The Energy Center, KNUST

RENEWABLE ENERGY FOR EFFICIENT FOOD PROCESSING TO IMPROVE RURAL LIVELIHOODS (RE4FOOD) PROJECT

REPORT ON A CASE STUDY OF POST-HARVEST MAIZE FOOD LOSS ALONG MAIZE VALUE CHAIN IN GHANA

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SUMMARY

This report by The Energy Centre, KNUST, Kumasi, is the output of a study undertaken as part of the RE4FOOD project, which sought to assess and analyse post-harvest food losses and waste along the value chain.

The study examined post-harvest food losses (quantitative and qualitative) along the maize value chain in Ghana. Maize farming communities in Ejura-Sekyeredumase Municipality and two major maize markets – Ejura market in the Ashanti Region and Agbobloshie market in the Greater Accra Region were used as case studies. The study sought to identify traditional practices and management practices adopted by smallholder farmers and traders in maize production and marketing respectively. The impact of these practices on maize food losses in the maize value chain, particularly, during harvesting and shelling as well as marketing was also investigated.

The study was conducted during the 2013 minor maize farming season. Through purposive and simple random sampling, 150 farmers from maize farming communities across 10 cluster zones base on geographical location of farm within the Municipality were selected for the study. Maize traders were also selected from both Ejura market (markets close to farmers) and the Agbobloshie market (market close to consumers) for the study. In all, 30 traders were randomly selected from each market. Presence and level of aflatoxins in maize samples taken from both markets and farms was determined using Afflatest-AOAC-2007.

Analysis of results showed that, a significant percentage of farmers (approximately 93%) employ field drying and late harvesting during the minor season. During this period, approximately 20% of the total expected yield is intermittently harvested fresh (milking stage) and sold, while the remaining 80% is left to grow to its physiological maturity, and allowed to dry on the field before it is harvested.

Quantitative assessments of food loss in the minor season for maize production revealed estimated average loss of 1.91% due to unpicked maize cobs from the farms, and 6.6% due to inefficient shelling method used by the farmers. Per farmers interviewed assumption that losses attributed to feeding by scavenging cattle, theft, non-germination, pest and diseases is 1.45%, the total production losses were, therefore, estimated to be 10.06%. This represents an average maize food loss of 153 kg/ha per the estimated average yield of 1.53tons/ha from the field loss assessment on the farms. In economic terms, a farmer in the study area loses a bag of maize (140kg, bush weight) for every hectare of maize harvested. This directly affects the profit margin and household food consumption.

Types of aflatoxin determined from sampled maize grains were G2, G1, B2 and B1. Grains from the farms showed either zero or below limit of detection of aflatoxins. However total values of 50.234ng/g, 70.102ng/g and 30.943ng/g were respectively obtained from samples taken from the Ejura market. Additionally,, higher levels of aflatoxin, 677.480ng/g, 101.748ng/g and 4831.942ng/g were detected in samples taken from the Agbobloshie market.

All respondents who were interviewed during the study demonstrated lack of knowledge on aflatoxin contamination and it causes. Moreover, 63% of traders from both markets (Ejura and Agbobloshie markets) believed that, when contaminated maize is consumed by humans,

will have no health effect on the consumer since food products such as *kenkey, banku, tom brown, etc.* from maize are normally cooked before eaten.

It was concluded from the study that, aflatoxin contamination in maize seems to clearly increase through the channels of distribution from the farm up to market centres. Presumably, consumption of aflatoxin contaminated foods due to unavailability of safe foods may render consumers more susceptible to consequent adverse health effects. Farmers and traders must therefore be educated and encouraged to adopt management practices that reduce or prevent the incidence of aflatoxin contamination in the field and during handling at the market centres to make maize grains less susceptible to aflatoxin infestation thereby ensuring the safety of the final consumer. On the whole, strenuous efforts are required on the part of policy makers to help reduce losses at all levels of the maize value chain, especially at the post-harvest stage.

1.0 BACKGROUND

Maize is one of the most important staple food crops in Ghana. Maize is a very important food crop for both humans and livestock. It provides energy, vitamins and negligible amount of protein. According to Coulter *et al*., (1993), maize is a staple crop grown in almost all parts of the country, and is the most important source of carbohydrate in most Ghanaian meals. Each year, a significant proportion of food produced for human consumption is lost or wasted. The United Nations (UN) estimates that 1.3 billion tons of food is lost globally, every year (Gustavsson et. al, 2011). The exact causes of food losses vary throughout the world, and are very much dependent on the specific conditions and local traditional practices in a given country. Food loss is of high importance in the efforts to combat hunger, raise income and improve food security, globally. Food losses have an impact on food security, food quality and safety, on economic development, and on the environment (Gustavsson et al., 2011). Irrespective of the level of economic development and maturity of systems in a country, food losses should be kept to a minimum. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security. With the world population expected to reach 10.5 billion by 2050 (UN March, 2013), food availability and accessibility will need to be increased by increasing production, improving distribution, and reducing losses. Using food production levels at 2005, Alexandratos and Bruinsma (2012) estimated that, food supplies would need to increase by 60% in order to meet food demand in 2050.

1.1 Definition of Food losses

Food loss refers to the edible parts of plants and animals produced or harvested for human consumption but not ultimately consumed by people. It represents a decrease in the mass, caloric, and/or nutritional value of edible food intended for human consumption at any stage in the food value chain. “Food loss” refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. Food loss typically occurs at the production, storage, processing and distribution stages of the food value chain. “Food waste” refers to food that is of good quality and fit for human consumption but that does not get consumed because it is discarded either before or after it spoils. Food waste typically, but not exclusively, occurs at the retail and consumption stages in the food value chain and is the result of negligence or a conscious decision to throw food away (Brian et al, June 2013).

Each year, a significant proportion of food produced for human consumption is lost or wasted. Roughly one-third of the edible parts of food produced for human consumption gets lost or wasted, globally, which is about 1.3 billion ton per year. Food is wasted throughout the food supply chain, from initial agricultural production down to final household consumption (FAO, 2011). Food losses take place at production, postharvest and processing stages in the food supply chain (FAO 2010):

- Production: losses due to mechanical damage and/or spillage during harvest operation (e.g. threshing or fruit picking), crops sorted out post-harvest, etc.
- Postharvest handling and storage: including losses due to spillage and degradation during handling, storage and transportation between farm and distribution.

- Processing: including losses due to spillage and degradation during commercial or domestic processing, e.g. juice production, canning and bread baking. Losses may occur when crops are sorted out if not suitable to process or during washing, peeling, slicing and boiling or during process interruptions and accidental spillage.

- Distribution: including losses and waste in the market value chain system e.g. wholesale markets, retail and farm gate markets.

- Consumption: including losses and waste during consumption at the household level.

1.2 Value chain

This is a series of activities a product or service must pass through until it serves its final purpose of solving a customer need. In each phase of the value chain the product or service gains some value. If a phase is malfunctioning the chain will break down and the mission of generating value for the customer will not be accomplished. The flow of seeds to farmers and grains to the market occurs along chains. These can be referred to as value chains because as the product moves from chain actor to chain actor e.g. from producer to intermediary to consumer it gains value (Jon and Madelon, 2006).

Value chain analysis is a useful strategy in understanding overall trends of industrial reorganization. It can be used to identify key players, change agents and leverage points for policy and technical interventions. The main value chain actors in maize production include:

- Producers (farmers)
- Market (traders)
- Processers (processing factories, food vendors and consumers)

Figure 1 shows the principal chain activities maize go through before reaching the final consumer.

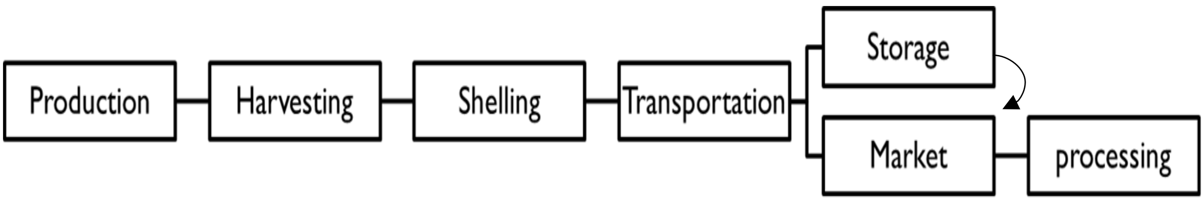

Figure 1: Maize Production chain

1.3 Maize production in Ghana

Maize (*Zea mays*) is the highest produced cereal crop and the most widely consumed food in Ghana with increasing production since 1965 (FAO, 2008; Morris et al., 1999). Maize is cultivated in all the ten regions of the country however the leading producing areas are mainly in the middle-southern part (Brong Ahafo, Eastern and Ashanti provinces) where 84 percent of the maize is grown, with the remaining 16 percent being grown in the northern regions of the country (Northern, Upper East and Upper West provinces). In 2012, maize accounted for over 60 percent of all grain output followed by paddy rice, sorghum and millet (MoFA 2013). Since the last decade, production has been fairly stable with a significant increase starting from year 2008 (see Figure 2). Maize is also an important component of poultry feed and to a lesser extent the livestock feed sector as well as a substitute for the brewing industry. In Ghana, maize is produced predominantly by smallholder poor farmers under rain-fed conditions. Under traditional production methods and rain-fed conditions, yields are well below their attainable levels – maize yields in Ghana average approximately 1.9 metric tons per hectare. However, achievable yields as high as 6 metric tons per hectare are possible, if farmers use improved seeds, fertilizer, mechanization and irrigation (MoFA, 2013). As an important commodity in Ghanaian diet, maize is used to prepare local and traditional dishes such as *banku*, *apkle*, *kenkey*, *and tuo zaafi*.

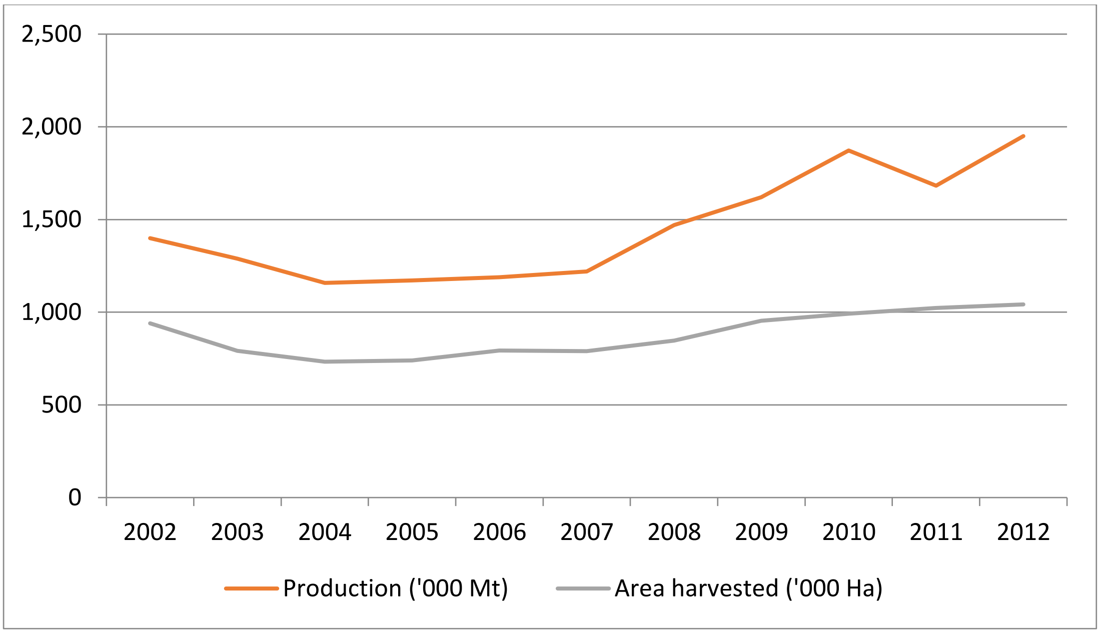

Figure1: Maize area and production trends in Ghana (2002-2012)

Source: Data on production and harvested area are from the Ministry of Food and Agriculture, Statistics, Research and Information Directorate (SRID, 2013)

1.4 Maize food losses

Domestic maize production seems to be meeting the local demand for human consumption. The maize supply in Ghana has been increasing steadily over the past few years with an average supply at 1.4 million MT over the period 2005-2010. Dzisi et al., (2007), identified field and post-harvest losses (PHLs) as the most important constraints limiting maize production in Ghana. They reported losses in the field and post-harvest sectors as 5-10% and 15-20% respectively. Obeng-Ofori and Amiteye, (2005), reported a 20% loss of an estimated total annual harvest of 250,000-300,000 tonnes of maize in Ghana, due to storage pests including *Sitophilus Zeamais*.

1.5 Food losses along maize production

Food loss and waste occurs throughout the food value and supply chain, from initial agricultural production down to final household consumption (Brian et al., 2013); Gustavsson et al., (2011). The losses incurred at each step vary depending upon the organization and technologies used in the supply chain. For example, as depicted in Figure 2, Hodges, et al., (2011), reported that, larger losses are incurred during drying, storage, processing and in transportation, particularly in less developed countries where the supply chain is less mechanized.

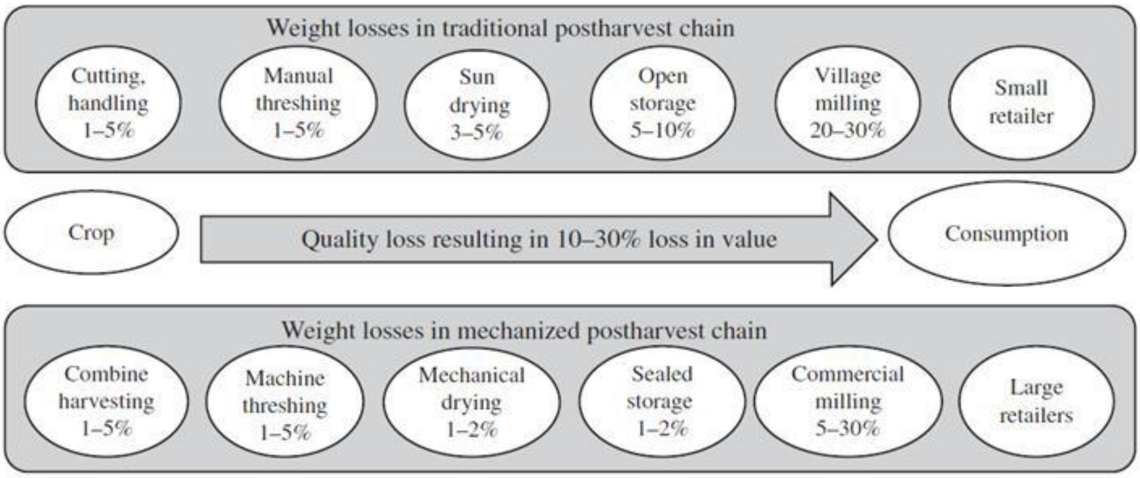

Figure 2: Traditional versus mechanized postharvest chain. Source: Hodges et al., (2011)

As rightly noted by Aulakh and Regmi (2013), consistent measurement of food losses is a necessary first step toward reaching the goal of reducing post-harvest losses. They however, reiterated that, no single and consistent framework exists which is used in the estimation of PHLs. The African Postharvest Losses Information System (APHLIS) according to Aulakh and Regmi (2013) is an attempt to provide a framework to address the need for a consistent estimation of PHLs. It has a regional focus and is designed to compute quantitative postharvest losses for cereals under different farming and environmental conditions. But it has mainly provided the countries of East and Southern Africa with cereal PHL figures (Hodges et al., 2010). The parameters used in the online calculator are also often old or based on studies conducted in other parts of the world. It as well does not include losses from processing (e.g. milling) or from quality changes. (Aulakh and Regmi, 2013). Rembold et al. (2011) also report some limitations to the calculator which need to be addressed to improve its accuracy. They propose generating more loss data at various stages along the post-harvest chain. Evolving correct policies for minimizing PHLs would therefore crucially depend on reliable and objective estimates of such losses at different stages (Basavaraja et al., 2007).

According to Hodges et al., (2010), most postharvest grain losses tend to occur close to the farm in Sub-Sahara Africa (SSA). Limited work though, has been conducted in the estimation of PHLs. Most of the published works available on PHL estimation for developing countries are FAO initiatives, based on questionnaire surveys (Aulakh and Regmi, 2013). However, Studies made to assess grain losses in Ghana over the years have focused on storage (Compton et al., 1998; Compton and Sherington, 1999), ignoring the field and post-harvest segment of the value chain which also contribute to the total loss of the crop. This report, therefore, investigates the role of traditional practices in maize production and its impact on food losses in the maize value chain, particularly, during harvesting and shelling

1.6 Stages for food losses in maize production

Maize grain losses contribute to food insecurity and low farm incomes not only in Ghana but also in other sub-Saharan African countries. Efficient post-harvest handling, storage and marketing can therefore tremendously contribute to social economic aspects of rural communities.

The losses are directly measurable in economic, quantitative, qualitative, (nutritional) terms. Economic loss is the reduction in monetary value of maize grain as a result of physical loss. Quantitative maize loss involves reduction in weight and therefore can be defined and valued. Qualitative loss although difficult to assess because it is frequently based on subjective judgments (like damage), can often be described by comparison with locally accepted quality standards (Magan and Aldred, 2007).

As stated above, food loss occurs at production, postharvest and processing stages in the food supply chain. Maize production in Ghana are modelled as mixed cropping, where maize is planted first and other crop such as cassava, cocoyam, yam and plantain are planted later The life cycle stages of maize in Ghana are described briefly in the following:

1.6.1 Agricultural Production

The "cultivation phase/stage" of the system includes:

- Land preparation (clearing)
- Planting (laying-out, tilling, planting)
- Weeding/farm maintenance
- Harvesting/transportation for off-farm activities:

1.6.2 Harvesting

Currently most of the maize grown in Ghana is harvested manually using a cutlass and transported from the farm through head carrying and by the use of vehicle, but few commercial farmers use combine harvesters. The harvested maize is transported to the house and is mostly stored on the husk in cribs. Depending on the variety, harvesting can be undertaken from 7-8 weeks after flowering when the vast majority of maize cultivars are physiologically matured. But harvesting can also be delayed depending upon the season of production.

1.6.3 Transport and distribution

Main transport routes for maize are from farm to house or storage site, from storage site to market from market to processing and from processing back to market.

1.6.4 Processing

In smallholder enterprises, all operations are done manually. Larger commercial processing centres use machines. A major processing stage of maize in Ghana is drying, this is normally done manually by on-farm sun drying on cobs and drying at home on open field after shelling, however this system is prone to theft, and interruption by rainfall thereby resulting in losses and poor quality of grains. In some villages in Ghana drying is achieved during storage by burning of firewood under cribs.

1.6.5 Storage

The quantity of grain produced in a season influences the nature of storage method and the duration of the storage period (Owusu, 1981). Maize storage in Ghana is predominantly in traditional cribs with cobs drying out gradually through natural ventilation. There is also the improved narrow crib which enhances faster drying and storage (Nicol et al, 1997). There are three main traditional storage systems based on type and location and these are; indoor, outdoor and underground systems (Osei-Akrasi, 1999). The indoor and outdoor structures are usually used to store both shelled and unshelled maize but the underground storage is for shelled maize and it is used in drier regions.

Thus, maize storage structures tend to be specific to a climatic zone and are constructed to meet the requirements of that particular area (Nicol et al., 1997). Small quantities of seed maize are usually stored indoors using calabashes, gourds and earthenware clay pots at the rural household level. On the large-scale maize is stored in jute sacks or bins in large warehouses after shelling, drying and treating with the recommended pesticides.

Many farmers store their maize cobs with the husk on, which does not significantly affect the rate of grain drying in cribs (FAO, 2007). Undehusked maize and grains on the cob are less susceptible to *S. zeamais, Tribolium sp*. and *Rhyzopertha sp.* attack than the shelled, but shelled maize suffers less damage from pest such as *Prostephanus truncatus* than maize stored on the cob (Meikle, 1998).

1.7 Aflatoxin contamination in maize

Maize, just as any other crop can be contaminated with storage fungi, some of which may develop as by-products of mycotoxins that can be harmful to animal and human health. Mycotoxins that develop from Aspergillus flavus, common post-harvest fungi in maize are called aflatoxins. These toxins are hazardous to animals and human health, and constitute a factor in economic losses in food production in the world (Lubulwa and Davis, 1994). Aflatoxin, which commonly affects maize, causes illness and even death when consumed in large quantities. According to WHO (2006), acute aflatoxicosis is an under-recognized and under-reported cause of liver damage; aflatoxin is a Group 1 human liver carcinogen. Low-level, chronic exposure is carcinogenic and has been linked to growth retardation, underweight, neurological impairment, immunosuppression and mortality in children (Strosnider et al., 2006). High levels of aflatoxins have been found in groundnuts and cereal grains in countries such as Gambia, Ghana, Guinea, Nigeria, Senegal, South Africa and Uganda. Kpodo, (1996), reported of high levels of aflatoxin in maize in Ghana and its related health concerns.

In 1991, World Health Organisation (WHO) explained that food-borne diseases create an enormous burden on the economies of developing countries and consumer costs include medical, legal, and other expenses, as well as absenteeism at work and school. Economic consequences as a result of rejection of exports and loss of credibility as trading partners have been reported. In Nigeria, the Food and Drug Administration destroyed aflatoxin-contaminated food worth more than US$ 200 000. The quantity of safe food required to replace contaminated food during the outbreak of acute aflatoxicosis in Kenya in 2004 was 166 000 tonnes for 1.8 million people over six months (WHO, 2006).

Contamination by afltoxins can occur both at pre-harvest and post-harvest. Aflatoxins infestation in maize starts in the field or during storage of the grains (Kumar et al., 2000), thus making the grains unwholesome for consumption. The predisposing factors of infection include; improper drying, high relative humidity and temperature, farmers' production practices, intercropping with aflatoxin infected grains, early and delayed harvesting and poorly constructed storage structures. Stress while crops are growing, insufficient drying, and poor storage practices also increase the likelihood that crops become contaminated (Wilson and Payne, 1994; Hell et al., 2008).

While aflatoxin itself is invisible and tasteless, its presence may be correlated with other attributes that facilitate or result from fungal growth, including physical damage to the protective outer layer of the kernel, discoloration, and compromised taste quality. Based on maize consumption patterns in Kenya and possible aflatoxin contamination levels of 20ppb, the population at risk of liver cancer in countries with high hepatitis B virus (HBV) infection rates could be 11 per 100 000 population per year (WHO, 2006). Given that maize is the primary staple grain for Ghanaians, accounting for 36% of total food caloric intake (Kirimi et al., 2011), even relatively low levels of exposure may have significant negative health effects (Shephard, 2008).

1.8 Objective of the study

The study examined post-harvest food losses of maize along the value chain in Ghana. Specifically this study looked at the following objectives which were to;

1. The role of traditional practices in maize production and its impact on food losses in the maize value chain, particularly, during harvesting and shelling
    - Identify potential causes of losses along the value chain
    - Estimates maize food losses during harvesting and shelling
2. Assess management practices adopted by farmers, long distance wholesale, market-based wholesale/retail traders at markets close to production and consumption centres in handling and storage of maize and how these practices relates to aflatoxin contamination
    - Determine the level of aflatoxin contamination of maize in the farm and markets.
    - Identify practices of farmers and traders and its impact on aflatoxin contamination

2 METHODOLOGY

2.1 Selection of study sites

One of the study areas, Ejura Sekyeredumase Municipality in the Ashanti Region of Ghana was selected because it is one of the leading maize producing areas in Ghana and also due to its strategic location. The municipality is located in the transition zone between the Northern and Southern zones of the country and has one of the largest maize market known as Ejura market in the sub-region. Wholesale traders or retailers from other regions in the country and even from neighbouring countries like Burkina Faso, Niger, Mali, Togo and Ivory Coast all buy maize from this market to sell. Maize samples for the aflatoxin test were collected from two major markets in Ghana- [1]Ejura market in the Ashanti Region and [2]Agbobloshie market in the Greater Accra region of Ghana. Maize sold in the Ejura market mainly come from farming communities such as *Kasei, Nokaresa, Nyamebekyere, Ashakoko, Yaabraso, Bemi* and others all in the Municipality. Wholesale traders (middlewomen/men) and retailers from Kumasi, Takoradi, Obuasi, Accra and other parts of the country.

The Agbobloshie market is the largest maize market close to consumers in Ghana. It is located in the Capital, Accra where the traditional food of the indigenes known as *kenkey* is prepared from maize. About 80% of maize sold in the market has its roots from the Ejura market.

2.2 Data collection and research instrument

The study was undertaken during the 2013 minor maize season. Two methods for data collection were employed: a survey to identify traditional practices used in maize production in the study area and direct field measurement to estimate losses particularly during harvesting and shelling.

After reviewing literature on recommended best practices in maize production and marketing, 2 sets of semi-structured questionnaires were developed to investigate empirically the practices used by farmers and traders in maize production and marketing respectively in the study areas. The questionnaire for the farmers sought information on farmer's household demographics and agronomic activities (e.g. type of land preparation, type of seeds planted, time of planting, planting method used, weeding practices, fertiliser application etc.); harvesting activities (e.g. time of harvest, criteria used to assess maize maturity, harvesting method and yield). Post-harvest management practices by farmers on drying, shelling, transportation, and storage were also considered. Traders' management practices on maize handling at the market centers as well as their storage practices were also investigated including traders' and farmers' perceptions or knowledge of contaminated maize and aflatoxins.

Face-to-face interview schedule was used to solicit responses for the survey questions. The questions were standardised to increase interviewer consistency (Fowler, 2002). Sampling spear, and sampling bags, weighing scales, tally counter to count grains for analysis, Mini GAC plus grain moisture analyser, stereo microscope to identify weevils and other insects, forceps, and High-Performance Liquid Chromatography (HPLC) system were used to collate data on aflatoxins levels in sampled maize food from the markets and farms. The

[1] Maize market close to maize producing areas or farms
[2] Maize market close to consumers. It is normally located in city centers

questionnaires were pre-tested before the actual survey to screen out the questions, ensure data verification and also allow enumerators familiarise with the questions.

To estimate shelling and harvest losses a Geographical Positioning System (GPS) tool, tape measure, weighing scales, tarpaulin, sampling bags, mark-out poles, and harvest and shelling data sheets were used to collate data on maize food losses using selected farmer's fields in the study area.

2.3 Survey sample

The target respondents were maize farmers in the study area. Though the municipality has 32 operational areas consisting of 19,000 maize farmers, 18 active operational or farming areas were selected with the help of the Municipal Agricultural Office. The 18 operational areas were reduced to 10 using the following criteria. Areas with low maize production (below 4 bags/ha) and has limited access to Agriculture Extension Assistants (AEAs) were eliminated and areas under the jurisdiction of one AEA were combined. This reduced the number of farmers to about 9,000. According to Okoth (2012), 10% sample size is normally considered optimal representation of the total target population for analysis. The target population were therefore further reduced to 900 sample size. However, by geographical or ecological location of farms (forest and guinea savannah), the target population were grouped into clusters. In all, 10 clusters made up of 134 communities were formed in the 10 operational areas selected. Random stratified sampling procedure (Harris and Lindblad, 1997) was used to select respondents in the clusters, aiming to ensure that, the final sample was a good representation of the different sub-category (farms within the same geographic or ecological zone). A final purposive selection of 150 maize farmers across the 134 communities in the 10 clusters was selected for the survey.

In accordance with the procedures proposed by the National Academy of Sciences (1978) for field investigation of losses, typical maize producing farms were selected in each geographical location for the assessment. The 10 clusters were sub-categorised into 3 zones defined by vegetation and topography of the area: forest area with inland waters; thicket and grassland and guinea savannah woodland. To make a good representation in terms of losses for the study area, a farm was selected in each area for the field loss assessment.

The maize traders in both markets were also put into clusters depending on their scale of business. Three clusters were formed in each market, Cluster 1- retailers who buy maize within the market's and sell to individuals who buy for their personal consumption. Such traders usually don't have storage facilities at the market; cluster 2 involved retailers who buy from wholesale traders and only sold to food processors, and millers. They usually have some storage facilities at the markets. Cluster 3 was made up of wholesale traders or middle-women/men who buy maize directly from farmers or bring maize from producing markets to sell at the consuming markets. Ten traders were randomly selected from each cluster at both markets. In all, 30 traders were selected from each market for the survey.

For the determination of aflatoxin contamination levels/presence, maize samples were harvested from three randomly selected farms each located in one of the 3 geographical or ecological locations for the analysis. Samples from traders for the analysis were also randomly collected from traders in each of the clusters at both markets.

2.4 Estimation of harvest and shelling losses

2.4.1 Estimation of maize produced

To estimate the total expected amount of maize produced, total farm size was measured using the GPS device. Three harvest areas of size 10m by 10m were randomly selected and pre-marked a month prior to harvest. This was to ensure farmers did not harvest the marked area before measurements were taken. Knowing the total area of a farm (m^2) and the average yield of shelled maize (kg) for the three plots of size (100 m^2), the total maize yield (kg) for each farm was estimated by using equation 1.

$$\text{Total maize produced on a farm (kg)} =$$

$$\frac{\text{Total measured area for a farm } (\mathrm{m}^2)}{Plot\ size\ (100\ m^2)} \times Average\ yield\ for\ the\ three\ plots\ (kg)\ \ldots\ldots\ldots\ldots \quad (1)$$

2.4.2 Estimating harvest losses

Adopting the methodology used by Carlson (2011), harvest losses experienced on three selected farms were estimated. Three plots of size 10m by 10m (100 m^2) each were randomly measured on the field after harvesting and gathering. Number of maize cobs identified within the specified areas were picked and recorded. The cobs were manually shelled and weight of maize grain was determined in each plot and the average weight recorded for each farm. Knowing the average maize grain which was not harvested over the 100 m^2 area, the total loss in terms of unharvest grains for the entire farm was then estimated by simple comparison. The percent harvest loss was then calculated using equation 2;

$$Harvest\ loss\ (\%) = \frac{A}{B} \times 100\% \qquad (2)$$

Where A = Total weight of unharvest or unpicked grains for a farm
B = Total weight of expected yield for a farm

2.4.3 Shelling loss estimation

All the maize harvested in the three farms and the municipality at large are shelled using mechanised maize shellers, powered by the Power Take Off (PTO) of a tractor (see Figure 3).

Figure 3: A mechanised maize sheller

Shelling loss was estimated based on losses due to unshelled maize on cobs and scattering. Using the method proposed by Harris and Lindblad (1978), random samples of cobs weighing 26 kg in total were taken and the grain shelled using the mechanised sheller in Figure 3. The procedure was replicated thrice in each farm. All the shelled grain was collected and weighed and a sample taken (sample 1). The grains left on the spent cobs were hand-stripped and weighed and a sample taken (sample 2). Moisture content of the two samples of grain was measured with a moisture meter. The percentage ratio of the hand-stripped grains to the total represented the percent loss due to maize grain left on cobs or unshelled maize.

Losses due to scattering and spillage, which occurred during shelling was evaluated separately by recovering scattered or spilled grains using a tarpaulin. The recovered amounts from the three shelling replications were weighed and the average weight recorded. The percentage ratio of the scattered grains to the total shelled grains represents the percent loss due to scattering.

2.5 Percentage usable proportion

Usable proportion after shelling in the respective farms were estimated using equation 3

$$Usable\ propportion\ by\ number = \frac{number\ of\ undamaged\ grains}{200} \times 100\% \ldots.\ (3)$$

2.6 Determination of aflatoxin contamination levels

The double tube sampling spear was used to randomly sample a maximum weight of 1.0 kg composite/aggregate grains from farmer's harvested grains, and grains stored at market centers. The samples in three replicates were each kept in sampling bags and brought to the Food and Post-harvest laboratory of the Department of Agricultural Engineering-KNUST, Kumasi and immediately put in a freezer at $0^{o}C$ until the test was conducted. Each replicate sample was made into three sub-samples of about 300g each, European Union (EU) standards (2003). Levels or incidence of aflatoxin presence in ground samples of about 25g for each sub-sample was determined by Afflatest-AOAC-2007 method and the average level calculated for the analyses. The High-Performance Liquid Chromatography (HPLC) system at the Aflatoxin Laboratory of the Department of Food Science and Technology, KNUST, Kumasi was used for the test. Moisture content determination of samples was determined using the grain moisture analyser. Insect infestation levels and grain damaged by insects and mould, in the collected maize samples were subjected to visual inspection by the use of a stereo microscope.

2.7 Data analysis and presentation

Quantitative data obtained from field loss investigation was recorded using a data sheet. The quantitative data collected with the semi-structured questionnaires and data sheets were analysed using Statistical Package for Social Science (SPSS) version 16 to provide descriptive statistics of the sample. Specifically, the farming and post-harvest management activities of the farmers were analysed using arithmetic means, and presented in tables.

3 FINDINGS

The results of the study focused on a description of the traditional practices used by maize farmers in the Ejura Sekyeredumase Municipality. Influence of these practices on maize food losses particularly during harvesting and shelling has also been presented. The result also focussed on aflatoxin contamination in maize (on-farm and at the market)

3.1 Personal characteristics of respondents

Table 1 presents an overview of the general characteristics of the respondents of the households that were surveyed. Due to the intensive labour or the drudgery associated with maize production, it was realised that majority of the respondents (64.7%) were males. This gives credence to the perception that, males dominate the production of maize while the marketing and trading is the preserve of women. Majority of the respondents (88%) were married with more than half of the households (81.4%) having family size ranging from 5 to 14 people. As a result, most households have access to costless labour for their farming activities. More than half of the household heads (81.34%) had only attended primary school. This may pose a challenge to their understanding and acceptance of modern practices in agriculture since education facilitates farmer's adoption of innovative technologies (Onemolease, 2001). With an ageing farming population (92% above age 30), and their low educational background, there is a high possibility of strong ethical and cultural belief in the way agriculture is practiced in the study area, and this can constrain the adoption of new methods for agriculture. This is corroborated by Basavaraja et al., (2007), who in their study observed a negative association between post-harvest losses with age and education of the farmers.

Table 1: Personal characteristics of respondents (n= 150)

Variables	Frequency	Percentages
Gender		
Male	97	64.7
Female	53	35.3
Marital status		
Married/cohabiting	132	88
Single/never married	5	3.3
Divorced/separated	6	4.0
Widowed	7	4.7
Educational Level		
None	67	44.67
Primary	55	36.67
Secondary	24	16.0
University	3	2.0
Other education	1	0.67
Age		
30 and below	12	8.0
30-50	106	70.7
50 and above	32	21.3
Household size		

4 and below	16	10.7
5-9	82	54.7
10-14	40	26.7
14 and above	12	8.0

Source: Field Survey, January, 2014

3.2 Respondent's household income and food security

The primary source of household income as indicated by the majority of the respondents (85.1%) is from the sale of their farm produce. According to Hertel and Rosch (2010), farming families may benefit from higher food prices as long as they earn more from their harvested crops than they spend on food. Higher earnings will also provide households more income to purchase food which they don't grow. Unfortunately, as it was observed from the survey, economic returns from maize farming activities in the area are very low with an average farmer with 1 ha land size earning between GHS 200 to 500 per annum. Such low incomes may be due to the rudimentary and inefficient farming practices used by the farmers resulting in poor harvest and low yields. However, majority of the respondents' (79.3%), indicated they do not experience food deficit in their households as they normally engage in mixed farming by cultivating other crops such as yam, cowpea, cassava, cocoyam etc to support household food needs. Approximately 21% of respondents suggested that they experience food deficit, and that it happens for a short time only - about 1 to 3 days- in a 30 day period. During the period of food shortage, purchasing of food was the common practice among households to address their food deficits. This is confimed by Hertel and Rosch (2010), who reported that, many smallholder farmers actually spend more on food than they earn from selling their harvested crops.

Table 2: Household income and food security of respondents

Variables	Frequency	Percentages
Source of household income		
Sale of farm produce	126	85.1
Petty trade	11	7.4
Livestock rearing	1	0.7
Salary work(e.g. teaching)	5	3.4
Service job (e.g. sewing)	3	2.0
Other	2	1.4
Household income (GHS*)		
< 200	54	36
200-500	90	60
> 5000	6	4
Household experience food deficit		
Yes	31	20.7
No	119	79.3
Number of days with lack of food a 30 day period		
1-3 days	21	67.7

4-10 days	4	12.9
Above 10 days	6	19.4

*Exchange rate as of January 2014; $ 1 = GHS 2.36
Source: Field Survey, January, 2014

3.3 Maize farming activities

The results in Table 3 show that, 62% of the respondents are smallholder maize farmers whose farm sizes were about 2 ha (5 acres). The study revealed that, majority of respondents (82%) interviewed use local varieties as their maize seed for planting. Such varieties have lower yield compared to improved varieties (Tengan et al., 2011). It was revealed that, though local varieties are more susceptible to insects and disease attacks, farmers still resort to the use of local varieties as seed materials because of the high seed cost of the improved varieties (GHS[3] 9 per kilogramme as of the time the survey). Among the improved varieties cultivated by some few farmers (18%), *Obatanpa*, was identified to be the mostly cultivated improved variety (see Table 3). According to Tengan et al., (2011), the *Obatanpa* maize variety is quality protein maize (QPM), white, open pollinated (OPV) and drought tolerant. It has a yield potential of 5.5 ton/ha, and recommended to be planted in the major season. However, the research showed that, 88.9% of farmers planted it during the minor season, and this could affect the yield potential.

From the study, it was realised that, 89.3% of the respondents relied solely on chemical fertilisers (NPK) for maize production, however, crop residues such as maize husk, maize cobs and stover are left on the field after harvesting and shelling. These decay with time and ploughed into the soil acting as fertiliser. The study also showed that, about 53.5% of the respondents use herbicides to control weeds. The use of fertilizers and other farm inputs such as herbicides are a major cost input, which increases the cost of maize production in the area.

Table 3: Farming activities of respondents (n=150)

Variable	Frequency	Percentage
Land size for maize cultivation		
Below 2 acres	11	7.5
2-5 acres	82	54.5
Above 5 acres	57	38.0
Type of maize seeds cultivated		
Local variety	123	82.0
Improve variety	27	18.0
Improved variety normally cultivated		
Obatanpa	24	88.9
Abelehe	1	3.7
Okomasa	2	7.4

Source: Field Survey, January, 2014

[3] $1 = GHS 2.36 as at January 2014 when the survey was conducted

3.4 Farmers harvesting and drying practices

The results in Table 4 reveal that, only 31.3% of the respondents' knew the maturity period of the maize. Majority of farmers (68.7%) used criteria such as dried tassels, drooping of cobs as sign of matured maize before harvesting. Harvesting is done by hand mainly by women and children. During this process, few maize cobs are lost through stovers. The losses at this stage are influenced by lack of supervision and experience of the harvester is also a factor.

The maturity period for most early to intermediate maize varieties is within 90-110 days, though extra-early varieties with maturity period of 80-85 days have also been developed (Tengan et al., 2011). The results in Table 4 indicates that majority of the farmers interviewed (92.8%), harvest their maize late beyond the maturity period. Late harvesting of maize during the minor season is a common practice in the municipality, in general. Crops left to dry in the field becomes more vulnerable to losses caused by several factors, including infestation by insect, pests, and damage by birds, scavenging animals such as cattle (a common situation in Ghana) and theft. Approximately 93% of respondents resorted to late harvesting to allow field drying of their maize. Cracking of maize with the teeth was also identified as one of the traditional practices of the farmers (79.5% confirmed this practice) in the study area to determine the dryness of their maize before harvesting.. It is impossible to determine an accurate moisture content using this method, effective methods such as the use of a moisture meter should be encouraged. During the minor season, majority of the farmers (64%), after harvesting, normally gather, shell, transport home, clean and sell However, depending on the economic situation of the farmer, some store and sell later as was confirmed by 30% of the respondents.

Table 4: Respondents maize harvesting activities (n = 150)

Variable	Frequency	Percentage
Criteria for determining maturity of maize before harvest		
Known maturity period	47	31.3
Assumed maturity based on	103	68.7
1. Dried tassels		
2. Drooping of cobs		
Days after planting (DAP) before harvesting		
90 -120 DAP	10	7
More than 120 DAP	140	93
Method of moisture content determination before harvest		
Cracking maize with teeth	93	79.5
Using moisture meter	2	1.7
Mere observation	20	17.1
Other	2	1.7

Source: Field Survey, January, 2014

3.5 Respondent's maize shelling activities

The results presented in Table 5, show that majority of farmers (97%) mostly use a mechanised maize sheller for maize shelling. These mobile machines are driven by the tractor PTO when it is in operation (see Figure 2). In the minor season, it is normally used for on-farm maize shelling. It is an improvised multi-operated sheller that simultaneously dehusks and shell maize cobs. Though the process does not allow farmers to select out cobs that are insect or mould damaged and has the potential to reduce the quality and market value of the grain, farmers rely on it because the process is quicker and far less tedious compared to the manual approach. 88% of the respondents however, indicated losses are encountered by the use of this method due to inefficiency of the shelling machine.

Table 5: Shelling activities of respondents (n=150)

Variable	Frequency	Percentage
Method for maize shelling		
Beating maize in sacks with sticks	2	1.3
Use of a Sheller	146	97.3
Shelling by hand	2	1.3.0
Experience of losses using sheller		
Yes	132	88
No	18	12

Source: Field Survey, January, 2014

3.6 Means of transportation of harvested maize

The results of Table 6 shows that, majority (90.4%) of respondents uses the trailer of a tractor as a means for transporting their maize from farm to the house or market. 5.4% resort to the use of motor tricycles. Approximately 38% of respondents indicated experiencing losses during transportation. These losses are mainly as a result of delay in transportation of produce due to bad road network linking farms to households and market particularly during the major season. The mean distance to the nearest market was estimated to be 7.40 km which requires an average time of 1.38 hours by truck to reach there from farthest farm in the study area. Respondent spend an average of GHS[4] 60 on transportation of maize from farm to the market.

Table 6: Transportation of harvested maize to household or market

Transportation of harvested maize to household or market

Variable	Frequency	Percentage
Method of transportation		
By head porters	2	1.7

[4] $1 = GHS 2.36 as at January 2014 when the survey was conducted

Use of trucks	104	90.4
Use of motor tricycle	6	5.2
other	3	2.6
Experience losses due to delay in transportation		
Yes	56	37.6
No	93	62.4

Source: Field survey, January 2014

3.7 Storage practices

Once the harvested maize grain is sufficiently dry and cleaned, it should be put in storage. The study showed that, majority of farmers (64%) indicated that, during the minor season they sell their maize after harvest, but, keep a bag or two for household consumption. However, 36% indicated that, they store and sell when prices are more favourable or when they need money for their household up keep. For easy marketing, majority of the farmers (66%) stored their maize using open weave sacks made of polypropylene. Storage of maize is normally within 1 to 3 months period (70%) and is normally done at the household level in rooms. If maize grains are stored in open-weave sacks for periods exceeding 3 months, then there is a danger that insect infestation may cause significant damage thereby increasing losses. Most farmers (66%) indicated that, they protect their stored maize from insects mainly by the use of chemicals such as Actellic. More than half of the respondents (76%) determine moisture content of the maize before storage but only 42 % intermittently check moisture content of their stored maize. Cracking maize with teeth (76%) is often the method respondent use in determining moisture content of the stored maize. This method can be hardly relied on, the actual moisture content can be very difficult to established using this method. Other methods include; pushing their hand through the bagged maize (20%) and sometimes by mere observation (4%). These practices can result in storage loss which was confirmed by 36% of respondents.

Table 7: Storages practices

Variable	Frequency	Percentage
Storage of maize for future use, household consumption or sale		
Yes	150	100
No	0	0
Storage method		
Bulk storage (storage on cob)	51	34
Bag storage	99	66
Length of storage		
< 1 month	20	13.3
1-3 months	105	70
till the next planting season	25	16.7
Moisture content determination before storage		
Yes	114	76

No	36	24
How moisture content of maize is determined before and during storage		
cracking maize with teeth	87	76.3
pushing hand through	23	20.2
mere observation	4	3.5
Structure used for maize storage		
cribs or barns	41	27.3
Room	106	70.6
on platform in the open	1	0.7
cooperative warehouse	2	1.3

Source: Field survey, January 2014

3.8 Level of losses from the farmer's perspective

Figure 8 indicates level of losses experience by farmers at each stage of the production chain. During harvesting majority of the farmers indicated experiencing losses below 5 kg, percentage of farmers that experience losses below 5kg are in decreasing order of drying, shelling, storage, harvesting and transportation. However percentage of farmers that experience losses above 50 kg bag are in the order of harvesting, storage, shelling, transportation and drying. This indicates that from the farmers own perspective losses are experience more during harvesting than any other stage. This can largely be attributed to inefficiencies in the harvesting method employed.

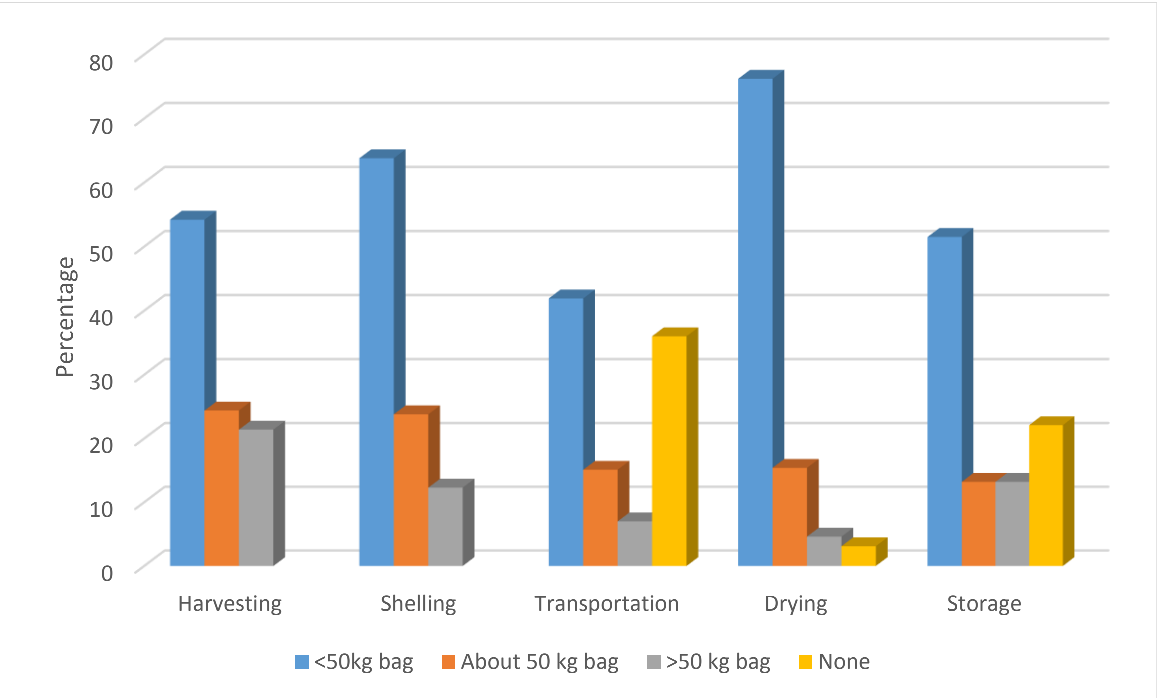

Figure 4: Losses Experienced along the value chain from the Farmers Perspective

3.9 Process/supply flow chart

The figure below shows the supply flow chart of maize in the study area

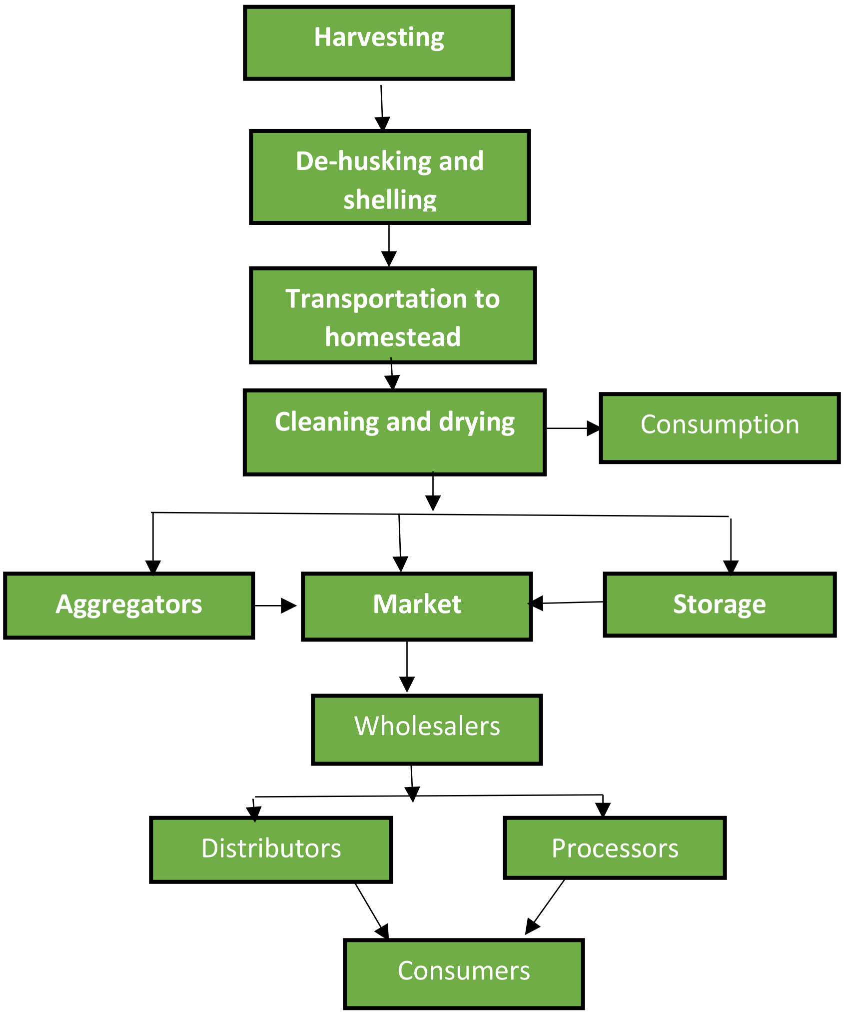

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Figure 5: Supply flow chart of maize in the study area

3.10 Maize production cost and income

The table below shows the cost involve in maize production. The base scenario was cultivation of 8 ha of land which yielded 33 bags of maize. Total cost involved in the production activities was GHS 1,209.00 ($512.28) Cost of Post-harvest activities was GHS 203.00 ($86.02) this constituted; cost of packaging material (27%), shelling cost (43%) and transportation cost (30%). Total revenue generated from the sale of the 33 bags of maize was GHS 1,980.00 ($838.98). Total profit of GHS 771.00 ($326.69) was generated. Base on this information it can be deduced that profit per bag of maize is GHS 23.00 ($9.75).

Table 8: Breakdown of Production cost and income

Production Activities	**Cost (GHS)**	**Cost ($)**
Total cost of land preparation using tractor	279.00	118.22
Manual land preparation (	326.00	138.14
Cost of fertilizer	225.00	95.34
Labour cost for top dressing	47.00	19.92
Price of chemical	73.00	30.93
Cost of labour for chemical application	49.00	20.76
Harvest cost	210.00	88.98
Sub-total A	**1,209.00**	**512.29**
Post-harvest activities		
Cost of packaging material	54.00 (27%)	22.88
Shelling cost	88.00 (43%)	37.29
Cost of transportation	61.00 (30%)	25.85
Sub-total B	**203.00**	**86.02**
Total cost (A+B)	**1,412.00**	**598.31**
Price of a bag of maize	60.00	25.42
Total number of bags	33.00	13.98
Total revenue	**1,980**	**838.98**
Total profit	**771.00**	**326.69**

Source: Computed from survey data 2014

3.11 Maize residues generated

Maize residues are mostly generated on farm where de-husking and shelling are done. Estimation of the amount of crop residue available was done using the residue to product ratio (RPR). Residue to Product Ratio (RPR) is simply the ratio, by mass, of a crop's residue to the actual product. An RPR of 1 means the amount of residue of the particular crop equals the amount of product obtained from the same crop. Field work was conducted to determine RPRs of maize stalk, husk, and cob in the municipality (see table 9). Using equation 1, waste generated for 1 ha and 2 ha farms were estimated (see table 9). The total maize residues generated in the municipality were estimated to be 75,645.84 tons/yr. Since shelling is done on farm in the study area, waste generated are left on field and are not used. The generated residues can be used to generate heat for drying of maize

$$\text{Residue in wet tons (w)} = \text{RPR} \times \text{Weight of crop produced (tons)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Table 9: Estimation of maize residues generated

Residue type	RPR	I ha farm/yr (tons)	2 ha farm/yr (tons)	Amount of residues/yr (tons) in the Municipal
maize stalk	2.68	3.16	6.32	63,751.84
maize husk	0.25	0.30	0.59	5,947.00
maize cob	0.25	0.30	0.59	5,947.00
Total residues		**3.75**	**7.50**	**75,645.84**

Source: computed from field data 2014

3.12 Management practices of maize traders at Ejura and Agbogbloshie markets

Approximately 97% of traders interviewed from both markets had their education not exceeding primary school level, with 57% selling maize for 10years and above. The analysis also revealed that only traders in Agbogbloshie market performed some basic post-harvest management activities such as winnowing or cleaning, pest control and intermittent exposure of grains to the sun to control weevil infestation (see Figure 6). This is a common phenomenon in consumer markets as traders may likely have their stock kept for long before they are sold out. However, approximately 83% of respondents at both market centers did not practice any management practices to control storage pest.

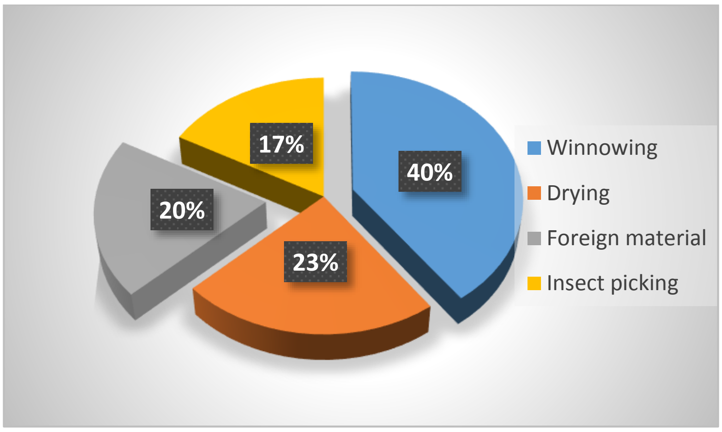

Figure 6: Post-harvest activities at the market center

Inspection of storage facilities of traders at both market centers revealed that, 50% of the traders use some temporal wooden stalls to store their maize. The structures were identified to be poorly constructed with no openings for ventilation, thereby, making the stored maize susceptible to insects and fungi infestations. Approximately 23% resort to leaving their produce in the open after a day's trade, and covered with tarpaulin at night and rainy days. This practice exposes maize grains to humid conditions, thereby, increasing the likelihood of fungi infestation or mould growth. This is confirmed by Christensen and Mirocha, (1976), who reported that, the growth of *A. flavus* increases dramatically when relative humidity increases above 85%. They further stated that, in this range, even a small increase in moisture can be very influential in terms of increasing the risk of aflatoxin contamination. It was, however, discovered that 27% of traders store their maize in ordinary rooms or warehouses. Bagged maize in these stores is put on wooden platform to prevent contact with the floor. This has the potential of reducing or preventing contamination from insect and fungi infestation. Hell (1997) reported that maize stored in baskets and platform stores showed low mean aflatoxin levels.

Assessment of grains from both markets revealed some level of mould and weevil infestation. While the level of infestation was low at Ejura market with only 10% of the traders whose samples were assessed having signs of weevil and mould infestation, grains from Agbogbloshie market were heavily infested with weevils. Evidence of high weevil infestation was identified among 83% of maize traders whose samples were assessed at the Agbobloshie market. As rightly noted by Bekele et al., (1997), high level of insect infestation of stored maize are due to poor storage facilities, improper storage methods, poor food distribution, poor transportation facilities and insects pest resistibility to chemicals used to store the maize. The other reasons are climatic conditions which are conducive for insect activity. All these state factors were clearly identified at the two markets. The infestation of maize grains by insects makes it more susceptible to aflatoxin contamination. This is confirmed by a study by Lamboni and Hell, (2009), who reported that, storage pests, in particular *Cathartus quadricollis* and *Sitophilus zeamais*, have been shown to play an important role in the contamination of foods with fungi, especially those that produce toxins. Edusei *et al.*, (2004), also stated that, damage done by insects encourages infection by bacterial and fungal diseases through transmission of their spores.

3.13 Moisture content of sampled maize

The moisture contents of maize samples from the Ejura market were found to be in the range of (12.5% to 13.4%). This is close to the recommended moisture content (13%) for effective maize storage proposed by (Christensen and Kaufmann, 1974 cited in Garuba et al., 2011). The lower moisture content observed can be attributed to late harvesting, a common practice by farmers in the study area during the minor season where they leave the maize to dry on the field. The harvested maize normally ends up in the Ejura market. Recorded moisture content of maize samples collected from the Agbogbloshie market was between 13.1 to 16.6%. The increase in moisture content can be attributed to reabsorption of moisture by grains due to the humid conditions created by the use of tarpaulin at night and when it rains. The recorded high moisture content of maize samples at Agbogbloshie market correlates with the high insect infestation observed. This is corroborated by Shejbal (1997), who reported that, grains of moisture content above 13% are likely to be attacked by pest and moulds.

3.14 Trader's knowledge or perception of contaminated maize

All the respondents (farmers and traders) indicated they have no knowledge of aflatoxin contamination. However, 57% perceived contaminated maize as that which is infested by insects such as weevils. Approximately 23% also perceived contaminated maize as one with mould growth,10% perceived contaminated maize as one with discoloration, and 10% believe maize with high moisture content above the recommended storage moisture of 13% is contaminated (see Figure 7).

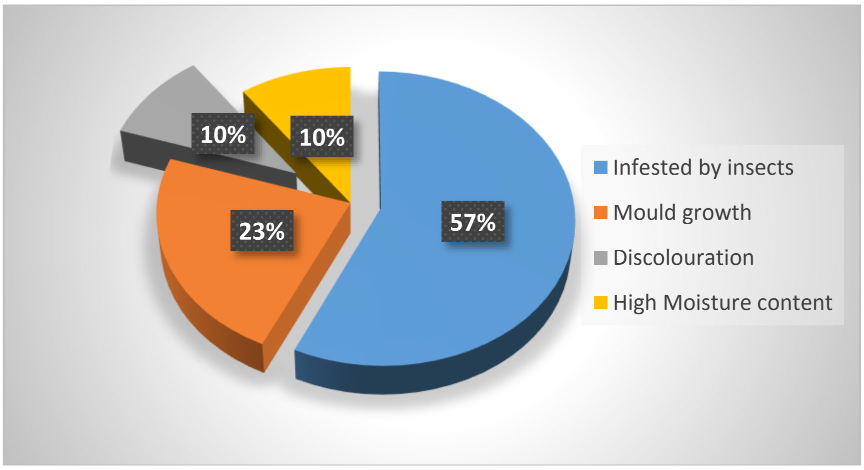

Figure 7: Traders perception of contaminated maize

Poor management practices are principally the cause of contamination, and contribute to the vulnerability of maize to fungi infections, which can further lead to aflatoxin contamination. But interestingly, majority (63%) of the respondents believed that, consumption of contaminated maize will have no health effect on humans, mainly due to the rigorous cooking maize food products are subjected to before eating.

4 FIELD LOSS ASSESSMENT

The characteristics of the farms are presented in Table 10.

Table 10: Geographical characteristics of selected farms

Farm	Topography	Geographical location	Maize variety	Duration on farm
1	Flat land with moist conditions	Forest	*Obatanpa*	Aug – Jan
2	Slopy land terrain	Thicket and grassland	*Obatanpa*	Aug – Jan
3	Flat land with dry conditions	Guinea savannah	*Adelehe*	Sept – Jan

Source: Field survey, January 2014

4.1 Estimation of expected maize plant population and yield

Average maize plant population for a 100m^2 area on the farms were determined to be 230, 418 and 378 plants for Farm 1, 2 and 3 respectively. The actual farm sizes were measured with a GPS device (see Table 11). The total maize plant population for the farms were, therefore, estimated to be 34,604, 44,241 and 68,342 plants respectively. Knowing the total weight of maize expected for each farm, and the average bush weight of a bag of maize determined to be 158kg, expected number of bags of maize for each farm was estimated (see Table 11).

Table 11: Estimated maize plant population and yield

Farm	Average plant population per 100m^2	Farm size (m^2)	Plant population	Average weight (kg) of shelled maize for 100m^2	Total expected weight of maize (kg) from farm	Expected number of bags	Actual number of bags recorded
1	230	15,045	34,604	15.33	2,306.90	14.56	10
2	418	10,584	44,241	21.67	2,293.20	14.47	9
3	378	18,080	68,342	8.89	1,607.11	10.13	8

Source: Computed from field data on loss assessment, January 2014

4.2 Harvest loss due to unpicked maize on field

Most smallholder farmers in developing countries harvest their maize crops by hand and thresh them later. Maize cobs are plucked from the plant then gathered simultaneously. The harvested cobs are placed directly on the ground which results in contact with the soil, leading to moisture uptake, staining from the soil and the transfer of fungal spores that leads to fungal growth and mycotoxin production.

From Table 12, the results show that, during harvesting, some percentage of maize cobs was left on field as a result of the inefficiency of the manual harvesting method. Lodging or falling off plants may have also accounted for high losses as harvesters then to over -look such plants during harvesting, particularly, when fatigue and tiredness set in, and they have to continually bend over to pick cobs. Knowing the total expected yield for a farm and the amount of grains that were not harvested, the loss due to unpicked grains were estimated to 1.37%, 2.22% and 2.14% for farms 1, 2 and 3 respectively. Having strategically selected a farm from each geographical location in the municipal, the average loss due to unharvest maize grains anticipated for the municipality was determined to be 1.91% (see Table 12).

Table 12: Harvest losses

Farm	Weight of shelled maize for 100m^2 (kg)	Estimated average weight of unpicked maize grains for 100m^2 on farm	Estimated total weight of unpicked maize grains (kg) in a farm	Expected total weight of maize (kg)	Harvest loss (%)
1	15.33	0.21	31.59	2,306.90	1.37
2	21.67	0.48	50.80	2,293.20	2.22
3	8.89	0.19	34.35	1,607.11	2.14
Average					**1.91**

Source: Computed from field data on loss assessment, January 2014

The variations in losses in the respective farms may have been due to multitude of reasons: variety of maize cultivated, maize plant population on the farm, method of planting adopted by farmer (e.g. broadcasting or row planting), amount harvested for consumption and sale during the milking stage of the maize, pest and insect attacks on maize, duration on farm before harvest. This is collaborated by WABS (2008), who concluded in their study, that due to constrains faced by smallholder farmers in Ghana, in accessing production inputs such as improved seeds, agro-chemicals, fertilisers among others, smallholder farmers continue to use traditionally unproductive methods that result in low productivity and high post-harvest losses resulting in low annual yields and incomes.

Farms 1 and 2 had the highest yield - 1.53 ton/ha and 2.17 ton/ha respectively due to an improved maize variety (*Obatanpa*) cultivated. According to Tengan et al., (2011), the *Obatanpa* maize variety is characterised with yield potential of 5.5 ton/ha. Farm 3 recorded the lowest yield of 0.89 ton/ha. This could be attributed to the use of the local variety (*Adelehe*) which is a potential low yield variety as compared to the improved variety *Obatanpa*.

4.3 Quantitative shelling loss

Shelling was done on the farm one week after harvesting using a mechanised shelling machine which operated using the PTO of a tractor. The capacity of shelling machine was determined to be 0.56kg/s. Moisture content of grain during shelling was determined to be 12.9%. Average percentage shelling loss due to unshelled maize on cobs was estimated to be 6.44% for the three selected farms. Losses due to scattering during shelling were also estimated at 0.17% on the average for the three farms (see Table 13).

Table 13: Quantitative shelling loss

Farm	Losses due to unshelled maize on cobs (%)	Scattering losses (%)
1	5.32	0.22
2	9.8	0.14
3	4.20	0.16
Average	**6.44**	**0.17**

Source: Computed from field data on shelling loss assessment, January 2014

4.4 Percentage usable proportion

The qualitative loss assessment consist of insect damage and the presence of Aflatoxins in maize grain as seen from table in appendix A, after shelling percentage usable proportion by number was determined to be 93%, 94.5% and 98.5% for farms 1, 2 and 3 respectively This indicates that low percentage of the grain experienced sheller damage, it is also an indicative that, number of grains with insect and mould damage was low.

4.5 Proximity analysis of maize grain

The grains in farms 1, 2 and 3 had crude protein value of 10.7%, 8.9% and 8.4% respectively. The differences can be attributed to the differences in maize varieties. From the result it was observed that Obatanpa which is an improved variety of maize had higher crude protein than Adelehe (a local variety). Carbohydrate levels were also determined to be 64.08, 67.35 and 70.45 respectively. Crude fibre, ether extract, ash content and moisture content were also determined (see appendix B).

4.6 Aflatoxin contamination

Aflatoxins are produced as metabolites by the *Aspergillus Flavus* and *Aspergillus Parasiticus* and exist in nature world widely. The common aflatoxins are B1, B2, G1 and G2. Among these mycotoxins, the aflatoxin B1 is of most toxicity followed by G1, the toxicities of B2 and G2 are relative weak (Yang and Rong 2011). According to the European Food Safety Authority (EFSA), (2007), aflatoxins are genotoxic and carcinogenic and can cause both acute and chronic toxicity in humans. Aflatoxins are most commonly found in cereals (EFSA, 2013). Types of aflatoxin determined from sampled maize grains from both farms and markets were G2, G1, B2 and B1. Grains from the farms showed either a zero or below limit of aflatoxins (limit of detection of G2, G1=1.5ng/g and B2, B1=0.8ng/g). However average values of 50.234ng/g, 70.102ng/g and 30.943ng/g were respectively obtained from maize samples taken from the Ejura market. Higher levels of aflatoxin, 677.480ng/g, 101.748ng/g and 4831.942ng/g were however, obtained from samples taken from the Agbobloshie market. Aflatoxin contamination cannot be completely eradicated from foods, however, exposure through food should be kept as low as possible. According to Food and Drugs Authority (2011), level for aflatoxin in milk-stage of maize acceptable for human consumption is 0.5 ng/g, when dried is 20 ng/g and 100ng/g for feeds for cattle, swine and poultry. From the result obtained it can be seen that aflatoxin contamination is very high beyond the recommended levels. It is interesting to note maize with the high levels of aflatoxins are been consumed by humans and may have dire health implications on consumers. Pier (1991) has reported that, aflatoxins have been implicated in sub-acute and chronic effects in humans. These effects include primary liver cancer, chronic hepatitis, jaundice, hepatomegaly and cirrhosis through repeated ingestion of low levels of aflatoxin. It is also considered that aflatoxins may place a role in a number of diseases, including Reye's syndrome, kwashiorkor and hepatitis as well as affecting the immune system. There is a high risk of Hepatitis B and Hepatitis C carriers developing liver cancer when they are exposed to aflatoxin (Williams et al., 2004). Aflatoxin contamination has also been linked to micronutrient deficiencies in animals (Williams et al., 2004). From the result, it can be noted that, aflatoxin contamination is likely to increase along the value chain of maize, from the farm to the market.

5 CONCLUSIONS AND RECOMMENDATIONS

Food loss poses tremendous problems for national food systems. This study therefore, sought to investigate traditional practices adopted by maize farmers and traders and its impact on food loss in the maize value chain particularly during harvesting and shelling. The study

Per the survey and field investigation, it was revealed that, production practices adopted by majority of the farmers in the study area were inefficient and rudimentary. It was found out that improved seed use is low, as is fertilizer use and husbandry methods are lacking as are post- harvest handling and storage methods. Non-conventional planting method such broadcasting instead of row planting, field drying, late harvesting of maize, biting or cracking of maize grains to assess it dryness, physiological maturity determined by the use of signs such as dried tussles, drooping of cobs etc instead of date of planting were some identified practices used by farmers in the study area. Mechanised, maize shellers used for on-farm shelling of harvested maize were also largely inefficient resulting in high loss of grains.

All, these practices directly or indirectly have the potential to create imbalances in the maize food value chain. Through harvesting and shelling, effect of the identified practices on maize food losses was ascertained by direct field loss assessment in three typical farms purposively selected to represent each of the geographical/ecological zones identified in the municipality.

Estimated average maize loss due to inefficient harvesting and shelling was determined to be 1.91% and 6.7% respectively. Presuming pre-harvest losses due to pest and diseases, feeding from scavenging animals and non-germination is 1.45%. This brought the total production losses to 10.06%. This represents an average maize food loss of 153 kg/ha per the estimated average yield of 1.53tons/ha from the field loss assessment. In economic terms, a farmer loses a bag of maize for every hectare of maize harvested. By large, it can be inferred that, maize food loss in the municipality for the 2013 production season can be estimated as 3,185 tons given the provisional production figure of 31,659 tons.

Majority of farmers in the study area were smallholder farmers with average farm size of 2 ha. This implies, per the price[5] of a bag of maize at the time of the study, farmers in the municipality were likely to have their profit margins cut by GHS 120 ($50.85) per annum due to post harvest losses. Availability of loss food can give farming households the opportunity to earn more from their crops and able to have sufficiency in household food consumption. It can also have immediate and significant impact on farmer's livelihoods.

Field drying, late harvesting of maize, biting or cracking of maize grains to determine it dryness, were some identified practices used by farmers in the study area. Harvested maize is also sometimes heaped and left on the field for several days due to unavailability of shelling machines. The study further revealed that, unsold maize grains are normally stored in wooden stall but some are sometimes left in the open after a day's trade and covered with tarpaulin at night and rainy days.

These practices expose maize grains to insect infestation and fungi infection. This was invariably confirmed by the study. Sampled maize grains for analysis from the markets were infested with mould growth, weevils and some had high moisture content. These conditions make the grains susceptible to aflatoxin contamination. Types of aflatoxin determined from sampled maize grains were B1, B2 and G2, G1. Grains from the farms showed either absent or below limit of detection of aflatoxins. However total values of 50.234ng/g, 70.102ng/g and 30.943ng/g were respectively obtained from samples taken from the Ejura market with higher levels of aflatoxin, 677.480ng/g, 101.748ng/g and 4831.942ng/g recorded for samples taken from the Agbobloshie market. There is clear indication that, the level of aflatoxin contamination recorded is very high and beyond the recommended level of 20ng/g for human consumption.

Interestingly, all the respondents, both farmers and traders had no knowledge of aflatoxin contamination and it causes. Moreover, 63% of traders from both markets believed that consuming contaminated maize will have no health problems for consumers since food products from maize such as *Kenkey, banku* etc are normally cooked before eaten.

It is clear that, aflatoxin contamination in maize is likely to increase through the channels of distribution from the farm up to the market centers. Human consumption of aflatoxin contaminated foods due to unavailability of safe foods renders the population more susceptible to the consequent adverse health effects

Strenuous effort must therefore be made to reduce food losses along the maize value chain especially in the post-harvest stage. Farmers and traders must therefore be encouraged to;

1. Adopt effective drying methods such as using concentrated solar tents and use of mechanised dryers in the study area.
2. Use improved harvesting techniques, proper handling of maize grains, and proper management practices.

[5] Average price for a bag of maize was GHS 60 as of the time of the study

3. Improve on the inefficiency of the mechanised maize shelling machine
4. Use proper storage structures and practices.
5. Educate and encourage to adopt management practices that reduce the incidence of aflatoxin contamination in the field and in the market.

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7 APPENDICES

7.1 APPENDIX A

Table 14: Estimation of maize plant population: Linear planting

Farm	Plot	Number of rows in 10m width	Number of hills in row3	Number of hills in row 6	Avg. Numb. of plants in 6th&3rd Row	Spacing between rows(cm)	Spacing between hills(cm)
1	A	9.00	7.00	11.00	25.00	100.00	57.00
	B	12.00	14.00	14.00	18.00	100.00	62.00
	C	9.00	15.00	16.00	27.00	100.00	61.67
	Average	**10.00**	**12.00**	**14.00**	**23.00**	**100.00**	**60.22**
2	A	12.00	16.00	14.00	32.00	95.33	63.33
	B	11.00	21.00	20.00	37.00	110.00	60.50
	C	10.00	17.00	19.00	44.00	100.00	62.00
	Average	**11.00**	**18.00**	**17.67**	**38**	**101.78**	**61.94**

Table 15: Estimation of Maize Plant Population: Non Linear planting

Farm	Plot	Quadrant	Number of hills	Number of plant	Avg. Spacing(cm)
3	A	1	26.00	35.00	77.67
		2	24.00	30.00	79.33
		3	19.00	25.00	58.33
		Average	**23.00**	**30.00**	**71.78**
	B	1	20.00	36.00	65.00
		2	24.00	44.00	63.00
		3	12.00	18.00	53.33
		Average	**19.00**	**33.00**	**60.44**
	C	1	24	50	56.67
		2	26	47	50.33
		3	16	23	61.67
		Average	**22**	**40**	**56.22**
		Average for the farm	**21**	**34**	**62.81**

Table 16: Maize yield Estimation

Farm	Plot	Quadrant	No. of standing maize plant(X)	No. of lodged/fallen maize plants(Y)	No. of cobs/heads sampled(X+Y)	Weight of maize cob harvested(kg)	Total weight of shelled grains
1	A	1	6.00	12.00	18.00	2.15	1.80
		2	5.00	18.00	23.00	2.90	2.45
		3	12.00	10.00	22.00	2.70	2.30
		Average	**8.00**	**13.00**	**21.00**	**2.58**	**2.18**
	B	1	5.00	16.00	21.00	1.15	0.90
		2	14.00	6.00	20.00	0.75	0.60
		3	6.00	14.00	20.00	1.15	0.95
		Average	**8.00**	**12.00**	**20.00**	**1.02**	**0.82**
	C	1	9.00	18.00	27.00	0.90	0.70
		2	4.00	19.00	23.00	1.55	1.30
		3	5.00	27.00	32.00	1.80	1.45
		Average	**6.00**	**21.00**	**27.00**	**1.42**	**1.15**
		Average for farm	**7.00**	**15.00**	**23.00**	**1.68**	**1.38**
2	A	1	25.00	18.00	43.00	1.50	1.20
		2	17.00	17.00	34.00	1.15	0.92
		3	21.00	5.00	26.00	2.20	1.80
		Average	**21.00**	**13.00**	**34.00**	**1.62**	**1.30**
	B	1	43.00	8.00	51.00	3.80	3.25
		2	20.00	19.00	39.00	1.95	1.65
		3	34.00	9.00	43.00	2.55	2.15
		Average	**32.00**	**12.00**	**44.00**	**2.77**	**2.35**
	C	1	52.00	5.00	57.00	2.45	2.10
		2	20.00	11.00	31.00	2.30	1.90
		3	21.00	12.00	33.00	3.15	2.60
		Average	**31.00**	**9.00**	**40.00**	**2.63**	**2.20**
		Average for farm	**28.00**	**11.00**	**40.00**	**2.34**	**1.95**
3	A	1	26.00	9.00	35.00	1.10	0.85
		2	14.00	16.00	30.00	0.90	0.70
		3	7.00	18.00	25.00	1.30	1.00
		Average	**16.00**	**14.00**	**30.00**	**1.10**	**0.85**
	B	1	31.00	5.00	36.00	0.60	0.45
		2	35.00	9.00	44.00	0.95	0.80

	3	8.00	10.00	18.00	0.60	0.45
	Average	**25.00**	**8.00**	**33.00**	**0.72**	**0.57**
C	1	45.00	5.00	50.00	0.75	0.60
	2	41.00	6.00	47.00	1.35	1.05
	3	15.00	8.00	23.00	1.55	1.25
	Average	**34.00**	**6.00**	**40.00**	**1.22**	**0.97**
	Average for farm	**25.00**	**9.00**	**34.00**	**1.01**	**0.80**

Table 17: Harvesting loss assessment

Farm	Plot	Number of cobs/heads	Weight of maize cobs(kg)	Total weight of shelled grains(kg)
1	A	7	0.3	0.21
	B	7	0.15	0.1
	C	8	0.4	0.31
	Average	**7.33**	**0.28**	**0.21**
2	A	25	0.85	0.62
	B	16	0.6	0.41
	C	17	0.55	0.41
	Average	**19.33**	**0.67**	**0.48**
3	A	12	0.2	0.19
	B	11	0.25	0.21
	C	14	0.2	0.16
	Average	**12.33**	**0.22**	**0.19**

Table 18: Quantitative Shelling Loss Assessment

Farm	Weight of shelled maize	Mc of maize grain (%)	Weight of shelled maize at 15% Mc	Weight of maize grain hand stripped from unshelled cobs (kg)	Weight of maize hand stripped from unshelled cobs at 15% Mc	Percentage loss due to unshelled maize (%)	Weight of scattered maize grain (kg)	Weight of scattered maize at 15% Mc	Percentage loss due to scattering of maize	Weight of shelled maize/bag (kg)	Number of bags obtained
1	19.20	10.70	20.74	0.85	0.893	4.31	0.038	0.04	0.20	169.20	**10**
	17.6	15.60	17.28	0.75	0.75	4.34	0.05	0.05	0.27	171.90	
	15.2	12.40	15.68	1.10	1.13	7.21	0.032	0.03	0.19	168.30	
Avg.	**17.33**	**12.90**	**17.9**	**0.90**	**0.95**	**5.32**	**0.04**	**0.04**	**0.22**	**169.80**	
2	16.20	11.62	16.84	1.59	1.65	9.79	0.016	0.017	0.10	160.30	**9**
	18.31	14.30	18.46	1.80	1.81	9.80	0.035	0.035	0.19	164.34	
	15.45	15.14	15.42	1.51	1.51	9.79	0.020	0.020	0.13	150.29	
Avg.	**16.65**	**13.69**	**16.91**	**1.63**	**1.66**	**9.80**	**0.024**	**0.024**	**0.14**	**158.31**	
3	19.10	11.40	19.91	0.82	0.85	4.26	0.0289	0.0301	0.15	149.02	**8**
	16.45	10.90	17.24	0.67	0.70	4.06	0.0226	0.0269	0.16	145.50	
	18.10	11.40	18.87	0.77	0.80	4.24	0.0331	0.0345	0.18	146.75	
Avg.	**17.88**	**11.23**	**18.67**	**0.75**	**0.78**	**4.20**	**0.028**	**0.031**	**0.16**	**147.09**	

NOTE. Weight of unhusked maize used in each shelling section is 26 kg

7.2 APPENDIX B

AFLATOXIN LABORATORY

Department of Food Science and Technology
College of Science. KNUST, Kumasi.
Email: aflalab.knust@gmail.com

Certificate of Analysis

Submitted Date: 03 – 03 – 14 ***Report Date: 07 – 04 – 14***
Client's Name: Energy Centre, KNUST ***Test Type:*** Proximate Analysis
Samples: Maize ***Method Used:*** AOAC 2005

Proximate Analysis	**NUT A**	**NUT B**	**NUT C**
% Crude Protein	10.7	8.9	8.4
% Crude Fibre	2.22	2.25	1.65
% Ether Extract	6.0	5.50	4.00
% Ash Content	2.00	2.00	1.50
% Moisture Content	15.00	14.00	14.00
% Carbohydrate	64.08	67.35	70.45

*woa**

Signed
Laboratory Analyst/ Manager

DEPT. OF FOOD SCIENCE & TECHNOLOGY
COLLEGE OF SCIENCE
K.N.U.S.T.
KUMASI, GHANA

AFLATOXIN LABORATORY
Department of Food Science and Technology
College of Science, KNUST, Kumasi.
Email: aflalab.knust@gmail.com

Certificate of Analysis

Submitted Date: *03 – 03 – 14*
Client's Name: Energy Centre, KNUST
Samples: Maize

Report Date: *31 – 03 – 14*
Test Type: Total Aflatoxin
Method Used: AFLATEST- AOAC - 2007

Sample ID	Type of Aflatoxin (ng/g)				
	G2	G1	B2	B1	TOTAL
EYA	<LOD	<LOD	absent	<LOD	<LOD
EYB	<LOD	<LOD	<LOD	absent	<LOD
EYC	<LOD	<LOD	<LOD	<LOD	<LOD
NE1A	absent	absent	absent	absent	absent
NE1B	<LOD	<LOD	absent	absent	<LOD
NE1C	<LOD	<LOD	<LOD	<LOD	<LOD
NE2A	<LOD	<LOD	<LOD	<LOD	<LOD
NE2B	<LOD	<LOD	<LOD	<LOD	<LOD
NE2C	<LOD	<LOD	<LOD	<LOD	<LOD
AG1	<LOD	absent	23.564	653.916	677.480
AG2	<LOD	<LOD	10.498	91.250	101.748
AG3	26.302	1670.888	133.856	3000.896	4831.942

*woa**

Notes

⇒ *LOD = Limit of Detection (G2, G1 = 1.5ng/g ; B2,B1 = 0.8ng/g)*

Signed
Laboratory Analyst/Manager

DEPT. OF FOOD SCIENCE & TECHNOLOGY
COLLEGE OF SCIENCE
K.N.U.S.T.
KUMASI, GHANA

7.3 APPENDIX C

7.3.1 Field work

7.3.2 Poor road networks to farms