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Journal of Stored Products and Postharvest Research

*Full Length Research Paper*

# Aflatoxin management in Northern Ghana: Current prevalence and priority strategies in maize (*Zea mays* L)

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**The production and utilization of maize have increased tremendously across all regions of Ghana in recent times. However, aflatoxin (AF) contamination in grain maize has remained a critical food safety concern. The study was conducted in 6 districts in the Upper East and Upper West regions of Ghana to assess farmers' knowledge on AF, and determine AF levels under farmer storage conditions. A total of 240 respondents from 24 communities were covered using a structured questionnaire, and 240 maize samples were obtained for AF analysis. All the samples were collected within 2 to 6 weeks after harvest for AF analysis using the Indirect Enzyme Linked Immunosorbent Assay method. Overall, 78% of the respondents were aware of AF although majority (68.1%) did not perceive AF as a major food safety issue. Aflatoxin prevalence ranged from 0.011 to 308 ppb with wide variations occurring within and across communities and districts. Though no clear pattern was established, AF prevalence in Garu-Tempane and Wa-West districts was marginally higher compared to counterpart districts. Grain samples from Nabdam district showed the least AF levels with all samples recording safe limits of <4 ppb. Overall, 78.8, 92.9 and 95.4% of the samples recorded safe limits of <4, <20 and <30 ppb, respectively. There is need to scale up proven pre-and-post-harvest technologies to the mainly small-holder growers to keep AF within safe limits. The Food and Drugs Board, the main food regulatory agency in Ghana, should be strengthened to conduct periodic testing for AF in grain markets in addition to food safety education.**

**Key words:** Aflatoxins, food safety, maize, on-farm storage, consumer perception.

## INTRODUCTION

Maize (*Zea mays* L.) has become an important staple food crop in all parts of Ghana. Currently, maize-based cropping systems have become dominant in the drier northern savanna areas of Ghana where sorghum and millet were the traditional food security crops. According to the Statistics Research and Information Division (SRID, 2013) of the Ministry of Food and Agriculture (MoFA) of Ghana, maize is the most cultivated on 1,023,000 ha of arable land compared to rice (197,000 ha), millet (179,000 ha), sorghum (243,000 ha), cassava (889,013 ha), yam (204,000 ha) and plantain (336,000 ha). Currently, Ghana is a net-importer of maize even

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though it has great potential to be self-sufficient and a net-exporter. Per capita consumption is estimated to be 44 kg/person/year (FAOSTAT, 2013). After harvest, the produce is stored on cob in traditional grain silos or shelled into grain and stored in jute and poly-sacs with or without protection. Aflatoxin, a group of highly toxic mutagenic and carcinogenic poly-ketide compounds, contamination in grain maize however still remains a critical food safety concern to consumers in developing world. Maize and groundnuts are suitable substrates for AF contamination (Richard and Abbas, 2008). The fungi responsible for the production of toxins are mainly *Aspergillus flavus*, A. *parasiticus* and A. *nomius* (Stoloff, 1977). Generally, AF contamination can occur at both pre-and post-harvest stages of food production. Poor agricultural practices during planting, insect damage, drought, harvesting, drying, transportation and storage are predisposing factors. This may however vary between geographic locations, including commodity susceptibility to fungal invasion during production to storage. During storage, toxin production depends on kernel moisture and temperature relations as well as storage method and duration (Saleemullah et al., 2006; Ramesh et al., 2013). Toxin production is highest at 20 to 18% grain moisture and stops at below 13% moisture content. The optimum temperature range for AF production is 25 to 35°C, although production can occur over a wider range of temperatures (11 to 40°C). Therefore, in storing cereals for prolonged period in warm humid conditions, adequate steps should be taken to minimize the risk of AF contamination (Saleemullah et al., 2006). Paz et al. (1989) reported that delayed drying could lead to rapid increase in AF from 14 ppb at harvest to 93.8 ppb, if maize is not dried for 5 days after harvest. A study in Benin (Hell et al., 2003) found that post-harvest contamination with AF in groundnut increased when harvesting took more than 5 days and drying was delayed.

In general, AF are among the most potent of carcinogens found in staple foods such as groundnuts, maize and other oil seeds. Carry-over sources from animal products such as milk and eggs are additional source of risk to humans (Kana et al., 2013). Aflatoxins are stable in foods and resistant to degradation under normal cooking procedures, and therefore difficult to eliminate once produced. Aflatoxins can be acutely and chronically toxic to humans, causing acute liver damage, onset of tumours and teratogenic effects (Stoloff, 1977; Bryden, 2007; Khlangwiset et al., 2011). Chronic dietary exposure to low doses is a known risk factor for liver cancer and may affect protein metabolism and immunity, thus worsening infectious diseases and malnutrition (Williams et al., 2004). Aflatoxins are generally classified into sub-types, the most important ones are $B_1$, $B_2$, $G_1$ and $G_2$ often distinguished by their colour blue or green under ultraviolet light. In addition, aflatoxin $M_1$ and $M_2$ are hydroxylated metabolites of AF $B_1$ and $B_2$. In particular, aflatoxin $B_1$ is considered the most potent and classified by the International Agency for Research on Cancer (IARC) as a class-1 human carcinogen (IARC, 1993). Several studies have demonstrated that AF exposure is linked with growth impairment in both animals and humans (Bryden et al., 2007; Khlangwiset et al., 2011). Aflatoxin $B_1$ is reported to inhibit nucleic acid and protein synthesis by modifying lipid metabolism and the mitochondrial respiratory pathway, where an excessive accumulation of lipids may occur in the liver. It is also associated with several other health conditions including jaundice, decrease levels of serum vitamin A and E and even death (Jolly et al., 2007). Due to these adverse effects, many countries have placed strict regulatory control measures, especially with regard to tolerance levels in food, feed and fodder. For instance, the EU maximum tolerable limit for $AFB_1$ and total AF is 2 and 4 ppb, respectively. In the United States of America, the Food and Drugs Administration (FDA) action levels for aflatoxin in human food, animal feed and animal feed ingredients are: 0.5 ppb (AF $M_1$) in milk for human consumption, 20 ppb in food, groundnut, maize, groundnut products and feed for immature animals, and 100 to 300 ppb for various feed ingredients for specified types and ages of animals (FDA, 2011).

Therefore, aflatoxin contamination in maize and groundnut has been considered as a major non-tariff barrier to international trade since agricultural products that exceed the permissible levels of contamination (4 to 20 ppb) are banned. About $1.2 billion in commerce is lost annually due to AF contamination, with African economies losing $450 million each year (IITA, 2013). Most small-holder farmers lack the capacity to protect crops against contamination due to food insecurity and inadequate national food safety regulations (Ilesanmi and Ilesanmi, 2011). Some studies suggest that 60 to 85% of consumers in developing countries are not protected by commercial food safety regulation (Wild, 2007). Due to the high per capita consumption of maize (44 kg/person/year; FAOSTAT, 2013) in Ghana, there is need for coordinated strategies to reduce consumer risk to aflatoxins. Earlier studies on aflatoxin contamination in maize in Ghana, Togo and Benin showed high ranges of 0.4-490, 0.7-108 and 24-117.5 ppb, respectively (James et al., 2007). Another study (Jolly et al., 2006) to measure the levels of aflatoxin B(1) (AFB(1)) albumin adducts in blood and aflatoxin M(1) (AFM(1)) metabolite in urine of consumers in major maize and groundnut consuming regions of Ghana showed high AFB(1) albumin-adduct levels in the plasma (mean+/-SD=0.89+/-0.46 pmol/mg albumin) and high AFM(1) levels in the urine (mean+/-SD=1,800.14+/-2602.01 pg/mg creatinine) of most participants. Therefore, developing integrated strategies to reduce AF to safe limits would be a critical step to upgrading the maize value chain. These should include integrated strategies targeted at post-harvest, food handling and preparation operations to reduce risk to aflatoxin exposure. This study assesses the AF prevalence in maize in order to determine consumer risk to AF in Ghana. The study characterizes the current farmer harvesting and storage operations and how these operations influence AF accumulation under small-holder storage structures.

## MATERIALS AND METHODS

### Study area

The study was conducted in six districts in the Upper East and Upper West regions of Ghana. The area has alternating wet and dry seasons with the wet season occurring between May and October during which about 95% of rainfall occurs. Severe dry conditions exist between November and April each year, during this period the northeasterly winds which stream from the Sahara desert bring masses of dust. There is wide fluctuation in temperature and relative humidity (RH) averaging around 30±5°C, 60-80%RH from June to October and 33±5°C, 30-55%RH from November to May.

### Scope of study

The survey was conducted in 6 districts, comprising of 3 districts each in Upper East and Upper West regions of Ghana, from November to December 2013. The research tools employed included field surveys, focus group discussions and key informant interviews. A purposeful sampling approach targeting main producing districts, communities and households was adopted in selecting the communities and households. In all, 240 respondents in 24 communities were covered using structured questionnaire which captured information on demographic and socio-economic factors; cropping systems and scale of production; harvesting and drying operations; storage and storage methods; duration of storage, integrated pest management strategies; farmers' knowledge of aflatoxins; and challenges in maize storage. Focus group discussions were carried out in all the 24 communities with randomly selected farmers using a checklist designed to capture all relevant information.

### Sampling and sample analysis

Grain samples (240 samples) were obtained from farmer storage units: granaries, barns, bags and silos of the respondents. Sampling was conducted in the drier part (Nov. Dec. 2013) of the year (ambient temperature ~22-33°C, Rh~45-60%); at approximately 2 to 6 weeks after harvest. Mould and aflatoxins occur in an extremely heterogeneous manner in food commodities. To ensure that samples are representative of the entire batch, triplicate samples were obtained from the proximal, mid and distal points of grain maize stored in bags, whereas the same procedure was followed at the upper, middle and bottom points of maize stored in silos, granaries and barns. The samples were then reduced to working samples through the coning and quartering method. The samples, each weighing up to 50 to 100 g, were analysed for total aflatoxin at the Plant Pathology Laboratory of ICRISAT, Mali, using the Indirect Enzyme Linked Immunosorbent Assay (ELISA) method (Waliyar et al., 2009).

### Data analysis

The socio-demographic data was analyzed using Statistical Package for Social Sciences (SPSS 16). Data sets on aflatoxin levels were subjected to Analysis of Variance (ANOVA) to determine significant differences among samples using Statistix 9. Descriptive statistics involving frequencies, mean and range were employed in reporting.

## RESULTS

### Socio-demographic characteristics

Table 1 summarizes the socio-demographic characteristics such as gender, educational level, marital status and average household income of the respondents. The average household size was 7±5 individuals and majority of respondents (72 to 77.8%) had no formal education. Most of the respondent (45.7) were could be classified as low income households of less than GH₵1000 (~US$ 256) per annum. Just a little around 10% of growers were into commercial maize production to supplement household income. Information from the focus group discussions showed that maize-based cropping systems are becoming dominant due to the high yield potential per land area compared to sorghum or millet. The contribution of maize to household income was marginal since a larger proportion of harvested grain is consumed as food. Access to market was not a critical challenge to growers; however, seasonal glut, low prices and exploitation by trader middle-men were mentioned at the group discussions.

### Postharvest operations

The main postharvest operations: method of storage; length of storage; trend of pest infestation; and pest management strategies are described in Table 2. After harvest the maize is further sun-dried, shelled and bagged for storage, but may be stored in the husk or unshelled in the silo or baskets. Majority of respondents (71.3 to 86.4%) stored maize in polypropylene (poly-sacs) compared to jute sacs; due to low cost and ready availability. Though the use of Purdue Improved Cowpea Storage (PICS) sacs has recently been introduced only few champion farmers (1%) utilized them for maize storage due to high initial cost. Majority of respondents stored maize for 5 to 8 months, and less than 1% stored beyond 12 months. Combined infestation by insect pests, rodents and grain moulds were identified by 44.1 to 60.2% as the critical challenge in maize storage (Table 2). From the group discussions, pest infestation was noticed throughout storage; albeit severity increases with prolonged storage. The duration of storage, however seems that most farmers will escape the peak insect pest infestation since they would have exhausted their stock by 8 months after storage. The common IPM strategies adopted included the application of a cocktail of pesticides to manage insects broadly described as weevils. A considerable number of respondents (20.9%)

**Table 1.** Detail socio-demographic characteristics of the 240 respondents from 2 regions of Ghana.

| Socio-demographic characteristics | | Region of Ghana | | | |
|---|---|---|---|---|---|
| | | Upper East | | Upper West | |
| | | Frequency | Response (%) | Frequency | Response (%) |
| Gender | Male | 85 | 78.7 | 93 | 78.8 |
| | Female | 23 | 21.3 | 24 | 20.3 |
| Educational level | Non-formal | 84 | 77.8 | 85 | 72.0 |
| | Basic | 14 | 12.0 | 21 | 17.8 |
| | Pre-tertiary | 8 | 7.4 | 8 | 6.8 |
| | Tertiary | 2 | 1.9 | 2 | 1.7 |
| Age | < 20 years | 2 | 1.8 | 1 | 0.88 |
| | 20-45 years | 60 | 55.6 | 75 | 63.6 |
| | 46-60 | 29 | 26.9 | 34 | 28.8 |
| | >60 years | 17 | 15.7 | 8 | 6.6 |
| Household size | 1-5 | 9 | 8.3 | 20 | 16.9 |
| | 6-8 | 24 | 22.2 | 25 | 21.2 |
| | 9-12 | 34 | 31.5 | 35 | 29.7 |
| | >12 | 41 | 38.0 | 38 | 32.2 |
| Marital status | Single | 5 | 4.9 | 9 | 7.6 |
| | Married | 95 | 88.0 | 104 | 88.1 |
| | Widowed | 8 | 7.4 | 4 | 3.4 |
| | Separated | - | - | 1 | 0.1 |
| Average household income (GH₵) | < 500 | 25 | 23.1 | 26 | 22.0 |
| | 500-1000 | 24 | 22.2 | 28 | 23.7 |
| | 1000-2000 | 33 | 30.6 | 36 | 30.5 |
| | >2000 | 26 | 24.1 | 28 | 23.7 |

did not adopt any form of protection or resorted to re-drying if infestation was noticed. Indiscriminate use of common grain protectants such as Actellic (Pirimiphos methyl), bioresmethrin (pyrethroid), phostoxin (Aluminum phosphate) was widely reported. Most farmers acquired agro-chemicals from non-accredited agro-input dealers without training on appropriate use.

## Knowledge, perception and prevalence of aflatoxins

Tables 3 to 5 describe current knowledge and perception as well as prevalence of aflatoxins (AF) from 240 maize samples. Overall, 78% have heard about AF although 68.1% did not perceive it as a major food safety issue (Table 3). Only 21.9% of respondents ever received training on AF management, however majority (88.1%) expressed readiness to adopt AF management strategies. The AF prevalence (ppb) in 240 maize samples from 24 communities is summarized in Table 4. Though no clear trend was noticed from the analysis of variance, AF prevalence in Garu-Tempane and Wa-West districts was marginally high compared to counterpart districts. Aflatoxin prevalence ranged from 0.011 to 308 ppb with wide variations occurring within and across communities and districts. Grain samples from Nabdam district showed the least aflatoxin levels with all samples recording safe limits of <4 ppb. Overall, 78.8, 92.9 and 95.4% of the samples recorded safe limits of <4, <20 and <30 ppb, respectively (Table 5).

## DISCUSSION

Aflatoxin (AF) contamination in maize have remained a significant challenge in programmes designed to improving production and utilization as well as linking small-holder farmers to international markets. This study characterized current on-farm harvesting and storage operations and provides in-depth information on AF levels which is critical to determining consumer risk to AF. Cumulatively, 92.9% of samples showed total AF not exceeding safe limit of <20 ppb; a much accepted maximum permissible level used by many countries. However, broad conclusions and inferences on AF prevalence from this study should take into consideration

**Table 2.** Description of major postharvest storage operations in the study communities.

| Postharvest operations | | Region of Ghana | | | |
|---|---|---|---|---|---|
| | | Upper East | | Upper West | |
| | | Frequency | Response (%) | Frequency | Response (%) |
| **Method of storage** | Jute sacs | 28 | 25.9 | 11 | 9.3 |
| | Poly-sacs | 77 | 71.3 | 102 | 86.4 |
| | PICS sacs | - | - | 1 | 0.8 |
| | Mud-silo | 3 | 2.8 | 1 | 0.8 |
| | Bare floor | - | - | 1 | 0.8 |
| **Duration of storage (months)** | < 4 | 36 | 33.3 | 25 | 21.2 |
| | 5-8 | 65 | 60.2 | 72 | 61.0 |
| | 9-12 | 7 | 6.2 | 19 | 16.1 |
| | >12 | - | - | 1 | 0.8 |
| **Problems of storage** | Insect pest | 33 | 28.2 | 53 | 49.1 |
| | Rodents | 10 | 8.5 | 2 | 1.9 |
| | Grain moulds Insects | 7 | 3 | 2 | 1.9 |
| | Rodents and grain moulds | 72 | 60.2 | 52 | 44.1 |
| **Peak period of insect infestation (months)** | ≤4 | 58 | 53.7 | 50 | 42.2 |
| | 5-8 | 42 | 38.9 | 37 | 31.4 |
| | After 9 | 5 | 4.6 | 5 | 4.2 |
| | No incidence | 3 | 2.8 | 26 | 22.2 |
| **Method of crop protection** | No protection | - | - | 28 | 23.7 |
| | Sun-drying | 39 | 36.1 | 7 | 5.9 |
| | Botanicals | 2 | 1.9 | 3 | 2.5 |
| | Fumigants | 11 | 10.2 | 23 | 19.5 |
| | Actellic super | - | - | 10 | 8.5 |
| | Cocktail of insecticides | 19 | 17.7 | 46 | 39.0 |

**Table 3.** Overall knowledge and perception of aflatoxin contamination in communities.

| Previous knowledge and perception of aflatoxins | Strongly disagree | | Disagree | | Not sure | | Agree | | Strongly agree | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Frequency | % | Freq | % | Freq | % | Freq | % | Freq. | % |
| I have encountered health problems from eating aflatoxin contaminated food | 64 | 28.3 | 64 | 28.3 | 44 | 19.5 | 41 | 18.1 | 13 | 5.8 |
| I have heard of aflatoxin contamination in maize | 25 | 11 | 35 | 15.5 | 6 | 4 | 75 | 33.2 | 81 | 35.8 |
| Aflatoxin contamination is a serious problem in this community | 25 | 11.1 | 50 | 22.1 | 82 | 35.9 | 45 | 9.9 | 25 | 11.1 |
| Aflatoxin contamination affects price of maize | 22 | 9.9 | 60 | 26.5 | 64 | 28 | 59 | 26.1 | 21 | 9.3 |
| I have been trained on aflatoxin management | 129 | 57.1 | 48 | 21.0 | 5 | 2.2 | 30 | 13.3 | 14 | 6.2 |
| I will adopt aflatoxin management strategies or resistant genotypes | 3 | 1.3 | - | - | 1 | 0.4 | 23 | 10.2 | 199 | 88.1 |

**Table 4.** Aflatoxin prevalence (ppb) in maize samples from 24 communities.

| Region | District | Community | Minimum | Mean±S.E | Maximum |
|---|---|---|---|---|---|
| Upper East | Bongo | Gowrietingli | 0.5 | 0.8±0.1 | 1.5 |
| | | Duah | 1.3 | 7.6±2.14 | 23 |
| | | Samboligo | 0.03 | 0.9±0.19 | 1.9 |
| | | Adaboya | 0.06 | 2.3±0.88 | 9 |
| | | | 0.03 | 2.9 | 23 |
| | Garu-Tempane | Denegu | 2.3 | 6.7±0.87 | 10.6 |
| | | Konkumada | 2.8 | 7.9±1.32 | 15.2 |
| | | Batantarugu | 1.5 | 13.4±5.36 | 50.2 |
| | | Wariyanga | 1.8 | 14.3±3.72 | 36.6 |
| | | | 1.5 | 10.2 | 50.2 |
| | Nabdam | Dasabligo | 0.011 | 1.5±0.39 | 3.1 |
| | | Sakote-Dasang | 0.2 | 1.1±0.25 | 2.7 |
| | | Sakote-Poting | 0.6 | 1.4±0.28 | 3.1 |
| | | Sakote-Kotintab | 0.5 | 1.2±0.31 | 3.1 |
| | | | 0.01 | 1.3 | 3.1 |
| Upper West | Jirapa | Nimbare | 0.1 | 1.0±0.2 | 2.0 |
| | | Ul-kpong | 0.1 | 1.3±0.22 | 2.7 |
| | | Baazu | 0.3 | 13.0±10.23 | 104.2 |
| | | Gbari | 0.5 | 1.0±0.1 | 1.9 |
| | | | 0.1 | 14.1 | 104.2 |
| | Nadowli | Ombo | 0.4 | 14.9±14.17 | 142.2 |
| | | Takpo | 0.5 | 0.8±0.05 | 1.0 |
| | | Papu | 0.6 | 31.7±30.73 | 308.3 |
| | | Nator-Douri | 0.2 | 3.5±2.55 | 23.6 |
| | | | 0.2 | 12.7 | 308.3 |
| | Wa West | Nahaa | 0.1 | 30.5±1.32 | 146.8 |
| | | Tendoma | 0.3 | 17.7±9.77 | 84.8 |
| | | Nyoli | 0.4 | 0.8±0.17 | 2.2 |
| | | Gurungo | 0.6 | 17.3±15.5 | 156.7 |
| | | | 0.1 | 16.6 | 156.7 |
| | | Grand mean | 0.01 | 8.0 | 308.3 |

Region = NS, District = NS, Community= NS, Region x District x Community = NS, S.E.D. = 12.82, CV = 57.6% Number of samples collected was 240 consisting of 40 per district and 10 per community; samples were collected in November to December 2013; about 2 to 6 weeks after harvest.

that sampling was conducted at 2 to 6 weeks after harvest. In addition, sampling was conducted in the drier part (Nov. Dec. 2013) of the year (ambient temperature ~22 to 33°C, Rh~45-60%). Yearly and seasonal influence on AF incidence has been observed in other studies. For instance, maize samples of the Kharif season in India showed higher incidence of AF (47%) compared to the Rabi season (17%) (Chandra et al., 2013). Also stored maize recorded higher incidence of AF (43%), and most contaminated samples contained AF at levels above 20 ppb.

In many related studies, similar trends and levels have been reported. In Malawi, 29 and 14% of household and local market samples, respectively exceeded the EU safe limits of 4 ppb (Manyo et al., 2009). The proportion of samples within safe levels of 4 ppb declined by approximately 30% (from 77 to 54%) after 11 months of storage under smallholder conditions while the proportion of samples deemed unsafe for human consumption (≥20 ppb) increased by 62%. In parts of Pakistan, the most prevalent mycotoxins in maize samples were AF followed by type B trichothecenes (Khatoon et al., 2012). In their study, majority of samples (27.7%) contained AFB1 ranging from 5 to 850 ppb; followed by AFB2 (18.46%). Other detected mycotoxins included nivalenol (12.31%), deoxynivalenol (9.23%), and 3 acetyl-deoxynivalenol (7.69%) with average values of 1326, 1549 and 356 ppb,

**Table 5.** Analysis of the proportion of samples considered safe for consumption based on various safe limits for total aflatoxins (ppb).

| | **Proportion of samples based on 4 safe limits for total aflatoxins for humans** | | | | **Feed and fodder limits for different types of animals** | |
|---|---|---|---|---|---|---|
| District | <4 ppb | <15 ppb | <20 ppb | <30 ppb | Up to 100 ppb | >100 ppb |
| Bongo | 33 (82.5) | 38 (95) | 39 (97.5) | 40 (100) | | |
| Garu-Tempane | 11 (27.5) | 33 (82.5) | 34 (85) | 37 (92.5) | 3 (7.5) | |
| Nabdam | 40 (100) | | | | | |
| Jirapa | 38 (95) | 39 (97.5) | 39 (97.5) | | | 1 (2.5) |
| Nadowli | 37 (92.5) | 37 (92.5) | 37 (92.5) | 38 (95) | | 2 (5) |
| Wa-West | 30 (75) | 33 (82.5) | 34 (85) | 35(87.5) | 2 (5) | 3 (7.5) |
| **Total frequency** | 189 | 220 | 223 | 229 | 5 | 6 |
| **Overall (%)** | 78.8 | 91.7 | 92.9 | 95.4 | 4.6 | 100 |

(a) Values in parenthesis are valid percentages (%) of samples per district; (b) number of respondents was 40 per district; (c) 240 samples were collected in November to December 2013; about 2-6 weeks after harvest.

respectively. Out of 660 pre-and post-harvest grain samples from major maize growing areas in Tamil Nadu of India, AF contamination was observed in 40.2% of samples (Karthikeyan et al., 2013). AFB1 was detected in 22.97% of pre-harvest and 53.9% post-harvest samples, whiles 12.1% of the total samples exceeded 20 ppb. In total, AFB1 was detected in 40.2% of samples with amounts ranging from 0.4 to 149.3 ppb. From most of these studies, the post-harvest phase was the favourable stage for AF production and thus requiring control strategies to be targeted at good storage operations.

In this study, close to 78% of respondents were aware of AF although 68.1% did not perceive AF as a major food safety issue (Table 3). This level of awareness was significantly high given that the respondents were mainly farmers in rural communities, and 74.3% had no formal education (Table 1). In a related study among health workers in Nigeria, it was found that 95% of respondents had previous awareness of AF, however class room lectures was the common source of information to 56% of respondents (Ilesanmi and Ilesanmi, 2011). They noticed that none of the health workers had ever discussed with their patients about the risk AF in food. It is well established that risk to AF ingestion is greatly reduced through information diffusion by awareness campaigns (Jolly et al., 2006; Ilesanmi and Ilesanmi, 2011). Therefore, a cocktail of information dissemination including training and radio broadcast in local languages should be adopted. Extension massages should put emphasis on prompt harvesting, adequate drying, safe moisture content, sorting out poor quality grain, grain cleaning and integrated pest management strategies (Waliyar et al., 2013). For instance, ordinary sorting in groundnut significantly reduced AF to safe levels.

Host plant resistance alongside other pre- and post-harvest strategies is often the most effective approach; however access to AF resistant varieties is still a challenge. In groundnut, the applications of lime (or any calcium source fertilizer) alone is reported to reduce AF contamination by 72% compared to farm yard manure which reduced AF by 42% under field conditions (Waliyar et al., 2008). When combined, the two sources reduced AF contamination up to 84%. Recently, the effectiveness of biological control involving the use of Aflasafe™ in the field has been reported (IITA Report, 2013). The International Institute of Tropical Agriculture (IITA) in partnership with the United State Department of Agriculture - Agricultural Research Service (USDA-ARS) and the African Agriculture Technology Foundation (AATF) developed the aflasafe™ which uses native strains of *A. flavus* that do not produce aflatoxins. These atoxigenic strains are applied to 'push out' their toxin cousins so crops are less contaminated, in a process called 'competitive exclusion'. Aflatoxin contamination in maize and groundnut was consistently reduced by 80 to 90% using aflasafe™ (IITA Report, 2013).

## Conclusion

There is need to up-scale pre-and-post-harvest strategies as well as improved food handling and preservation operations to reduce consumer risk to aflatoxins. Proven pre-harvest strategies such as resistant genotypes, soil amendments and the Aflasafe™ should be introduced to the small-holder growers. Although quite substantial information exist on risk of AF, the respondents in this study did not generally perceive AF as a critical food safety issue. This is contrary to the several fragmented projects on AF management which were being implemented by different agencies in those districts. Thus requiring the need for greater collaboration among the partners to achieve considerable progress in this regard. The Food and Drugs Board, the main food regulatory agency in Ghana, should be strengthened to provide periodic testing for AF in grain markets in addition to food safety education.

## Conflict of Interest

The authors have not declared any conflict of interest.

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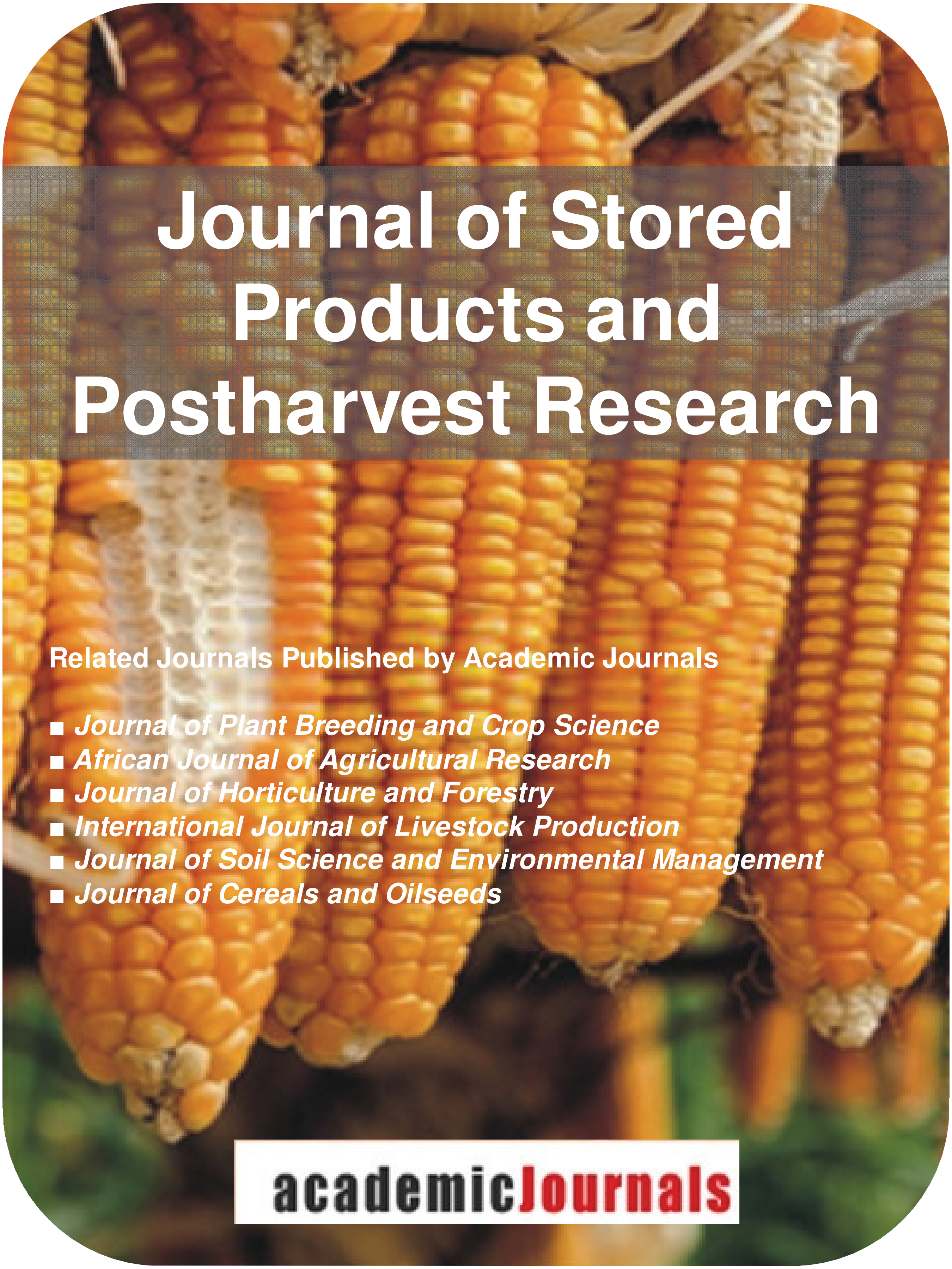

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