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Effects of practices of maize farmers and traders in Ghana on contamination of maize by aflatoxins: Case study of Ejura-Sekyeredumase Municipality

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Contamination of maize by aflatoxins is of major concern to governments and the international community because high degrees of aflatoxin in food render the food unsafe for human consumption. The disposal of such foods also constitutes an economic loss in food production. This paper reports the findings of a study conducted during the 2013 minor maize farming season in Ejura-Sekyeredumase Municipality in the Ashanti region, and in Agbobloshie market in the Greater Accra Region of Ghana. The study was to investigate management practices employed at the market level and on farms by maize traders and smallholder farmers, respectively, and their impact on aflatoxin contamination. Purposive sampling was used to select 150 farmers from maize farming communities across 10 cluster zones based on geographical location of farms within the municipality. Maize traders were also selected from a market close to maize farms and a market close to consumers for the study. In all, 30 traders were randomly selected from each market. Maize samples were collected from both markets and selected farms to determine the presence and level of aflatoxins using the Vicam Aflatest immunoaffinity column method. The study revealed that, farmers and traders adopt practices that expose maize grains to aflatoxin contamination. These include: use of farmer-saved seed stock as planting material; delayed harvesting, heaping harvested maize cobs on the field; planting by broadcasting method, use of hand dipping and teeth cracking method to determine dryness of maize, use of wooden stalls with no proper ventilation for maize storage at market centres and temporal storage in the open using tarpaulin resulting in heat build-up and moisture re-absorption. Types of aflatoxin determined from sampled maize grains were G2, G1, B2 and B1. Grains from the farms showed below detection limit at 1 ppb of aflatoxins. However total values of 50.234, 70.102 and 30.943 ng/g were, respectively obtained from three composite samples taken from Ejura market. A similar occurrence was observed at Agbobloshie market, where higher levels of 677.480, 101.748 and 4831.942 ng/g were detected in composite samples analysed. All respondents had no knowledge of aflatoxin contamination and it causes. Moreover, 63% of traders from both markets believed that, consuming contaminated maize have no health implications for consumers as food products from maize are normally cooked before consumption. In conclusion, the study reveals that, practices of farmers and traders has direct effect on maize quality. It was noted that, aflatoxin contamination of maize is likely to increase from the farm through markets and ultimately compromise the health of consumers. Farmers and traders need to be encouraged to adopt best practices in maize production and marketing to ensure food safety of the final consumer. Education on aflatoxin and its health implications must also be given the necessary attention.

Key words: Maize, traders and farmers practices, aflatoxins contamination, Ghana.

INTRODUCTION

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 is a source of 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. The economic importance of maize and its role in ensuring food security in Ghana cannot be over emphasized. Annual production has been more than 1,000,000 MT since 2000, averaging 1,772,300MT over the period 2009 to 2012 (MoFA, 2013). The maize market in Ghana is dominated by several small-scale traders, with a greater proportion being women. Five main participants in the maize trade may be identified: the farmer/seller, the local assembler, the commission agent, the long distance wholesaler and the market-based wholesaler/the market-based retailer (Obeng et al., 1990).

Post-harvest activities such as drying and storage are among the key areas along the maize value chain that is of critical importance to small-holder farmers/traders in Africa. On-farm storage and storage of produce by small-scale traders in Africa, represents 75-85% of national storage (Pother and Hotchkisss, 1995). However, due to ineffective storage practices adopted by small-holder farmers and traders, some level of grain losses due to insect infestation, mould growth and discolouration, contamination by aflatoxins, re-wetting and germination of grains is usually encountered. According to Addo et al. (2002), major storage techniques utilised by small-holder producers in Western Africa vary greatly, but include on-field, open storage, jute bags, polyethylene or polypropylene bags, raised platforms, conical structures with thatched roofs and giant woven baskets. Moreover, drying of maize by small-holder farmers is normally done either in storage or while the crop is on the field. According to Kaaya et al. (2006), delay field drying of maize could result in serious grain losses during storage. Platform drying, which raises the maize off the ground for longer-term drying, was however, reported to be associated with losses of up to 3.5% in Zambia (Rembold et al., 2011).

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* and common post-harvest fungi in maize are called aflatoxins. These toxins are hazardous to animals and human health, and constitute a factor in economic loss 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.

In 1991, World Health Organisation (WHO) explained that, food-borne diseases created an enormous burden on the economies of developing countries, and consumer costs included; 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 also 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 a six months period (WHO, 2006).

Contamination by aflatoxins 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. According to Wilson and Payne (1994); Hell et al. (2008), 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 and storage practices as well as stress induced while crops are growing.

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 (Hoffmann et al., 2013). Based on maize consumption patterns and possible aflatoxin contamination levels of 20 ppb, the population in countries with high hepatitis B virus (HBV) infection rates could be at risk of liver cancer at 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).

In light of the discussion above, this study was

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undertaken to assess management practices adopted by farmers, and traders in handling and storage of maize and its impact on aflatoxin contamination.

MATERIALS AND METHODS

Selection of study sites

The survey on farming practices was undertaken in Ejura Sekyere-Dumase Municipality in the Ashanti Region. Maize samples for the aflatoxin test were collected from two major markets in Ghana Ejura market (Maize market close to maize producing areas or farms) in the Ashanti Region and Agbobloshie market in the Greater Accra region of Ghana (Maize market close to consumers. It is normally located in city centers).

The rationale for selecting Ejura Sekyeredumase Municipality was because it is one of the leading maize producing areas that accounts for more than 60% of maize produced in Ghana. About 60% of the labour force in the Municipality also engaged in agriculture, and maize is the main crop cultivated. Strategically, the Municipality is located in the transition zone between the Northern and Southern zones of the country and has one of the largest maize markets in the sub-region. The Ejura market is a major maize 'producing' market. Maize sold in this market mainly comes from farming communities such as Kasei, Nokaresa, Nyamebekyere, Ashakoko, Yaabraso, Bemi in the Municipality. Wholesale traders (middlewomen/men) and retailers from Kumasi, Takoradi, Obuasi, Accra and other parts of the country, as well as, from neighbouring countries like Burkina Faso, Niger, Mali, Togo and Ivory Coast all buy maize from this market.

The Agbobloshie market is also amongst the largest maize markets located 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 and Techiman market.

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 practices of farmers and traders used in maize production and marketing respectively. Maize samples collected from selected farms and markets were later tested for the incidence or presence of aflatoxins.

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 (type of land preparation, type of seeds planted, time of planting, planting method used, weeding practices, fertiliser application etc.); harvesting activities (time of harvest, criteria used to assess maize maturity, harvesting method and yield) as well as post-harvest management practices by farmers on drying, shelling, transportation, and storage. Traders' management practices on maize handling at the market centres, as well as, their storage practices were also investigated. The traders' and farmers' perceptions or knowledge of contaminated maize and aflatoxins were also investigated.

Face-to-face interview script 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 grains from the selected markets and farms.

Survey sample of respondents

The target respondents were maize farmers and traders in the selected study sites. The maize farming areas in the Municipality were put into 3 cluster zones based on geographical or ecological location of farms (forest, thicket and grassland, and guinea savannah). One hundred and fifty (150) maize farmers were purposively selected across 134 communities in the three cluster zones for the survey based on their farming activities and production output.

Maize traders in both markets were also put into clusters depending on quantity of bags handled and storage method practiced. Three clusters were formed in each market, Cluster 1-retailers who buy maize (<10 bags) within the market's and sell to individuals who buy for their personal consumption. Such traders usually do not have storage facilities at the market and may store the few bags in the open, covering at night with tarpaulin. Cluster 2 involved retailers who buy maize (10– 50 bags) from wholesale traders and only sell to food processors, and millers. These were classified as contract traders. Contract traders have storage facilities at the markets, and will only store at the request of their customers from a few days to a maximum of 4 weeks. Cluster 3 was made up of wholesale traders or middlewomen/men who buy maize (>50bags) directly from farmers or bring maize from producing markets to sell at the consuming markets. They sometimes own storage facilities or store their maize at warehouses close to the market. In all, 10 traders were randomly selected from each cluster, bringing the total number of traders selected for the survey to 30.

Collection of maize smples and aflatoxin analysis

Collection of maize samples was done in accordance with the process recommended by the FAO for maize collection for aflatoxin analysis as reported by Njapau (2008). Specifically, multiple samples from randomly selected parts of each farm or market cluster zone were combined to produce a representative 3-kg composite sample. A maximum weight of 1-kg grains from the composite was sampled from each farm in the three locations, and market cluster zones for the analysis. Maize samples from the farms were collected before harvesting. The samples were kept and transported for analysis in paper bags to control moisture content. The analysis for aflatoxin levels was done at the Aflatoxin Laboratory of the Department of Food Science and Technology, KNUST, Kumasi. Moisture content of maize samples was determined using a grain moisture analyser, while the presence of insect infestation and mould was determined using forceps, a stereo microscope and visual inspection.

Extraction and clean-up

A mixture of ground maize (25 g) with 5 g of sodium chloride and 125 ml of methanol/ deionized water (70:30) was blended at high speed for 2 min and filtered through a fluted filter paper. The extract (15 ml) was diluted with 30 ml of deionized water and filtered through a1.0 µm microfiber filter. In reference to Reiter et al. (2010), the diluted extract (15 ml) was passed through Vicam Aflatest immunoaffinity column (IAC), which was washed twice with10 ml deionized water. Aflatoxin was eluted from the IAC with 1 ml HPLC grade methanol and 100ul of the eluent was injected into the HPLC.

HPLC determination

A Cecil-Adept Binary Pump HPLC coupled with Shimadzu 10AxL fluorescence detector (Ex: 360 nm, Em: 435) with Phenomenex HyperClone BDS C18 Column (150 x 4.60 mm, 5 um). The mobile phase used was methanol: water (40:60, v/v) at a flow rate of 1 ml/min with column temperature maintained at 40°C. To 1 L of mobile phase were added 119 mg of potassium bromide and 350 ul of 4 M nitric acid (required for postcolumn electrochemical derivatisation with Kobra Cell, R-Biopharm Rhone. Aflatoxin Mix (G_1, G_2, B_1, B_2) standards were prepared from Supelco® aflatoxin standard of 2.6 ng/µL in methanol. Calibration standards were prepared by spiking 25 g blank maize matrix with 2.6, 13, 52, 78 and 104 ppb. The correlation coefficient (R^2) of the standard curve using spiked samples for each toxin was greater than 0.974. Recovery was greater than 77% at 26 ppb of total aflatoxin of spiked sample. LOD (Limit of Detection) was established at 1 ppb.

Data analysis and presentation

The data was analysed using Statistical Package for Social Science (SPSS) version 16 and Microsoft excel. The data were subjected to simple descriptive and inferential statistics.

RESULTS AND DISCUSSION

Personal characteristics of farmers

Majority (62%) of the respondents interviewed were smallholder farmers with an average farm size of 2 ha. Majority of the farmers (71%) interviewed were aged between 30-50 years with a dominance male population of about (65%). Average households had family sizes from 5 to 9 members. They usually assist in farming activities such as planting, weeding, harvesting etc, implying reliable and constant access to labour for farm work. Out of the 150 farmers interviewed, 45% had no formal education and 36% had their education up to the primary school level. This has the potential of impeding farmers understanding of aflatoxins infestations, its causes, implications and measures to minimize its infestation since education facilitates farmers' adoption of innovations (Onemolease et al., 2005).

Practices of maize farmers in the study area

Majority (62%) of the farmers were smallholder farmers. From the survey, it was realised that farmer-saved seeds was the common planting material used every season. This reflects an over reliance on the use of farmers own maize seed varieties. These are more susceptible to insect and disease attacks, and have a lower yield compared to improved varieties (Tengan et al., 2011). Among the key factors that influence farmer's choice of seed material was cost. Cost of seeds per kg for improved varieties such as *Obatanpa, Akomasa, Abelehe etc.* was GHC 9 ($1 = GHS 2.36 as at January 2014 when the study was conducted). This made majority of farmers (82%) rely on their own seed stock for planting material. Among farmers who cultivated improved varieties, 85% preferred *Obatanpa* to other varieties due to its drought tolerant characteristics and yield potential of 5.5 ton/ha. Though it is recommended to be planted in the major season, most of the farmers planted it in the minor season, disregarding the effect time of planting could have on the yield potential. This was confirmed by an estimated average yield of 1.5 ton/ha (Estimated yield obtained during field investigation of maize food losses in the study area) as opposed to the 5.5 ton/ha that could potentially be realised. Harvesting maize in the study area is usually done by women and children through manual means. The study reveals that, majority of farmers (69%) did not harvest based on the physiological maturity period of the planted maize. Consequently, they employ traditional practices like observing the dried tassels of cobs and drooping of cobs as a sign of maturity before harvesting. Other traditional practices used by the farmers to determine the dryness of their maize was by cracking/biting with their teeth. These techniques are not accurate, and therefore, harvested maize may still have high moisture content, thereby making the grains highly susceptible to aflatoxin contamination (Hell et al., 2008).

Late harvesting of maize during the minor season was identified as a common practice in the study area. Though, late harvesting may expose maize grain to diseases and pest attack, thereby increasing quantitative and qualitative loss of maize, approximately 93% of farmer's interviewed practice this method. With mechanical drying perceived to be very expensive, farmers resort to this practice as the best method in drying their maize grains in the minor season since most often there are no rains during this period. Extended field drying of maize could result in serious grain losses during storage (Borgemeister et al., 1998; Kaaya et al., 2006) and as such, harvesting immediately after physiological maturity is recommended to mitigate the likelihood of aflatoxin infestation (Hell and Mutegi, 2011). Kaaya and Kyamuhangire (2006), observed that, aflatoxin levels increased by about 4 times by the third week, and more than 7 times when maize harvest was delayed for 4 weeks in Uganda.

The study also reveal that, farmers sometimes leave the harvested maize on the field for a couple of days or weeks before shelling and transporting home or to the market. According to Hell and Mutegi (2011), leaving the harvested crop in the field prior to storage promotes fungal infection and insect infestation. Udoh et al. (2000) reported that, this is a common practice in Africa, and is often due to labour constraints, and the need to let the crop dry completely prior to harvest.

Management practices of maize traders at Ejura and Agbogbloshie markets

Approximately 97% of traders interviewed from both

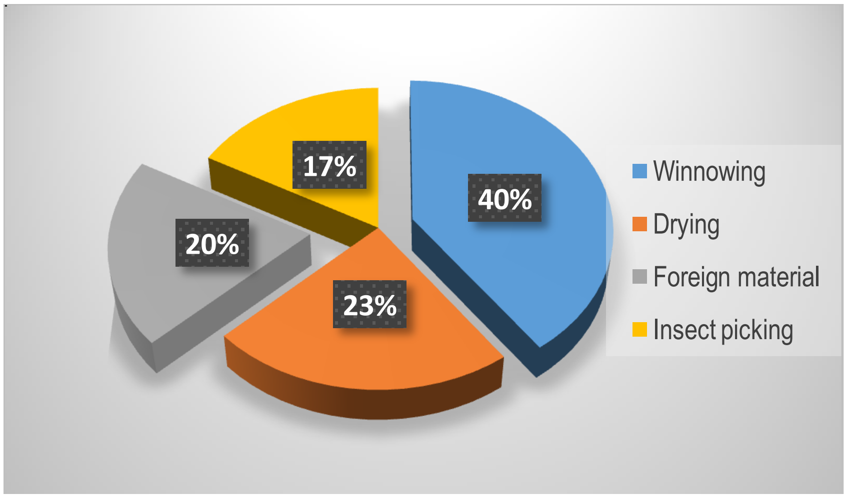

Figure 1. Post-harvest activities at the market center.

markets had their education not exceeding primary school level, with 57% trading in maize for 10 years 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 (Figure 1). 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.

Inspection of storage facilities of traders at both market centers revealed that, 50% of the traders use 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 (high relative humidity) 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 conducted 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 reported that, damage done by insects encourages infection by bacterial and fungal diseases through transmission of their spores.

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. The harvested maize

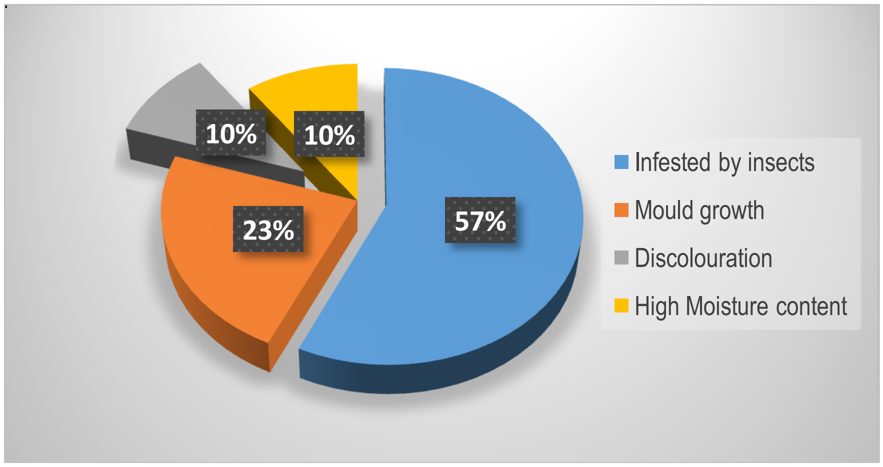

Figure 2. Traders perception of contaminated maize.

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 high moisture content recorded can be attributed to reabsorption of moisture by such 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.

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 grains infested by insects such as weevils. Approximately 23% also perceived contaminated maize as one with mould growth,10% perceived contaminated maize as one with discolouration, and 10% believe maize with high moisture content above the recommended storage moisture of 13% is contaminated (Figure 2).

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.

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. They reported that, they are most commonly found in cereals. Types of aflatoxin determined from sampled maize grains from both farms and markets were G2, G1, B2 and B1 (Table 1). When estimating aflatoxin levels, the values that were less than the limit of detection (LOD) were substituted with LOD.

Aflatoxin levels determined on maize grains sampled from the three farms were recorded as below detection (Limit of detection of G2, G1=1.5 ng/g and B2, B1=0.8 ng/g) limit of 1 ppb (<LOD @1ppb). However, as presented in Table 1, total values of 50.234, 70.102 and 30.943 ng/g were respectively obtained from maize samples collected from the Ejura market. Moreover, higher levels of aflatoxin, 677.480, 101.748 and 4831.942 ng/g were obtained from samples taken from the Agbobloshie market.

The high occurrence of aflatoxins detected in sampled maize from both markets could be attributed to, but not limited to the following reasons: delayed shelling after harvesting which occurs due to inadequate and unreliable services of mobile sheller operators. Farmers thereby, resort to heaping harvested cobs (Figure 3) on the farm sometimes for one to two weeks before shelling is done.

Many of the sheller operators tend to be in a hurry to move to other farms during the period and, therefore, do not take time or allow farmers to separate the moulded or infested cobs (see Figure 4) from the good ones before they are fed into the shellers. Thus, shelled grains after the shelling process becomes a mixture of both good and aflatoxin infested grains. Other potential reasons are; delay in transporting grains home or to the market due to

Table 1. Levels of aflatoxins in sampled maize from markets.

Sample ID	G2	G1	B2	B1	Total
EJ_1	19.132	<LOD	10.844	20.258	50.234
EJ_2	10.698	18.863	15.196	25.345	70.102
EJ_3	<LOD	<LOD	12.178	18.765	30.943
AG_1	<LOD	Absent	23.564	653.916	677.480
AG_2	<LOD	<LOD	10.498	91.250	101.748
AG_3	26.302	1670.888	133.856	3000.896	4831.942

LOD= limit of detection (G2, G1= 1.5ng/g; B2, B1= 0.8ng/g). R^2 = 0.974. Maximum limit for safe consumption of aflatoxin contaminated maize is 20ng/g (FDA, 2011). $AG_{1,2,3}$ and $EJ_{1,2,3}$ represents composite maize samples from the three clusters zones at Agbobloshie and Ejura markets respectively.

Figure 3. Heaped maize cobs on the field waiting for shelling (Source; Field photograph).

Figure 4. An infested cob among heaped cobs on the field. (Source: Field photograph).

Table 2. Summarised results of parameters determined.

Parameter	Farm	Ejura market	Agbobloshie market
Moisture content (%)	<13	12.5 – 13.4	13.1 – 16.6
Weevil infestation	Absent	Low	High
Presence of mould	No	Yes	Yes
Aflatoxins present	Yes	Yes	Yes
Level of aflatoxins	<LOD	>LOD	>LOD

LOD= limit of detection (G2, G1= 1.5 ng/g; B2, B1= 0.8 ng/g).

poor road networks, and use of rickety vehicles which often break down; prolong storage under unhygienic and unfavourable storage environments at the market places and poor storage practices (storage in the open) which leads to high infestation by weevils, and urine of rodents. Re-wetting of the grains is likely to occur under such storage conditions.

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. The results of this study, however, showed that, aflatoxin contamination levels recorded on sampled grains was very high and beyond the recommended level. This study suggests that consumers of maize from the study areas are at a risk of exposure to dire health implications such as aflatoxicosis. Pier (1991) 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 play 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 (*ibid*).

The results as summarised in Table 2 show that, aflatoxin contamination is likely to increase along the value chain of maize, from the farm to the market. Therefore, farmers and traders lack of knowledge on the subject and non-existing monitoring protocols by the appropriate authorities is a major concern.

Conclusions

The study sought to use a case study approach to investigate the effect of practices of farmers and traders in maize production and handling at the farm level and market centers, respectively, on contamination of maize by aflatoxins in selected farming communities and markets. The findings suggest that pre-harvest practices adopted by farmers in the study areas among the sample pool, as well as, post-harvest handling methods were inappropriate and inefficient. These practices exposed maize grains to insect infestation, fungi infection and increased levels of aflatoxin contamination, which could have significant economic implications for the farmers/traders and health implications for the final consumer.

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 before the cereal reaches the final consumer. In the interest of food security and safety of consumers, who have a right to safe food as declared by the Universal Declaration of Human Rights, 1948,farmers and traders need to be educated and encouraged to adopt management practices that reduce the incidence of aflatoxin contamination in the field and during handling at market centers. This will make maize grains less susceptible to aflatoxin infestation thereby ensuring the safety of the final consumer.

Conflict of interests

The author(s) did not declare any conflict of interest.

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