compared to 5 or more ton/ha achieved on similar soils and weather conditions in developed economies). The maize value chain also comprises aggregators and cooperatives. An aggregator or cooperative is a business owned by an individual or farmers' cooperative which engages in the buying of grains from smallholder farmers for sale to large grain processors such as the World Food Programme (WFP) Purchase for Progress (P4P) initiative, National Buffer Stock Company (NAFCO), or the warehouse receipt system (WRS). Some aggregators and cooperatives provide transport and postharvest handling services such as drying, shelling, cleaning, and bagging to smallholder farmers.

Another important component of the value chain is warehouses which could, for example, be part of the WRS. The WRS enables smallholder farmers to deposit their commodities in a certified warehouse in return for receipts that can be exchanged for credit at a local financial institution. Commodities stored in this system need to meet certain standards of quality and grade to be accepted. The system offers a network of certified warehouses that guarantee farmers adequate storage conditions, sometimes better than those provided by farmers' organizations. Warehouses are also owned by organizations such as Millennium Development Authority (MIDA), Ghana Grains Council (GGC), and Masara N'Arziki Farmers Cooperative. Many of the warehouses operate as postharvest service centers (PSCs) that provide postharvest handling services. The maize value chain in the Middle Belt of Ghana also has various types of processors. These are businesses that engage in adding value to maize by processing it into final end-products such as flour, semolina, breakfast cereals, baby food, beverages, etc.

Losses Attributable to Insect Pests at the Small-Scale Farmer Level and Breakthroughs in Research and Development that Could Significantly Lead to Mitigation of Postharvest Losses

Maize (*Zea mays*) is the most important cereal in Ghana accounting for 74 % of the total cereals and domestic demand for the commodity keeps growing. Annually, Ghana produces maize in excess of 1,100,000 MT with small-scale farmers producing the bulk under rain-fed conditions. Over 90 % of the farmers produce white maize even though yellow maize attracts a higher price and the most common varieties grown include "Obaatanpa", "Mamaba", "Dadaba" and "Aburohoma". The Ministry of Food and Agriculture (MoFA) has reported that about $430 million is annually tied up in maize production at harvest, 50% of which is held by farmers, with the other half by traders, making the cost of tying up of capital quite enormous.

Maize production in Ghana has several challenges including limited use of improved seeds, fertilizer, mechanization, and inadequate post-harvest facilities. Average yields are well below attainable levels and post-harvest losses (PHL) also are high. PHL of maize are approximately 30%, with more of this percentage occurring during the major season due to drying challenges resulting from the short dry spell prior to the minor growing season, land constraints, poor handling of the maize in the field, delayed harvesting during the minor season, inadequate drying of the corn ear on bare ground and on inappropriate materials attracting heavy pest infestation right from the field. Shelling is often done in the field creating conditions attractive to insect infestation. In some cases maize collected from the field is not treated with insecticides since farmers start consuming the produce as and when it is ready.

In the Middle Belt, Pens Food Bank Enterprise (PFB) estimates major season PHL of maize due to field losses (over-maturity, harvesting, heaping), shelling or threshing, drying, storage losses (molds), storage losses (insects) at 5, 1.5, 0.5, 15, and 8%, respectively (a total of 30% loss).

During the minor season, these losses are estimated at 6, 1, 0.2, 2, and 10%, respectively (a total of 19.2% loss). Other stakeholders estimate that approximately 40% of harvested maize is lost to insect pests during the minor season while 20-30 % is lost during the major season. Generally, maize farmers cite insect pests, marketing of their maize and poor storage facilities as critical constraints to crop production and productivity, emphasizing that maize loss through pest damage is enormous. Reducing PHL has the potential to assure food security, as it serves as the most sustainable alternative for increasing food availability.

Farmers exhibited some knowledge of insect problems of maize and insects identified by farmers included corn earworm, maize and rice weevils, larger grain borer, lesser grain borer, termites, red flour beetle and Angoumois grain moth. Field infestation is high especially during the minor season when the crop 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 infestation that is transferred into storage. Farmers estimated losses caused by the different insect pests to be similar despite the fact that scientific studies report differences. For example, some sources report that about 15% of maize harvested in Ghana is lost annually to weevils alone. Interestingly, maize farmers recognize weevils as the most prevalent and the first to attack maize right after harvest.

Smallholder famers store maize using traditional grain storage structures and woven polyethylene bags but these forms of storage are unable to prevent insect infestation. Because of the risks associated with grain storage, farmers try to minimize losses by selling their grain soon after harvest, which leads to low market prices as the market is flooded with newly harvested grains. Farmers could obtain a much higher price if they were to sell their grains later in the season and this can only be possible if they could dry the crop in a timely manner to minimize mold and insect infestation. It is estimated that over 50% of the farmers in Ghana store their maize in bags (mostly woven polyethylene bags) with a large percentage of such farmers keeping them in household rooms, >30 % in local cribs and <1 % in household metal silos. Unfortunately, storing maize and cowpea in the same warehouse is a common practice among Ghanaian farmers but this practice, as explained by PFB, is unproductive as it has been found to attract more insects. This may be because cowpea weevils quickly deteriorate cowpeas thereby creating conditions that facilitate increase in the overall stored-product insect pest population.

Farmers who do not utilize large warehouses facilities for storage of their produce rely on fumigation using Phostoxin® tablets or use Actellic® EC or dust to protect their maize from insect pest attack. However, it is common knowledge that many of these farmers apply insecticides without following label recommendations, endangering their lives and those of other people. Repeated treatments are conducted when insect infestations are noticed. Some farmers continue to rely on traditional, eco-friendly and indigenous plant products to protect maize against insect pests in storage while some employ a combination of the traditional products and synthetic insecticides. In rare situations, some farmers use naphthalene tablets as repellents against insect pests during short-term storage. Some indigenous protectants used to protect maize kept for home consumption include plant oils (groundnut and palm oils), ground parts of plants such as neem, and wood ash. Actellic® is usually used to protect maize that will be sold later in the season.

Some farmers rely on warehouses for the storage of their maize. Use of such facilities is often restricted because warehouses are not close enough to farmers to be practical and, if warehouses are nearby they may charge exorbitant storage fees. In some cases farmers abandon their maize in these facilities due to inability to pay the service fees charged.

Research Needs

In order to significantly mitigate insect-related PHL, research needs to be conducted to:

1. Obtain quantitative baseline data on PHL arising from insect infestation in the field with the aim to identifying the most appropriate time to harvest maize in order to reduce field-related PHL.
2. Evaluate effective but affordable storage structures that would help farmers minimize insect infestation at the smallholder farmer level, for example, miniaturized and medium-sized steel and plastic bins.
3. Assess and improve practical maize drying methods that will significantly reduce both mold infection and insect infestation of maize, for example, solar dryers (Figure 6).
4. Assess the effectiveness of the Vestergaard Frandsen ZeroFly® deltamethrin-incorporated storage bags to mitigate insect-related PHL.

Training and Educational Needs

Educate smallholder farmers on safe handling and use of insecticides especially on fumigation using Phostoxin® and on proper stored maize management. Smallholder farmers also need to be educated to view farming as a business and stored maize as an investment that needs to be fiercely protected. They should be encouraged to utilize services offered by the postharvest service centers that charge fees for harvesting, shelling, drying, cleaning, and storage.

Areas in Warehouse Storage Causing the Most Losses Where Breakthroughs in Research and Development Could Lead to Significant Improvements in Food Security

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 (PSC) whose key goal is to improve agricultural production and food quality and reduce PHL. Examples of these are Millennium Development Authority (MIDA) assisted warehouse, Ghana Grains Council (GGC) warehouses, and Masara N'Arziki Farmers Cooperative warehouses. Nearly all maize held by PSCs is stored in warehouses. With the number of smallholder farmers belonging to PSCs such as Masara N'Arziki Farmers Cooperative increasing, it is expected that there is going to be an even greater increase in maize production in coming years. However, most warehouses in Ghana do not give adequate protection to maize from insects, mites, rodents, atmospheric moisture, and heat. 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.

Post-harvest 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: (1) losses due to storage of high moisture maize resulting in mold and aflatoxin, and (2) losses due to insect pests and rodents. Losses during handling and processing were also reported, but these appear to be solved through more training rather than an area for research and development. 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. There are technologies and tactics available that could greatly reduce these 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 were identified that show promise to be adaptable to conditions in Ghana.

1. Monitoring of Grain Moisture.

Maize was often stored without accurate determination of its moisture level. Moisture measurement is a critical first step to determine if maize is sufficiently dried to be safely stored. Storage of maize at the proper moisture reduces mold growth and the production of aflatoxin. Measuring moisture is important to determine if the drying process was sufficient prior to transferring the maize to bags or bulk storage. Proper drying will also facilitate the use of hermetically sealed bags that could help reduce losses due to insects.

A variety of methods are currently being used in Ghana to determine moisture content: for example, sticking an arm into a 100 kg bag and determining the level of resistance (Figure 5), or biting the maize kernels. None of these methods will give anything more than a rough estimate of grain moisture. Effective maize storage will require more accurate measures of moisture. Moisture meters are available currently in some warehouses in Ghana, but the meters being used are costly, and often labor and time intensive to use. As a result, maize is probably under-sampled which may lead to moisture issues even in maize that is tested. More widespread availability of moisture meters that are affordable and easy to use, coupled with training on their use, could make a huge difference in reducing postharvest losses (Figure 5)..

Specific research areas:

1. Evaluate different local techniques used to measure grain moisture to determine which ones are reliable estimators and which are not, and if any could be modified to make them more accurate. This information could provide important improvements in grain storage, while more accurate moisture meters are being developed and distributed.
2. Evaluate rapid, low cost moisture meters and grain sampling techniques and determine how these could be implemented into management programs.
3. Survey maize moisture levels soon after harvest in the different growing seasons. This information can be used to determine the greatest impact of moisture management to help facilitate the adoption of these new technologies.

2. Monitoring of Pest Infestations.

Losses due to insects were widely reported in Ghana, with lesser grain borer, weevils, and Angoumois grain moth being the most commonly reported species causing damage during storage. Larger grain borer was also reported as a pest in certain regions. Insect infestations can occur (1) in the field, (2) during drying, husking, and storage prior to being brought to the warehouse, and (3) during storage in the warehouses. Minor season maize was reported to have more infestation occurring in the field than major season maize and as a result to have higher overall pest infestation levels. Insect damage is likely still present in the major season grain, but may be less significant than moisture problems contributing to mold losses. However, little specific information was available on how much each species contributes to problems and where in the maize production and distribution system they are most likely to be a problem. For example, are certain species more likely to infest maize in the field and others more likely to infest in the warehouse. Understanding where the maize is becoming infested and by which species is critical to developing effective management programs.

A variety of insect monitoring methods were reported to be used in Ghana, including listening for sounds of insects chewing and visual inspection of samples from a bag or insects present on the outside of bags. These methods are likely to only detect extremely high insect infestation levels. Detection of insects using these methods was often reported to trigger treatment with the fumigant phosphine, but earlier detection and treatment, especially prior to storage in warehouse, could greatly reduce the need to fumigate. Many locations also treat with insecticides before putting grain in storage as a preventative even if this may not be needed. Detecting and eliminating infestations prior to putting grain in bags can make other storage techniques more effective – such as hermetically sealed bags and insecticide impregnated bags. More accurate monitoring methods both for grain within bags and within storage structures themselves are available, but may not all be cost effective under current conditions. However, there are a number of tactics and tools that could be adapted to work in Ghana.

Rodents were also reported as a problem when specifically asked, but not widely reported if just asked about pest problems. Additional losses due to vertebrates such as birds, goats and chickens during drying and in the field were reported. Use of rodent traps or bait stations was observed in some warehouses, but not all. Rodents were reported to damage storage bags and thus create routes of entry for insects and lead to additional losses during handling.

Specific research areas:

1. Compare currently used methods of insect detection compared to other more accurate direct sampling and trapping methods to evaluate the suitability of currently available techniques that might be adequate or easily improved.
2. Monitor the levels of infestation and determine the critical pest species to determine the scope of the problem. Particularly targeting different potential points of infestation (field level, during harvest, husking, and drying, and during storage in the warehouse). Determine the levels of infestation of bagged maize when it enters warehouses versus infestation during storage to facilitate the selection of the most effective treatment methods.
3. Insect and rodent activity in and around warehouses is not well known, so an initial assessment of these levels would be important for developing effective warehouse pest management programs.
4. Given the lack of monitoring and the relatively high costs of most commercially available traps and attractants, development of effective, low cost monitoring tools that could be used at different points in the maize value chain would be useful. Specifically, insect and rodent monitoring devices in warehouses and tools/protocols for sampling insects in bagged grain would be helpful.
5. Accurate data on production and storage and percent losses due to specific sources at each stage of the maize value chain is needed to provide a baseline against which to assess improvements to programs. Some of this information was shown during the assessment trip, but we still need to verify how it was collected, how accurate it might be, and what additional gaps need to be filled.

3. Improve Maize Drying Prior to Storage

Drying of maize to a suitable moisture level for long term storage is essential for reducing losses. Drying in Ghana is primarily accomplished by spreading whole ears or shelled kernels on the ground to air dry after harvest. Dryers – typically diesel powered – were found but their numbers are limited, they are often too far from the point of harvest to be useful for farmers, and they are very expensive to use. There is a need for better drying methods that could be scaled to work from the farmer level up to the larger warehouse level. These dryers need to be low cost and made with locally sourced materials to facilitate adoption. Solar based dryers appear to be a good approach for meeting this objective, and working models of this approach were observed during the assessment trip. Research into optimizing solar dryers for use in the Ghana system is a highly researchable question with a high probability of success. There are many designs already available and different models may fit best at different points in the maize distribution system.

Specific research areas:

Evaluate currently available solar dryers by computer modeling and field tests to refine current designs as needed to make them effective at drying maize under conditions in Ghana. Focus should be on determining heating rates and exposure times needed to mitigate mycotoxin development, improving drying efficiency and potential for supplemental biomass heating, and a flexible design to handle the appropriate volume of maize to make them practical at different production levels. Dryers that may be less efficient but which could be cheaply and easily built and used at the farmer level would likely have the greatest impact in terms of starting the maize off at the proper moisture level. Field testing of the most suitable dryers using local cooperators to determine how well they fit within current agricultural practices needs to be conducted to validate computer models.

4. Improve Insect Pest Suppression Tactics

Insect pest management from the farmer storage level to the large warehouses relies heavily on only two insecticides: Phostoxin® and Actellic®. There was little information available on the efficacy of these materials, both from the standpoint of whether the insecticide formulations themselves are as labeled and from the standpoint of whether resistance is present in Ghana insect populations. Some farmers did report a loss of effectiveness of actellic, and resistance to both of these compounds has been reported worldwide. No information was obtained to show pest levels before and after treatments, so current efficacy is not known. There was a clear need for better training on the effective and safe use of these insecticides since a wide variety of usage patterns were reported, some of which presented potential worker safety problems.

Maize is usually stored in warehouses for varying periods stretching up to six months. Most warehouses do not practice proper stored maize management – proper sanitation and other insect control measures are often lacking. Additionally, warehouse managers are not well trained in sound grain management practices. As a result, stored-product insect pest infestation is high and PHL attributed to insects alone are as high as 25%. Operators and managers of maize warehouses use fumigation to reduce insect infestations, but there is variation in the methods used which could contribute to reduced efficacy and increased risk. Yedent Agro-Group of Companies located in Sunyani in the Brong-Ahafo region, for example, uses one Phostoxin® tablet for five 50 kg bags (0.25 mt) of maize packed under a sealed liner and repeat this treatment a week later if they failed to achieve good disinfestation. Covering bags with tarpaulins to create air-tight conditions can limit phosphine gas loss and increase effectiveness. A MoFA warehouse located in Nkoranza uses four tablets of Phostoxin® per tonne of maize over a 7-day period but fumigation is repeated every 2.5 to 3 months. In many warehouses bags under fumigation were not enclosed or covered with a tarpaulin, which can lead under dosing. Operators of warehouses that deal in certified maize seeds use cold storage after fumigation for maize preservation.

Use of high temperatures is a widely used control method for insect pests in developed countries, and increased use of solar dryers for grain moisture management in Ghana, as discussed earlier, presents a potential alternative treatment method to chemical insecticides. Use of solar grain dryers to eliminate insect infestations as well as for grain moisture management means that the same initial investment in equipment can be used for multiple purposes. Use of high temperatures (≈50°C) for pest management is also a much safer tactic than phosphine and actellic use. Insecticide-impregnated bags are also an alternative that should be evaluated. These bags are treated with reduced risk insecticides to reduce insect immigration and establishment within the bags. Combining solar drying to eliminate insect infestations prior to storage with insecticide-impregnated bags to reduce insect immigration into the bags during storage appears to be a fruitful area of research.

Specific research areas:

1. Evaluate the efficacy of currently available formulations of phosphine and actellic for treating stored product insects in grain bags.
2. Evaluate solar dryers (same ones being evaluated for grain drying) for their ability to kill the major pest insect species in maize. Determine temperatures needed for efficacy from the literature or by bioassay tests, measure heating rates and maximum temperatures obtained in solar dryers to calculate the times needed to treat maize under different seasonal conditions in different regions of Ghana. Could also evaluate heating rates in currently available diesel, gas or kerosene dryers to determine how they could be used for pest management as well.
3. Assess insecticide impregnated bags for their efficacy in preventing stored product insect infestations alone and in combination with solar drying. Evaluate currently available lab data and fill gaps as needed, then move to field tests of bag efficacy.

Aflatoxin Mitigation in Maize in the Middle Belt Region of Ghana

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. Average aflatoxin levels in samples of stored maize from Ejura-Sekyedumasi, North Kwahu and Nkoranza were found to be 12.0 ppb (Stdev 2.7), 15.3 ppb (Stdev 7.4), and 13.4 ppb (Stdev 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.

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 mold species that compete with the toxigenic *A. flavus*. Aflasafe is a field treatment and costs approximately $15 USD /ha. Initial development of an aflasafe product was done in Nigeria and is a transferred technology initially developed by USDA-ARS from the US. 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 Kwameh Nkrumah University of Science and Technology, Kumasi, Ghana for the reduction of aflatoxin in groundnuts. During our PHL assessment trip, no information was obtained for planned maize field trials although maize is sometimes intercropped with groundnuts. Other efforts seen to control aflatoxin currently are by screening and selection of maize varieties for resistance, and by rapid drying with solar dryers.

The potential use of aflasafe for maize production in Ghana could substantially ease some of the issues related to post-harvest loss by providing higher quality maize from the field. This critical first step must be followed by other proven practices throughout the post-harvest phase in order to maintain low aflatoxin levels. Timely management of threshing and drying operations is critical to maintaining quality. Safe storage moisture levels must be attained quickly after harvest and maintained throughout storage. Simple and affordable methods to measure and monitor moisture would be helpful for storage management and optimization of drying times.

Pens Food Bank (PFB), Ejura has collected data spanning a few years that list PHL by type. The major season losses are predominately due to molds while minor season losses are primarily due to insects. Major season mold losses can be a summation of loss during selective shelling (removing molded kernels) and mold loss during storage. Loss due to insects during the minor season is due to harvesting late to allow significant field drying. This extended field drying allows a greater opportunity for insect infestations but minimizes molding issues. PFB data quantified and confirmed the general statements given by farmers on the significant losses they experience for both seasons. The World Food Program (WFP) has recently introduced some quality assessment tools to farmers in the northern regions. This is referred to as the ‘blue box’ and includes an aflatoxin test kit as well as a moisture meter and quality testing equipment.

Farm Level Management Operations

Conversations with farmers revealed they are genuinely aware that moldy grain can cause illness and not just produce off-flavors in food. They are also aware that moisture content is critical to control of mold. Moisture measurement by farmers is done by biting kernels, shaking kernels in a hand and listening to the sound, and plunging an arm into a bag to feel the resistance of the bulk grain. It seems most farmers have developed a reasonable sense of when maize is properly dried using these methods.

Harvest. Major season moisture content at harvest can be very high depending ambient conditions. 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 up to 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. Mechanical threshing is common and can cause considerable physical damage at these moisture levels as kernel detachment is difficult. The short transition time between harvesting the major season crop and preparing for the minor season does not allow proper ear drying for threshing. Partial drying may occur when ears are piled and waiting to be threshed but molding is also likely to occur. Ears can remain in piles up to 10 days which can cause much heating and mold development. Minor season moisture levels at harvest are much lower due to better drying conditions and can be near 18%. Easy detachment of kernels begins to occur when moisture levels are about 18% and lower. Throughout the harvest phase, moisture measurement is minimal, the major season harvest commences as soon as the farmers think ears can be threshed. However, the minor season crop is allowed to dry for as long as field losses remain minimal (those usually caused by rodents, termites, birds, theft, etc).

Threshing. Most farmers use mechanical threshers that shell either whole or de-husked ears. The threshers are contracted which 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.

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, 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 alfatoxin 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 GHS10 /bag) ($US 1 = 3 GHS). Moisture is periodically checked during drying at commercial facilities to target the storage moisture level (≤ 12-13% MC). Several aggregation locations have heated air dryers (powered by either diesel fuel or electricity) but these were not always used due to the high cost of energy.

Diesel heated dryers were seen more often than electrical heat dryers, probably because of brief but frequent power outages.

Two solar drying greenhouses, one made of fiberglass and the other perspex acrylic glass (commonly known as “Plexiglas”), were visited at Nkoranza and Sekyedomasi (Figures 5 and 6, respectively) and seem to be very effective for drying. The Sekyedomasi unit dries about 0.6 MT/day on multi-layered racks and a moisture meter is used to monitor moisture during rack drying. The Sekyedomasi dryer is run by a farmer based organization (FBO) comprised of around 30 farmers. The solar drying system seems to be very successful although the solar dryer would be very difficult for a small group to afford. The dryer was paid for by Pens Food Banks as a demonstration project. An added benefit of this dryer is that insect disinfestation occurs due to the high temperatures (≥50^{o}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. Solar driers could have a large positive impact in relation to the alfatoxin problem by drying grain relatively quickly. This type of technology could be adaptable to the farm level, possibly made portable and financed through a farmer based organization.

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. Ambient equilibrium moisture conditions for maize hovered around 10.5% (ASABE) for the duration of our site trips (May 2014). It is unlikely that maize moisture equilibrated to ambient conditions while bagged and more likely grain was initially dried to 10.5%. Assuming the latter case is true, over-drying may be occurring which is okay for storage but may cause operational delays due to unnecessary drying and weight loss when sold. It would be worth examining what moisture levels are actually needed for long term storage and where the 12% target originated. Good climate data would help facilitate this. In one case, at Sahel Grains near Techiman, short term storage moisture for maize for poultry feed was near 15%.

Moisture meters

Moisture meters will be a significant tool for facilitating better drying management and maintaining safe moisture levels. Grain aggregators, buying from farmers, often use the same moisture measurement methods as farmers at the farm gate but have moisture checked by modern methods when maize is delivered to a warehouse or seed storage. Several meter types were being used, namely, Dikey-John, mini-GAC; vintage Eaton capacitance meter; G-won, GMK-303; and MD7822 spear probe. The MD7822 is a very low cost spear probe that would be ideal for probing bagged grain. Its accuracy is unknown but will be examined. The G-won meter is low cost but the small sample chamber necessitates measuring multiple samples to get a good estimate of average MC.

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 bag measurement and has a 0.5 m. probe that can be inserted into the grain bulk. The meter 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 usefulness.

Cross Cutting Issues of Gender, Nutrition, and Engagement

Gender

Roles Women Play in Post-Harvest Maize Management

During our two-week visit to the Middle Belt, we met with six groups of maize stakeholders. Of these, five groups were entirely farmers numbering 25-40 per group and a larger group of 67 with mixed representation including farmers, processors, aggregators, warehouse managers, extension educators and local political leaders. Of the approximately 230 stakeholders we met in these groups, over 30% were women.

We found that women play important roles in the establishment of maize markets (maize queens), in the construction of storage facilities – such as Agri-Business Center (ABC) storage, in leading change with a grading system – such as Mrs. Augusta Clottey, Executive Secretary of the Ghana Grains Council, and in trading maize (over 90% of the traders in the Wenchi maize market). Women also play an important role in farming (approximately 10% of the farmers in the Wenchi market and about 1/3 of the farmers in the Nkoranza, Digyawu, Mbanaa, Nkyensie and Santaso farmers meetings. This ratio is typical of the membership in the 36 Farmer Based Organizations that collaborate with Pens Food Bank. In the Ejura region however, Pens Food Bank Manager, Evans Nsiyah estimates that 40-80% of the total women in the population are engaged in farming).

Employment and Marketing Opportunities for Women

Women involved in aggregating maize from smallholders for subsequent marketing tend to be independent and very business oriented thinkers. One such female trader we met in Nkoranza does pay a premium price for higher quality maize (up to GHS100 per bag at harvest) even though this is not a widespread practice. Women traders such as this woman will be critical to broader adoption of grain standards and associated premiums.

At the Asuoyeboah Seed Warehouse, a cottage industry led primarily by women and children has emerged to provide cleaning, drying and bagging services to certified seed growers. This labor intensive work involves hand sifting and sorting of kernels and bagging seed in 1 kg sachets that are then packaged into 45 kg bags for wholesale merchants.

At the Ejura Maize market, there exists three primary types of buyers. One buyer segment is a group of women who buy on commission for distant traders. Another primary buyer group includes brokers who buy on behalf of the market queens. The third main buyer group, which likely tends to be primarily male, are market associations who cater to large traders – this group exerts the most influence on trade and market prices.

Although numerous opportunities were found to exist for women, limitations on their involvement are also present based on their gender roles in the home and community. For example, at the ABC Seed Warehouse, while women have been involved in making construction of the storage facilities possible, only 1-2% of the users of this warehouse are women farmers.

Roles Women Fulfill at the Farm Level

All stakeholder groups confirmed that women are involved in drying and bagging and in most villages, women are also involved in harvesting and cleaning of maize. In the Digyawu Farmer Based Organization with whom we met, the women work collaboratively as a harvesting crew – sharing the responsibility to gather and stack ears of corn at the field level for all farms in the organization. These same women are responsible for carrying the harvested ears to the mechanized sheller when one is available.

While we found heavy evidence of high levels of involvement of women in the labor of maize production and storage, in most situations decisions on quantities of maize to store and when to sell are made solely by men – occasionally in consultation with their wives. In the Middle Belt, it appears to be a fairly common practice for women to have their own small plots (1-2 acres) of land on which they are responsible for planting, harvesting and marketing the product. Funds generated from these women's plots are typically either re-invested in their farm or are used for home and family-based expenses such as school uniforms. A challenge expressed by women regarding this system is that frequently their husbands expect women to help with their harvest and planting before women are allowed to care for their own small plots. These gender roles often create delays in both planting and harvesting for the women's plots, thereby reducing their total yields and quality and as a result diminishing their earning potential. However, in Digyawu (a predominately Muslim community), some women manage their own Farmer Based Organization and make loans to one another for farm use as well as for necessary household supplies.

We realize that our efforts to collect data from women's perspectives were somewhat limited by the fact that we met with mixed gender groups for our focus groups. As a result, women were at times somewhat hesitant to engage in discussion together with men. We recognize the need to collect information from women in separate settings from the men's gathering and will make this change in our next assessment visit. We will also engage a local gender expert and engage this individual in our data collection.

Nutrition

Nutrition was found to be a primary concern of several processors and researchers with whom we met during our May assessment visit. Among these, Yedent Foods is processing fortified foods from maize and other grains. Many of these products are baby foods, but they also manufacture a product for the Ministry of Health that caters to tuberculosis patients. Yedent also collaborates with the World Food Program and the Global Alliance for Improved Nutrition. A very advanced processing facility by local standards, Yedent sets their acceptable aflatoxin limit for baby foods at four parts per billion and as a result, they tend to source grain from the Affram area in the North because in this region, aflatoxin levels are low and producers have access to maize dryers or it is inherently well-dried.

Recognizing the need to fill an existing void in human nutrition products, Sahel Grains has been in operation for less than two years, but is planning to convert their livestock feed facility to a human food product processing facility within the next year.

While local actors such as Yedent Foods, Sahel Grains and Premium Foods are relatively young local organizations, Nestle is a major international player working to process and distribute fortified infant foods throughout Ghana. The World Food Program is also heavily engaged with many in-country actors to make sure safe and nutritious food is available to the neediest Ghanaians.

On the public organization level, a subsidiary of the Ministry of Food and Agriculture - the National Food Buffer Stock Company (NAFCO) purchases food for governmental institutions to provide adequate nutrition to schools, prisons, etc. Additionally, research and education institutions including the Kwame Nkrumah University of Science and Technology (KNUST) are also involved in addressing the nutrition challenges experienced in Ghana. KNUST conducts aflatoxin research and is involved in a USAID groundnut Innovation Lab. Dr. R.T. Awuah – KNUST Professor of Plant Pathology, indicated that the national standard for acceptable aflatoxin limits is 14 parts per billion, but their research has recorded levels as high as 200 to 300 parts per billion in groundnuts. Aflasafe has been effective in reducing these levels significantly.

In our discussions with Farmer Based Organizations (FBOs) we learned that to the extent possible, peasant families are somewhat selective in their use of inferior quality maize for home consumption. For example, farmers indicated they make an effort to separate moldy ears from clean ears when de-husking by hand, but when using mechanized combines which de-husk and shell maize (more prominent in the major season in the Middle Belt), they are unable to separate ears based on mold content and resort to hand sorting threshed kernels. They stated that moldy or discolored kernels are not used for home consumption but additional research is needed to determine the level to which kernels must be damaged before they are deemed unsafe to consume. In some villages, the custom is to sort and clean stored maize approximately every two weeks at which time infested kernels and pulverized kernels are discarded.

Proper disposal of discarded maize is another area where limited knowledge appears to exist. In some villages, moldy grain is burned as a means of disposal, but in several cases infested kernels are used as livestock feed – potentially posing another risk of aflatoxin ingestion. Overly damaged ears are often discarded in the field, which is likely to increase rodent, insect, mold and aflatoxin activity/levels. While farmers are aware that consumption of moldy grain is not safe, we recognized most have a very limited knowledge of the specific health risks this can cause. Furthermore, very few farmers are aware of what aflatoxin is or the health risks aflatoxin infestations can cause.

We learned from farm families in Nkoranza that the struggle to provide safe food for their families must also be balanced with the necessity to market the maize with the best potential to generate income. As a result, farmers admitted that they tend to retain small ears of maize for home use and sell the maize from larger, fuller ears. Another example of the way markets drive management decisions is that while white maize is the culturally preferred foodstuff, many producers with whom we met are beginning to plant some yellow maize due to a growing market demand for yellow maize as a poultry feedstuff. One Digyawu farmer expressed that he harvests approximately 30 bags of maize from his three acres of cropland and that he typically stores two of these bags in his home for family consumption. He also admitted that some of this maize is used for seed for the next crop as well and that even though the stored grain is cleaned by his wife every two weeks, he loses about 20% of this to mold or insect damage.

We learned from multiple sources that banku quality (the primary food that the staple maize is converted to) is a key consideration in both purchasing decisions and in marketing gimmicks. At the Ejura maize market, year-old maize is sold at a premium price because the lower moisture content leads to more total banku dough. Also at the Ejura market, heavily insect infested maize is marketed as leading to "creamier" and therefore more desirable banku dough.

While it is not directly a nutrition concern, we did observe several more general human health concerns associated with the use of stored grain pesticides. The insecticides Actellic® and Phostoxin® are common, among farmers and warehouse operators and naphthalene is also occasionally used. We learned of widespread misuse and frequent overuse of Actellic® and Phostoxin®. These practices include producers fumigating with phostoxin in numerous dangerous ways including the common practice of fumigating stored grain in the same rooms in their homes in which they sleep with only 3-4 hour aeration times.

Engagement

During our initial assessment visit, we learned that a number of local actors are currently involved with creating opportunities to engage end-users with new knowledge and technical updates. The following section of our report will provide highlights of such activities offered by the various organizations with whom we met. While this is far from a comprehensive list of all such activity currently in Ghana, we believe it is fairly representative of the types of ongoing efforts to reach farmer groups and other maize stakeholders.

<u>Ministry of Food and Agriculture</u>

One entity with perhaps with longest history of engagement work in Ghana is the Ministry of Food and Agriculture (MOFA). During our discussion with the Honorable Kofi Humado and his team of directors, we learned that in addition to their widespread team of extension educators, the Youth in Agriculture program works to provide production inputs to farmer groups in order to increase yields and facilitate broader mechanization. Another MOFA effort that appears to have widespread coverage and fairly extensive usage is a national radio program that disseminates technical information to farmer audiences. The Ministry uses other forms of media as well and offered as an example that they have produced a YouTube video and a PowerPoint presentation on properly drying maize. Unfortunately, when we asked the Nkoranza maize stakeholder group if they had seen this video, none of them indicated they had seen it. These same stakeholders did indicate that training provided by MOFA has been and would be utilized, but that such training should be supplemented by programming offered by the farmer organizations and processor organizations to which they belong. Processors and warehouse operators in the group indicated a willingness to facilitate such training opportunities.

Ghana Grains Council

The Ghana Grains Council (GGC) has invested significant effort in the development of a standardized maize quality grading system. They have also worked toward the construction of a network of maize warehouses to implement a warehouse receipt system. These efforts have involved a great deal of engagement work leading the GGC to hire a fulltime manager of "business development and outreach" in Samuel Okang-Boye who has expressed interest during our meeting and more recently to be involved with our engagement advisory team and other engagement efforts. Mr. Okang-Boye has collaborated with MOFA extension educators to conduct Train the Trainer workshops on maize quality grades. He expressed the opinion that just as in other countries, some extension educators are effective and others are less effective with end-users. Other engagement efforts from the GGC include the development of a video about the warehouse receipt system.

Wenchi Maize Marketing Association

The Wenchi Maize Marketing Association has a group of market employees who each lead a group of approximately 25 farmers. These employees can serve as a critical bridge to producers for engagement efforts to capitalize on an existing relationship of trust. This relationship also extends to a well-developed distribution system within Ghana that enables buyers to call in orders without traveling to Wenchi and trust that their orders will be filled and delivered through an organized shipping system. Such coordination indicates an ability for the Wenchi Maize Marketing Association to play a critical role in engagement and training.

Kwame Nkrumah University of Science and Technology

The Kwame Nkrumah University of Science and Technology (KNUST) has a Department of Agricultural Economics and Extension Education. While this department does educate and prepare future MOFA extension educators, a bulk of their preparation tends to focus on how to conduct agricultural value chain assessments rather than a more broad definition of the role extension educators can play. Research conducted by KNUST faculty targeting extension professionals found that few of them are aware of aflatoxin issues. The potential exists for extension educators to raise awareness of aflatoxin. The KNUST leadership indicated that their extension education component could be expanded.

While the academic program in extension education has a somewhat limited scope, faculty in other departments have been involved in research that has led to farmer educational programming. One example of this includes the work of Professor of Plant Pathology, Dr. R.T. Awuah who is involved with a USAID groundnut innovation lab. As part of this effort, Dr. Awuah has conducted farmer training in three northern regions where farmers interplant maize with groundnuts. This training has established groups and connections which would also benefit from PHL engagement efforts. Connecting with these existing networks will be a high priority for our PHL training and data collection work.

Yedent Agro Processing Ventures Limited

Yedent Foods works with a number of aggregators who source their maize at the high standards of quality they demand for human nutrition including baby foods. These existing relations are an excellent target for identifying potential aggregators who would be potential trainers and for providing a source point to begin training that targets aggregators and potentially producers in the region surrounding Yedent foods.

Sahel Grains

Mr. Kwame Boateng – managing director of Sahel Grains estimates that the training conducted by NGOs acting in the Techiman district reaches approximate 10-20% of the farmers. He recognizes the need for more private sector involvement in providing producer training and is willing to shift his philosophy of leaving this work to NGOs to assist us with our engagement efforts provided the time commitment is not too excessive.

Coordinators of Farmer Based Organizations

Multiple local actors play a key role in initiating the formation of village level Farmer Based Organizations (FBOs) including Pens Food Bank, the World Health Organization, Masara N'Arziki, the MOFA Youth in Agriculture program, and MOFA Extension Educators in certain areas. These actors will be targeted for engagement coordination and input on most effective strategies to maximize our engagement efforts. During our assessment visit, we had the opportunity to meet with six such FBOs, one which was organized by MOFA and the other five which were assembled by Pens Food Bank.

In all groups of producers and other stakeholders, there was a very positive energy and attitude toward our involvement in addressing their challenges with post-harvest handling. Farmer Based Organizations (FBOs) expressed in a number of ways that they are aware their current practices are not the most effective, but given their current constraints and access to resources, they are doing the best they can. They clearly recognized the need for new information and technology in order to reduce PHL. The groups with whom we met consistently expressed a desire to follow and implement our recommended practices, but tempered this reaction with the qualifier that they will likely need access to equipment and markets that will provide premium prices for higher quality in addition to training.

Farmer Based Organizations have the potential to be powerful change agents at the local level. The collaboration we witnessed among FBOs provide basic solutions famers have with access to credit, potential for strategic pooled marketing, and a willingness to invest in shared shelling, drying and storage equipment and facilities.

As a result of their collaborative nature, FBOs also provide opportunities to expand engagement efforts to broader audiences. One FBO indicated that when training opportunities are made available in the local area, while not all members can get away from the farm, they identify and send representatives to the training sessions with the expectation that these delegates will bring new information back to the FBO. As another example, we met with an FBO that meets regularly to listen together to MOFA radio programming and then discuss strategies to implement what they've heard. They also indicated specific management decisions they've changed as a result of such programming including side dressing maize and starting to plant in rows rather than their previous method of broadcast planting.

Identifying multiple media formats to make our engagement efforts sustainable over the long term will be essential to the success of our work. One potential format may be the use of cellular phone technology which has been utilized successfully in other parts of the developing world. While many farmers in certain villages possess mobile phone technology, we found that this is not the case in all regions. Furthermore, very few of those who do have cellular access have the capability to access the internet with the devices they currently use. While mobile technology may serve as one method of conveying engagement information, it should not be the sole mode of distant communication.

Throughout our visit, we repeatedly witnessed needs for training among the various maize stakeholders with whom we met. These groups of producers, warehouse operators, aggregators, market administrators and processors indicated that while some general training on post-harvest handling may be useful, they would place greater value on engagement efforts that target more specific stakeholder groups and their needs and challenges. A limited selection of the topics we identified with immediate needs for training include the following:

- Improved awareness of common causes of post-harvest loss and how these can be easily prevented or minimized
- Safe and accurate usage of stored grain insecticides
- Proper disposal of aflatoxin infested maize
- Health and nutrition hazards associated with mycotoxins and aflatoxins
- Identification and monitoring strategies for stored grain pests
- Moisture content detection techniques
- Importance of producing and marketing higher quality maize and strategies to command a premium price for quality
- The impact of drying on shrinkage since most sales are on a volumetric basis rather than on a weight basis

- Cost effective means of quickly reaching appropriate maize moisture contents for safe storage
- Low cost strategies to improve grain storage
- Marketing strategies that will enhance cash flow during off-peak maize production periods.

Ideas Identified As Already Ripe for Scale Out and Could Form the Basis for Proposals for Sub-awards

1. Solar Drying to Control Moisture Content

During the assessment trip we saw several devices and equipment used for solar drying (Figures 5 and 6). 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 the northern and middle regions of Ghana. Often the maize ears are left lying on the ground during the rainy season, and they become wet and saturated. Most people we talked with were somewhat aware of the health hazards from wet moldy corn. Some screening of discolored ears was done and small-holder farmers did cull discolored ears when possible, but when food was scarce there was more consumption of moldy corn. KNUST in Kumasi conducted a survey of health professionals in Ghana to assess the knowledge concerning health hazards from moldy corn. There is considerable potential to develop solar drying systems that can be hand transported by one or two persons, but these dryers must be designed to get the ears off of the ground and onto some type of screen to facilitate drying. Although the rainy season will put some limitations on the practically of solar drying, this appears to be the most feasible option, especially for small-holder farmers. Experiments can easily be designed to compare solar drying in an improved device versus simply leaving the maize ears on the ground. New surveys could also be conducted to determine consumer awareness of the dangers posed by moldy corn.

Additionally, the Agricultural Engineering Department supports a team comprised of lecturers and faculty members that focuses on postharvest technologies. Some examples of their past efforts include student projects to design and build hand shellers for maize, building and testing small solar dryers for drying multiple agricultural products for household use, and assembling a small-scale biodiesel production system to generate fuel for campus vehicles. The department also houses a machinery development shop that supports projects and activities for faculty, staff, and students. Discussions with faculty members in this department during our assessment trip resulted in a verbal agreement to collaborate with Team members to advance technologies for reducing PHL. Specific areas identified were improved shelling equipment, solar dryers and low-cost moisture meters for small holder farmers and FBOs.

2. Monitoring Maize Moisture Content to Assess Baseline Levels

Problems associated with drying maize and determining moisture content during storage were repeatedly mentioned during the assessment trip. Often monitoring was done simply by determining how far one's arm could go into a 100 or 50 kg bag, the deeper the penetration the drier the maize. Simple experiments could be set up using the moisture meter developed by Dr. Paul Armstrong of the USDA-ARS in Manhattan, KS. Maize stored in selected sites in the northern and middle belts of Ghana, including small-holder farms, could be monitored by comparing traditional methods of assessing maize moisture content with the new moisture meter. These moisture meters are low cost, simple to operate, and could be manufactured locally. The meter was demonstrated at several sites and audiences seemed favorably inclined toward using such a device to monitor the moisture content of their stored maize.

3. Specific Training and Workshops on Phosphine Fumigation

Pest management practices regarding fumigation with phophine were often not explained very well to the assessment team. Record keeping was poor or non-existent, except for a few private companies that focused on providing high quality products with an emphasis on nutritional content. A prime example was Yedent Agro-Processing, which had an exceptionally clean facility and management practices were documented in much more detail compared to most locations we visited. Actual practices were variable and in many cases it was difficult to follow the explanations given regarding treatment procedures. The holding time for fumigation varied and ranged between 2 and 7 days. Rarely was a tarp or cover used and the low exposure times coupled with inadequate sealing did not seem to be sufficient to give a complete kill. Safety appeared to be compromised and there was inadequate concern regarding safety of workers handling phosphine. In many cases workers and even management personnel did not know exactly when the last fumigation occurred and only had a general idea. The assessment team actually became concerned about their own safety when entering warehouses because of the lack of specific information regarding phosphine treatments.

Some warehouses fumigated their bagged seed before it was placed in cold storage at 15-18°C, and only aerated for one or two days before the bags were put in cold storage. This could easily result in a phosphine failing to fully evolve from pellets or tablets, and off gassing could occur when the bags were removed from cold storage and placed in a warm environment. Worker safety would be seriously compromised if this occurred, especially in a more confined space compared to an open environment.

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. Private industry in

Ghana is already doing some training, especially companies like Yedent who have strict standards for their suppliers. 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.

4. Evaluation of Vestergaard-Frandsen insecticide-treated bags for maize storage by smallholder farmers in the Middle Belt and Northern Ghana

The northern region of Ghana is much more impoverished than the middle belt. The infrastructure is less developed, and the road networks are marginal or non-existent is some areas. In addition, there is much more home storage of maize in the Northern region as well compared to the rest of Ghana. Although average temperatures may be slightly lower in the north compared to the middle and south, the storage environment is still conducive to stored product insect infestation and development. A number of persons also mentioned field infestations of maize weevil that could be carried over into the home storage, resulting in damaged kernels, seed loss, food loss, and less maize available for planting during the following crop year. USAID is concentrating their efforts in the north and has 6 flagship programs to address poverty. Their efforts were described in detail by Brian Conklin of USAID. The Vestergaard-Frandsen (VF) bags could be utilized in a project to improve stored maize seed in northern Ghana. Many maize traders and warehousemen have their own bags for storing maize seed, but small holder farmers may only have bags of lower quality or no bags at all. A test could be conducted whereby an associate award is utilized to purchase bags, perhaps at a discount, and evaluate them along with hermetic storage (aka PICS) by storing well dried maize in a number of homeowner sites and small metal silos for several months and comparing the resulting maize quality on a monthly basis. USAID, Purdue, and VF personnel could be involved in the evaluation process. Maize could be evaluated for color and quality differences, moisture content, presence of insects and insect damage, mold activity, and grade. The VF and PICS bags can be re-used, therefore multi-year studies could be conducted to also determine residual longevity of the bags in an actual environment. Multi-year use would amortize the cost of the bags over the course of several years, which would make the bags more affordable for small farmers.

5. Utilization of Small Metal Bins for Storing Bagged Grain

Many of the storage warehouses (Figure 3) we visited were in the open and had some roof protection for stacked pallets but the sides were exposed to rainfall.. While the actual size of metals would have to be limited, metal bins with a roof would offer more protection than can be obtained through open air storage. There at least several companies that offer small storage bins, and farmers cooperatives are interested in the concept. PENS Food Bank has bins with capacity 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, listed as between GHS 6,000 and 8,000 for the 15-MT bins. However, the concept can be scaled up and evaluated. Simple comparisons could be done between storage in standard seed bags in the open versus storage of these same number of bags in a metal bin. A targeted associate award could be used to finance purchasing of these bins, along with farmer cooperatives. As USAID is interested in the north, a scaled-up project that evaluates these bins in the two different regions of the maize system would help address some key components of the points in the maize value chain where significant losses are occurring. NAFCO is also a potential cooperator in this project, as they specifically stated the warehouses they inherited from MOFA were old, of poor quality, and need to be replaced.

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 were present as well. There is little information on prevalence of insects in the rainy season versus the dry season, or differences between the Northern Region 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 would have to be carefully done so as to protect the baited traps from animal pests (reptiles, mammals, etc.).

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 with additional funding to support this related activity.

Potential Focus Areas for the Second PHL Assessment Trip in December 2014

Based on information gathered during the May 2014 PHL assessment, the team determined that additional information was needed in order to obtain a more complete view of the existing post-harvest situation regarding maize production in Ghana. The May 2014 assessment focused primarily on the heavy maize production areas in the Middle Belt comprising areas such as Wenchi, Techiman, and Ejura, which has two annual rainy seasons that lead to two maize production periods per year, as stated previously. In the Middle Belt, problems associated with inadequate drying, availability of labor and mechanical threshers, and effective storage solutions are intensified by the demands of limited time and labor during the harvest of the first crop and the need to quickly seed the second crop to maximize the minor season. In the Northern region, climatic conditions and cultural practices dictate a single maize crop per year coupled with dry conditions in most years at harvest. These differences suggest the necessity to collect data from producers and processors in the extensive maize production area in the North during the December assessment.

We plan to center most of our discussions with producer groups on those farmers working within the Masara N'Arziki Farmer's Cooperative Association in order to maximize their existing networks while also learning more about the cooperative structure and the support provided. While exploring differences between the Middle Belt and the North, we will focus on the extent of harvest and post-harvest mechanization, the types and usage of drying and storage facilities and their effectiveness, uses and types of bagging systems, and insect, mold and quality monitoring procedures in place. We will also investigate the current marketing system both direct from farmers to processors and those systems that use commodity aggregators. In all these, the assessment team will be documenting current grain handling and pest management tactics, stored-product insect activity and post-harvest grain losses in on-farm storages and in small-, medium-, and large-scale storage warehouses with the ultimate goal of identifying researchable areas in postharvest loss where breakthroughs in research and development could lead to significant mitigation of maize PHL.

In order to examine currently under-utilized or on-the-shelf technologies, we will collect data from sheller and other implement manufacturers/distributors and agro dealers who import and market post-harvest insecticides available to producers. While these local actors have the potential to provide valuable information regarding existing technology, our team believes they may have a critical role to play in the education and engagement aspects of the project. These input suppliers may also provide potential opportunities for women's self-help groups to invest in organizational models with potential for women's income generation.

In addition to meeting with producer groups, we will seek to learn more about grain quality and any mechanisms or organizations that exist to provide premiums to producers for improved quality. To collect comprehensive data on these topics, we will meet with animal feed processors, poultry production organizations and commodity aggregators and marketing associations.

During the May assessment trip, we had the opportunity to meet with the Honorable Kofi Humado – Minister of Agriculture as well as his team of directors (Figure 1). In December, we will follow-up previous discussions with the delivery of this report and will collect data on means to collaborate with MOFA Extension and the Youth in Agricultural Development Directorate in gaining more effective engagement with the end users of PHL research. Also related to engagement and MOFA extension, we will seek to learn more about existing MOFA

Extension radio programming targeting farmers and explore means to utilize this low cost and pervasive medium to more broadly distribute our results.

Our research focus will begin in earnest during year two of the project. Therefore, during the December assessment trip, we will collect research literature and invest in relationships with scientists at KNUST in Kumasi, the University for Development Studies and the Savanna Agricultural Research Institute in Tamale, and the University of Ghana in Accra.

Although collecting data to inform our pending research projects will be a primary focus of the December assessment visit, initiating and nurturing collaborative relationships with other USAID affiliated teams will be an important component as well. Opportunities for collaboration with the ATT, ADVANCE, SPRING, and FinGap teams will be explored. We will also follow-up earlier conversations with the World Food Program leadership who expressed interest in sharing our research with their Farmer Based Organizations. We recognize that our ability to leverage the investment in the PHL Innovation lab to partner with other local actors will be essential to the long term adoption of our research. Thus, for sustainable reasons we remain committed to find ways to forge effective collaborations with teams and organizations with compatible goals and complementary objectives.

People/Locations/Groups/Organizations/Government Entities Visited During the First Postharvest Loss Assessment trip

Agricultural Development and Value Chain Enhancement (ADVANCE) Ghana

"The Ghana Agricultural Development and Value Chain Enhancement (ADVANCE) Project is a 4-Year USAID sponsored project awarded to ACDI/VOCA and being implemented in partnership with a team of agencies including ACDEP as the lead implementer in the Northern Sector. Starting in late 2009, ACDEP is working on three commodity value chains (maize, rice and soybean) and has opened regional offices in Wa, Bolgatanga and the Head Office in Tamale to ensure effective implementation of the program" (http://acdep.org/wordpress/acdep-development-programs/value-chain/advance/).

Council for Scientific and Industrial Research (CSIR)

The CSIR mission is "To generate and apply innovative technologies which efficiently and effectively exploit Science and Technology (S & T) for socio-economic development in the critical areas of agriculture, industry, health and environment and improve scientific culture of the civil society. Technologies developed will be commercialized for Private Sector Development in Ghana and abroad" (http://www.csir.org.gh/index1.php?linkid=79).

Farmer Based Organizations (FBOs)

Each FBO usually has a minimum of 17 and a maximum of 30 smallholder farmers (SHF). The key goals of FBOs are bringing SHF together to facilitate 1) transfer of agricultural production knowledge and technology for improved yields, 2) linkage to finance - provision of credit facilities to member SHF at acceptable interest rates usually not exceeding 10% (banks charge up to 45% interest), and 3) facilitate implementation of agriculture-related projects that would be too difficult for one or a few SHF to accomplish. There are currently approximately 62 FBOs in the Middle Belt. Typically 30% of the members in each FBO are women.

Ghana Grains Council (GGC)

Has a vision "To become the leading industry association representing and advocating for the interests of all participants and service providers in the grain industry to create a more competitive, productive and efficient agricultural sector." GGC mission is 1) to advocate for and facilitate sustainable improvements and increased efficiency in the grain industry through strategically targeted interventions along the grains value chain, 2) to contribute to the establishment and enforcement of transparent rules, regulations and standards, and 3) to ensure a competitive industry while protecting the public interest. (http://ghanagrainscouncil.org/index.php/who-we-are/vision-mission).

Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

KNUST has carefully categorized academic departments into six colleges, a state of the art library complex housing a modern Information and Communication Technology Centre, several educational resource centres, modern laboratories, research facilities and a host of other facilities. KNUST delivers a high standard of education which reflects the pedigree of a University poised on attaining a status of being No. 1 in Africa. Academic related issues especially on studying and research has never been this convenient. This hallmark is evident in their ever increasing affiliate institutions. They claim to be the home of academic excellence. (http://www.knust.edu.gh/academics). Academic department personnel visited during our assessment trip included faculty and staff from Agricultural Economics, Agricultural Engineering, Agronomy, Entomology, and Plant Pathology.

Masara N'Arziki Farmers Association (MAFA)

"Masara N'Arziki (meaning "Maize for Prosperity") is headquartered in Tamale and covers the entire Northern part of Ghana (i.e Nortern Region, Upper East and Upper West Regions and parts of Brong-Ahafo Region [mapsofworld.com/ghana/]). Masara N'arziki Farmers Association (MAFA) is the culmination of Industrial Maize Program initiated in 2005 by Wienco (Ghana) Limited. Masara N'Arziki's vision is to help maize farmers do what they are doing much better, and receive more income through the use of improved technology that increases productivity of their farms. The program package consists of the provision of fertilizers, hybrid seeds, herbicides, insecticides, spaying equipment, innovative farm implements and technical advisory and training services to farmers on credit. (http://www.yaraghana.com/Support-Services/Masara-N-Arsiki-Farmer-Association.aspx).

Millennium Challenge Corporation (Millennium Development Authority (MiDA)

"Agriculture is the backbone of Ghana's economy accounting for about 40 percent of the country's gross domestic product, employing 60-70 percent of the labor force and generating more than 55 percent of the foreign exchange earnings. The program proposed under the compact would operate in the northern area, the central Afram Basin area and the southern horticultural belt area. Overall poverty rates in the target areas are generally above 40 percent. In the north, as well as in parts of the central Afram Basin area, poverty among the rural population is as high as 90 percent.

Through an act of its Parliament, the Government of Ghana created the Millennium Development Authority (MiDA), a public corporation that serves as the accountable entity for the implementation of the five-year program. MiDA is governed by an independent board of directors consisting of representatives of key government ministries, the private sector, and the non-governmental organization (NGO) community, with observers from the target areas and the environmental community. The program focuses on improving the productivity of agriculture, increasing production of high-value commercial and basic food crops, and fostering greater private investment in agriculture. To that end, the program aims to improve the physical and institutional infrastructure in this critical sector of Ghana's economy. The program was designed through a consultative process that included input by farmers, agricultural processors and marketers, NGOs, government ministries, international donors and others.

Agriculture ($241 million): The largest of the three components is designed to enhance the profitability of commercial agriculture among small farmers. It includes:

- Training for farmer-based organizations (FBOs) and agricultural enterprises to accelerate the development of commercials skills;
- Irrigation improvements with the building of a limited number of retention ponds and small dams requested by FBOs whose success requires access to water;
- Improved land tenure security and transaction support;
- Facilitation of strategic investments by FBOs and other businesses in post-harvest infrastructure, including cold storage and processing facilities, supported by enhanced compliance with international food protection standards;
- Improved access to credit provided by commercial and rural banks, and non-traditional financing channels; and
- Rehabilitation of up to 950 kilometers of single-lane roads in order to reduce transportation costs and time to major domestic and international markets, and social

service networks (including, for instance, hospitals, clinics and schools).” (http://2001-2009.state.gov/p/af/rls/fs/68866.htm).

Ministry of Food and Agriculture (MOFA), Republic of Ghana

MoFA's Mission is to promote sustainable agriculture and thriving agribusiness through research and technology development, effective extension and other support services to farmers, processors and traders for improved livelihood. (http://mofa.gov.gh/site/#).

National Food Buffer Stock Company (NAFCO)

“Ghanaian farmers may no longer experience post harvest losses. The government has through the Ministry of Food and Agriculture (MoFA) set up the National Food Buffer Stock Company (NAFCO) to ensure food security and to insulate farmers against losses resulting from anticipated increases in production” (http://foodsecurityghana.com/tag/nafco/).

Pens Food Bank Enterprise (PFB) – Mr. Evans Peter Nsiah

Pens Food Bank is strategically located within the Middle Belt (a.k.a. transitional zone), the heart of maize production, and connects many different active players involved with the maize value chain in the Middle Belt of Ghana. Therefore, PFB is a focal organization in the Ghana maize value chain. PFB is a private and profit-oriented organization that has a lot of social interventions that benefit stakeholders in the maize value chain in the Middle Belt. Mr. Evans Peter Nsiah is the Managing Director of PFB. In order to ensure regular supply at harvest time, PFB helps to prepare farmers’ lands for planting on a credit basis. Farmers pay cash or in-kind during harvest time. PFB also organizes trainings in Good Agricultural Practices (GAP) for Farmer Based Organizations (FBOs) to facilitate production of healthy and high quality crops and to enhance yields. PFB accepts maize from producers, traders and aggregators for cleaning, drying and storage for a fee. PFB uses its trade network, locally and within the West Africa sub-region to market grains for traders and farmer groups who request for volume sales on commission.

PFB activities span across the Middle Belt comprising places such as Ejura, Sekyedumas, and Mampong Municipalities. Its operations impact on an average of 40,000 farmers in about 62 Farmer Based Organizations (FBOs), 200 aggregators, 300 traders, and 150 processors.

Smallholder Farmers (SHF)

Ghana’s agricultural sector is primarily subsistence-based. According to the Ministry of Food and Agriculture Sector Development Policy (FASDEP II), family-operated smallholder farms account for nearly 80 percent of the country’s total agricultural output. Approximately 51% of the labor force is directly or indirectly engaged in agriculture with most holdings averaging less than two hectares. These figures imply there is a lot of on-farm storage.

United States Agency for International Development (USAID) – Accra, Ghana
(http://www.usaid.gov/what we do)

"In an interconnected world, instability anywhere around the world can impact us here at home. Working side-by-side with the military in active conflicts, USAID plays a critical role in our nation's effort to stabilize countries and build responsive local governance; we work on the same problems as our military using a different set of tools. We also ease the transition between conflict and long-term development by investing in agriculture, health systems and democratic institutions. And while USAID can work in active conflict, or help countries transition from violence, the most important thing we can do is prevent conflict in the first place. This is smarter, safer and less costly than sending in soldiers.

USAID extends help from the American people to achieve results for the poorest and most vulnerable around the world. That assistance does not represent a Democratic value or a Republican value, but an American value; as beneficiaries of peace and prosperity, Americans have a responsibility to assist those less fortunate so we see the day when our assistance is no longer necessary.

USAID invests in ideas that work to improve the lives of millions of men, women and children by:

- Investing in agricultural productivity so countries can feed their people
- Combating maternal and child mortality and deadly diseases like HIV, malaria and tuberculosis
- Providing life-saving assistance in the wake of disaster
- Promoting democracy, human rights and good governance around the world
- Fostering private sector development and sustainable economic growth
- Helping communities adapt to a changing environment
- Elevating the role of women and girls throughout all our work"

Warehouse Receipt Program (WRP)

The United States Agency for International Development (USAID) is currently funding the establishment of the Ghana Grains Council (GGC) through ADVANCE program. GGC runs the USAID Warehouse Receipt Program (WRP). The Ghana WRP was started in March 2010 and a number of WRP are planned for West Africa with the one in Ghana being a pilot project for these. The underlying reasoning behind the program is that there will be no impetus for grain quality without the WRP or something like it. Grain trade in Ghana is currently inefficient due to lack of a WRP or a commodity exchange system. The WRP will be mostly driven by issues related to grain quality, price stabilization, and the value chain. The goal of the program is to increase grain quality by ensuring low incidence of aflatoxins in the grain value chain. Consumption of aflatoxins can lead to immediate death or chronic effects such as liver cancer.

The WRP will also make grain trade more efficient by ensuring a reliable supply of good quality grain to warehouses, which will result in grain price stabilization.

World Food Program (WFP) Ghana

WFP works with the Government of Ghana to implement a development programme focusing on education, nutrition and climate change mitigation and adaptation projects. Some of WFP Ghana activities include 1) provision of school meals, 2) nutrition **-** provision of nutritious food supplements to pregnant and nursing women, chronically malnourished children under the age of two, children under the age of five suffering from moderate acute malnutrition, and people living with HIV on anti-retroviral therapy 3**)** resilience **-** building resilience of communities in Ghana through asset creation activities and training to promote sustainable livelihoods. 4) emergency operations **-** an emergency operation began in August 2011 to provide food to Ivorian refugees after the 2010 election crisis in Côte d'Ivoire, 4) Purchase for Progress (P4P) **-** the P4P initiative aims to address some of the major constraints smallholder farmers face, including low productivity, significant PHL, poor market infrastructure and inadequate access to markets, 5) local procurement **-** WFP Ghana buys a minimum of 60 percent of its food needs from surplus production areas in the country, which is then redistributed in food-insecure regions, 6) United Nations Humanitarian Response Depot **-** Ghana hosts one of five United Nations Humanitarian Response Depots in the world **-** logistics intervention fleet **- t**his centrally-pooled fleet of trucks is on hand for immediate dispatch to regional emergencies. (http://www.wfp.org/countries/ghana/operations).

Yedent Agro Processing Ventures Limited

The founder of Yedent Agro Processing Ventures Limited, Mr. Samuel Kwame Ntim Adu is a former manager at a multinational company in Ghana. Today, from the agricultural heart of Ghana, he is running his own company of over 40 employees from food scientists to engineers to factory hands. Yedent Agro Processing Ventures is developing an instant maize-based product enriched with vitamins and minerals that is the first of its kind on the market due to its affordability and natural integration with breastfeeding. Its goal is to improve the nutrition of more than one million children during their first 1,000 days of life, when they require the right nutrition to develop well mentally and physically throughout their life. (http://www.gainhealth.org/country/multinational-start-ghanaian-entrepreneur%E2%80%99s-commitment-providing-affordable-nutrition).

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Footnotes

[1] Department of Entomology and Plant Pathology, Oklahoma State University, Stillwater, OK, 74078-3033, USA.

[2] USDA, Agricultural Research Service, Center for Grain and Animal Health Research, 1515 College Avenue, Manhattan, KS, 66502-2736, USA.

[3] Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Private Mailing Bag, Kumasi, Ghana

[4] Communication & Ag. Education, 301 Umberger Hall, Kansas State University Manhattan, KS, 66503

[5] Vestergaard Frandsen SA, Chemin Messidor 5-7, 1006 Lausanne, Switzerland

[6] Biosystems and Agricultural Engineering Department, University of Kentucky, Princeton, KY 42445.

[7] Department of Biology, Fort Valley State University, Fort Valley, GA 31030.

[8] FtF IL for Reduction of Postharvest Loss, 1980 Kimball Avenue, Kansas State University, Manhattan, KS 66506

Table 1. Dates and locations, people, groups, or organizations visited during the first Ghana postharvest loss assessment trip.

Date	People/Locations/Groups/Organizations/Government Entities Visited
5/19/14	USAID Office of Economic Management, MOFA-Agric Mechanization, Ministry of Food and Agriculture (MOFA) Policy University of Ghana-College of Agriculture, Ghana Grains Council
5/20/14	World Food Program, Winneba Seed Storage Warehouse, Winneba MIDA Assisted Warehouse, Wienco, National Food Buffer Stock Company (NAFCO)
5/21/14	Kwame Nkrumah University of Science and Technology (KNUST)--Faculty members in Entomology, Plant Pathology, Animal Science, and Extension; Asuoyeboah Seed Warehouse
5/22//14	Yedent Agro Processing Ventures Limited, Kwame Boateng Maize Drying Center
5/23/14	MOFA Nkoranza, A MIDA Assisted Warehouse (Mr. Manso), Nkoranza Farmers Group
5/26/14	Pens Food Bank Warehouse, Alliance Farms, Ejura Farms
5/27/14	Mbaana Farmers Groups 1 and 2, Digyawu Farmers Groups 1 and 2, MOFA Ejura, Ejura Market,
5/28/14	Nkyensie Farmers Groups 1 and 2, Santaso Farmers Groups 1 and 2, Sekyedomasi Farmers Group, Maize Warehouse and Processing Facility,
5/29/14	Kwame Nkrumah University of Science and Technology (KNUST)--Postharvest faculty group in Agricultural Engineering, Council for Scientific and Industrial Research – Crops Research Institute (CSIR-CRI), Kumasi.
5/30	Exit Meeting with USAID Office of Economic Management

Appendix A

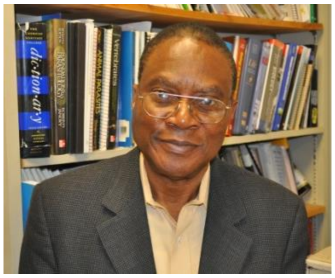
Biosketches of Ghana Project Team

Dr. Paul Armstrong is a Research Engineer with the United States Department of Agriculture, Agricultural Research Service in Manhattan Kansas. His primary research areas are the development of instrumentation for grain storage and quality measurement. His research includes development of moisture and carbon dioxide sensing systems in grain storage and the use of single-seed near-infrared spectroscopy for phenotyping, genetic selection and classifying defects in grain. He has authored several publications in these areas and is a member of the American Society of Agricultural and Biological Engineers. http://www.ars.usda.gov/pandp/people/people.htm?personid=33239

Dr. Franklin (Frank) H. Arthur is a Research Entomologist with the US Department of Agriculture at the Center for Grain and Animal Health Research in Manhattan, KS. His research interests include insect pest management in stored products; evaluation of new reduced-risk insecticides for insect control in bulk grain, flour mills, and processing plants; examining feasibility of alternatives to fumigation in stored products; and exploring new management strategies to reduce damage caused by stored product insects. Dr. Arthur is responsible for planning, coordinating, and developing an independent research program on insect pest management in stored raw agricultural commodities, mills, and food warehouses. He has cooperative research projects with state universities, other federal agencies, and private industry. Dr. Arthur regularly gives invited presentations on his research at scientific meetings, industry symposia, and training sessions sponsored by university Extension departments.

Ms. Oana Baban is an Environmental Biologist, working as Field Trials Manager for Vestergaard (www.vestergaard.com), based in Switzerland. She has extensive experience working with the design, implementation and management of field trials in developing countries. Her research programs focus on reducing post-harvest losses in the storage of grains in Sub-Saharan Africa and South East Asia. In her work, Oana engages with high-level in-country stakeholders and world-wide scientists to enhance research collaborations for the testing of Food security tools such as ZeroFly® Storage Bag.

Dr. James F. Campbell is a Research Entomologist with the United States Department of Agriculture, Agricultural Research Service, Center for Grain and Animal Health Research in Manhattan, Kansas USA. He is also an adjunct professor in the Department of Entomology at Kansas State University. His research interests include the spatial distribution and movement patterns of stored-product insects in food facility landscapes, improving the implementation and interpretation of insect monitoring programs, and determining the impact of different management tactics on pest populations within commercial food facilities. He has authored numerous peer-reviewed journal articles, given many invited presentations at national and international conferences and at stakeholder group meetings. He serves as the Secretary/Treasurer for the Permanent Committee of the International Working Conference on Stored Product Protection and is on the Editorial Board of the Journal of Stored Products Research. (www.ars.usda.gov/npa/cgahr/spiru/campbell).



Dr. George Mbata is a Professor of Entomology and Head of Department of Biology at Fort Valley State University, Fort Valley, Georgia, USA. His research interests are in the use of alternatives to chemical pesticides in the management of postharvest pests of commodities. His research focus has been on the use of modified atmospheres and biological control agents in controlling stored product pests. He has also investigated the chemical ecology, biology and behavior of insect pests and their natural enemies. He participates in a number of projects aimed at mitigating the impact of insect pests on agricultural productivity of West African countries. He has several journal articles and conference papers on mitigation of postharvest losses. In 2009, he was selected as a Fulbright specialist on postharvest integrated pest management.

Dr. Samuel McNeill is an Associate Extension Professor and Extension Agricultural Engineer in the Biosystems and Agricultural Engineering Department at the University of Kentucky Research and Education Center in Princeton, KY, USA. He is a registered professional engineer in the Commonwealth of Kentucky. His extension and research program focuses on post-harvest processing of grain and biomass crops for food, feed, fiber, and fuel production and he has extensive experience working with the design, operation and management of grain drying and storage facilities. He has authored numerous extension publications including topics on harvesting, drying and storing corn, canola, grain sorghum, soybean, and soft red winter wheat, which are available on the UK-BAE website (www.bae.uky.edu). An active member of the American Society of Agricultural and Biological Engineers since 1979, he is currently a member of the grain drying and storage, biomass products, and textbooks and monographs committees. Recent projects have focused on reducing postharvest losses of grains in West Africa.

Isaac Ayobami Ola is a Regional Area Manager with Vestergaard Group SA (www.vestergaard.com). He is responsible for the trade marketing and distribution of Vestergaard's Food Security Portfolio in Nigeria and Ghana. Isaac holds an MBA in marketing. He is a registered Pharmacist with over 19 years of experience in sales, marketing and channel development. He has a particular interest in commodity distribution, logistics and program management and development.

Dr. George Opit is an Associate Professor of Stored Product/Post Harvest Entomology in the Department of Entomology and Plant Pathology at Oklahoma State University in Stillwater, Oklahoma, USA. His broad research interests are integrated pest management and biological control of arthropod pests. Specifically, his research is focused on investigating the biology, behavior, and population dynamics of stored-product arthropod pests and their natural enemies and in using the information acquired to optimize pest management. His research activities involve the study of pesticide resistance of stored grain pests, while extension activities are in the area of integrated stored-product pest management both of which have led to numerous speaking opportunities at national and international meetings and conferences (http://entoplp.okstate.edu/profiles/opit.html).

Dr. Enoch Adjei Osekre is a Senior Lecturer in Entomology at the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. His broad research interests are integrated pest management and host plant-insect interaction with focus on population dynamics of insect pests and their application on development of integrated pest management strategies for both field and storage insect pests of vegetables, legumes and cereals. His extension activities have focused on education on safe handling and use of pesticides. He has participated in many scientific conferences.

Dr. Venkat Reddy serves as the Managing Technical Director of the Innovation Lab for the Reduction of Post-Harvest Loss. Prior to joining the Department of Grain Science and Industry at Kansas State University, Dr. Reddy was a senior principal engineer with General Mills and worked with product development, developed specialty flours for dry mixes for General Mills India, and developed high quality flour for Pizza Hut India. He had several other responsibilities under the international business units. Prior to working with General Mills, Dr. Reddy was an instructor in the Department of Grain Science and Industry at Kansas State University. (Email: pvreddy@ksu.edu).

Dr. Shannon G. Washburn is a professor of Agricultural Education in the Department of Communications and Agricultural Education at Kansas State University in Manhattan, KS, USA. Dr. Washburn's work revolves around educator effectiveness in agriculture and the affiliated sciences. His undergraduate and graduate courses address curriculum development, educational program planning, and professional development issues. As a State Extension Specialist in Teaching and Learning, Dr. Washburn leads secondary and post-secondary educators as well as extension educators in developing strategies to engage learners more effectively, to refine curricular expectations and goals, to improve methods of instructional assessment and evaluation, and to integrate multidisciplinary approaches to teaching technical content. As such, he has presented over 80 workshops and seminars addressing effective delivery of educational programming to secondary teachers, extension educators, and domestic and international educators. Dr. Washburn's previous international work has focused on agricultural curriculum development and human capacity building in delivery strategies in Haiti, Egypt, and Kenya.

Appendix B

Some Pictures from the First Maize Postharvest Loss Assessment Trip

Figure 1. Some members of the Ghana Project Team met with Hon. Clement Kofi Humado (in black attire), who was Ghana's Minister for Food and Agriculture in May 2014, and other high ranking officials in the referenced ministry. The current Minister for Food and Agriculture, Hon. Fifi Kwetey, was appointed by the President, His Excellency John Dramani Mahama on 28th June 2014.

Figure 2. Members of the Ghana Project Team visited Ejura maize market and other maize markets to discuss PHL-related issues with traders.

Figure 3. Several maize warehouses were visited during the PHL assessment trip.

Figure 4. Maize PHL assessment in the Middle Belt of Ghana involved visiting and discussing PHL issues with several farmer-based organizations (FBOs).

Figure 5. Demonstrations of grain moisture measurement methods in the Wenchi grain market (traditional method on left and USDA-ARS meter on right).

Figure 6. Multi-crop solar dryers with mesh covered racks seen in the Middle Belt of Ghana (near Nkoranza on left and Sekyedomasi on right) during our assessment trip.