integrated approach. Implementing good grain and system hygiene ensures insect numbers are limited, understanding insect species and their ecology assists in managing pests, and using chemical treatments and fumigants correctly ensures insects can be controlled when needed. Cooling grain using ambient aeration systems has increased in the past 10 years and is gaining widespread acceptance as a way of managing insects and quality by reducing grain storage temperatures.

Growers are increasingly becoming aware of the need to understand the quality of their grain, particularly to ensure grain out turned from their system meets market specifications. One of the advantages of on-farm storage is the ability to segregate grain more readily by using a combination of small, medium and larger storages.

Provided growers are willing to invest in a system which meets market requirements, they are in a unique position to provide a package which delivers product identity, traceability, can meet the needs of food safety requirements and best practise. There is no question that the on-farm storage system can build on and become a larger component of the supply chain, providing confidence and integrity to the market

Food Safety – Can on-farm storage meet this requirement?

The on-farm storage system is well placed to demonstrate that the product stored is safe for consumption. The grains industry has produced a number of codes and guidelines for growers and industry to enable this. "Growing Australian Grain – Safely Managing Risks with Crop Inputs and Grain On-farm" is a guide for growers and advisors to help manage risks with inputs, grain handling and safety on farm.

Grain Trade Australia has produced in collaboration with industry the Australian Grain Industry Code of Practice for the post harvest/post farm sector. Both of these documents enable growers to begin the journey to manage the risks associated with grain production and storage. The grains industry has also developed GrainCare which is a HACCP based quality assurance system which directly enables the grower to demonstrate they meet food safety requirements and are independently audited and assessed.

With the development of a modern, fit for purpose on-farm storage system, which can manage quality, identity preservation, outturn and food safety risks, there is a growing opportunity for the supply chain and market to access grain post farm gate with the confidence that supply chain integrity is maintained.

Conclusion

There is no doubt that the on-farm grain storage system is an integral and growing part of the supply chain. Growers need to ensure they understand their role in the supply chain, and invest in technologies, systems and training which enable them to implement best practise in their grain storage system.

Ensuring that the integrity of the supply chain is maintained requires all parties to do their part and give feedback to all stakeholders. Growers can and will respond to the needs of their market, providing a product which can provide traceability, product identity and assure the product meets food safety requirements. Managed correctly, the on-farm storage system can be a growing opportunity for markets to access quality products direct from the grower, minimising the risk to the end user and supply chain.

Strengthening national food safety for improved food security in Nigeria

Louise Abayomi

Natural Resources Institute, Food and Markets Department, University of Greenwich, ME4 4TB, UK
Email: l.abayomi@gre.ac.uk
DOI 10.5073/jka.2018.463.007

Abstract

A review of literature concerning the quality and safety of eight key staple products in Nigeria, West Africa, was made. These products included stored rice, maize, cashew, yam, cassava, millet, sorghum, and beans. Food safety notifications, both national and international concerning mycotoxins, pesticides, and quality in these foods are highlighted. Across these commodities, a significant number of non-conformances were found, arising from a combination of factors including lack of technical knowledge, supply chain management, and public institutional and policy challenges. The paper discusses the subsequent impact on health, well-being, and the economy. Current strategies aimed at improving food quality and safety in the country was also examined. Recommendations in addressing some significant issues are given.

Keywords: Food security, Nigeria, cowpea, safety, HACCP

The accepted definition of food security is when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life. In Nigeria, only recently, is food safety seen as an integral part of food security. According to a report by the Nigerian Federal Ministry of Agriculture and Rural Development (FMARD), the country is beset with an inability to either meet domestic food requirements or export agricultural products of the desired quality or safety standards. The agricultural sector in Nigeria suffers from inadequate infrastructure and resources, inadequate financial investments, weak food control systems, obsolete food regulation systems as well as inability to enforce compliance to international standards. The country lacks effective functioning, comprehensive food inspection mechanisms. Laboratory support is also woefully inadequate. Most supply chains in the country are inefficient, with poor traceability systems (The Agriculture Promotion Policy, 2016-2020), and thus national food control is weak.

Cassava, is one of a number of targeted export crops for 2016-2018 by Nigeria's Federal Ministry of Agriculture and Rural Development FMARD. In addition, rice, cowpea (beans), and maize are three of the five targeted domestic crops prioritized for 2016-2018. In terms of nutritional losses and safety, numerous studies have shown many marketed samples of rice across the Nigeria to contain harmful mould causing mycotoxins which is a public health concern (Makun et al., 2011; Egbuta et al., 2015). Maize samples across the country have been found to contain harmful levels of mycotoxins, particularly aflatoxins (Egbuta et al., 2015). The extent to which cashew nuts pose a real food safety risk owing to contamination during storage and marketing is not clear as there are few reported studies. Yam and cassava, however, are commonly processed into dried products using traditional methods. Dried yam derivatives such a 'Elubo' is common amongst the Yoruba tribe as a weaning food for babies. There have been many instances where Elubo has been found to contain elevated levels of mycotoxins, lead, and iron. Gari, a popular cassava derivative has again been found to contain aflatoxins in particular. Millet and sorghum samples across the country have also been shown to contain harmful mycotoxins in a number of studies. The Standards Organisation of Nigeria (SON) has drafted Codes of Practice for cowpea. However, maintaining cowpea quality is posing a significant challenge for farmers and traders, who may store for up to a year. Cowpeas vary according to the size of the grain, color of the skin, texture of the skin, and amount of damage resulting from insects. Consumers prefer beans with few insects present. This has led to the use of unauthorised pesticides in some cases. Due to the detection of high quantities of the unauthorised pesticide dichlorvos, the European Commission Implementing Regulation (EU) 2015/943 temporarily suspended the import of dried beans from Nigeria to the EU in 2015. The ban is still in place.

The Rapid Alert System for Food and Feed (RASFF) of the European Union which highlighted the safety concerns of Nigerian cowpeas was put in place to provide food and feed control authorities with an effective tool to exchange information about measures taken responding to serious risks detected in relation to food or feed. The legal basis of the RASFF is Regulation EC/178/2002 which highlights the principles and requirements of food law, and procedures relating to food safety. Concerning agricultural exports, processed or unprocessed, Nigeria does not export many products in significant volumes, with the exception of raw cocoa. Nevertheless, there were around 200

(RASFF) food-related notifications between the period January 2013 and March 2018 originating from Nigeria, over 50% of which were classified as ' serious', ~40% 'not serious' and around ~10% 'undecided'. Cowpea (or beans) were responsible for over 40% of the serious notifications and resulted in border rejections. The non-conformances mainly concerned the presence and levels of unauthorised chemicals such as dicholorvos, cyhalothrin, chlorpyrifos, dimethate, proferiofos, and trichlorphos in cowpea though the National Agency for Food and Drug Administration and Control (NAFDAC) has produced guidelines and regulations for the import, manufacturing and distribution of pesticides and other chemicals, food additives and fats and oils, and port inspections (http://www.nafdac.gov.ng/). Certification and inspection of food and produce is carried out by the Standards Organisation of Nigeria (SON), Agricultural Quarantine Service (NAQS), NAFDAC, the Federal Produce Inspection Service (FPIS), or a combination of agencies. In addition, the Nigerian Food Safety and Applied Nutrition (FSAN) Directorate's mandate is to ensure that food manufactured, imported, exported, distributed, sold, and marketed in Nigeria meets the highest standard of Food Safety reasonably available and protect public health and consumer interests. It is evident that the environments in most rural areas which is where significant production, postharvest handling, and processing takes place, the monitoring and enforcement of safety standards, and marketing and storage conditions are not conducive to protecting the highlighted products from contamination.

A group of international food safety experts and regional representatives met in 2012 to determine the requirements for an African food safety authority, similar to the EU's European Food Standards Agency (EFSA), along with a communication system such as the RASFF. The effectiveness of RASFF is achieved by having a simple structure: it consists of clearly identified contact points in the Commission, EFSA, EFTA surveillance authority and at national level in member countries. One of the issues highlighted for the failure of the Nigerian government to address over fifty warnings on exported cowpeas before the ban was imposed, was the uncoordinated reporting structure to the various responsible agencies responsible for food safety (TAIEX Report, 2016). A representation of structure of the RASFF is depicted below (Figure 1).

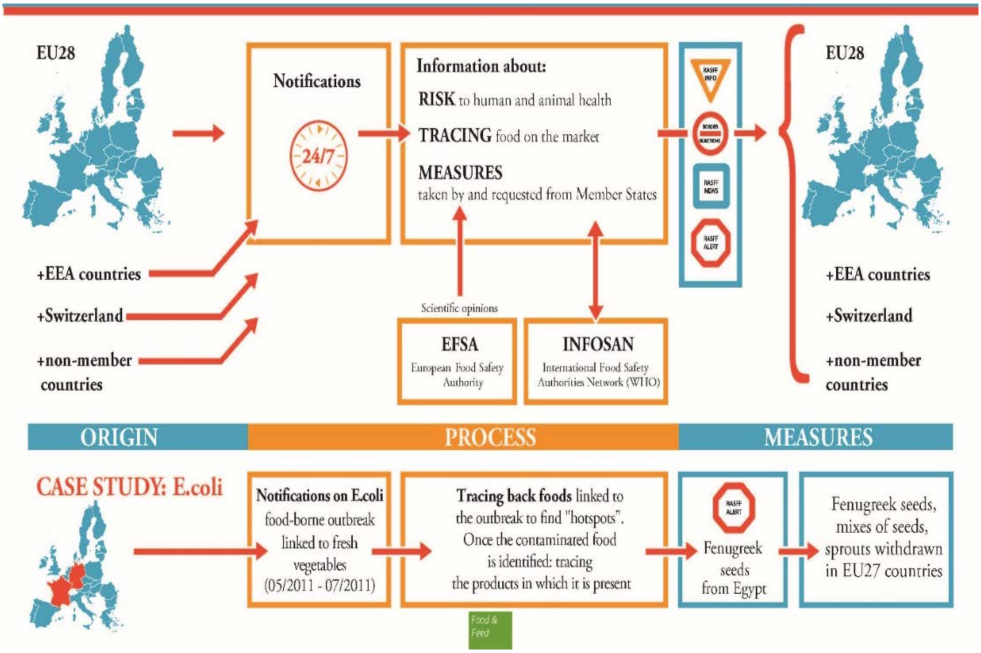

Figure 1: Workings of the European Rapid Alert System for Food and Feed

Source:https://ec.europa.eu/food/sites/food/files/safety/rasff/images/030614_how_does_it_work.jpg

Other serious RASFF alerts originating from Nigeria came in form of notifications relating to aflatoxin B1 (in nutmeg, groundnut, dried ugu leaves, dried bitter leaf, dried ginger, suya pepper, and sesame seeds in particular), various strains of Salmonella (in raw ginger, melon seeds, and sesame seeds in particular), *E. coli* (in ogbono, *Irvinia gabonensis*), and colouring Sudan Red in palm oil.

Unsafe food poses major economic risks. For example, the *E. coli* outbreak in Germany in 2011 was estimated to cost US$ 1.3 billion in losses for farmers. Food-borne disease outbreaks, such as cholera, typhoid, lassa fever, chemical contamination like lead and mercury as well as mycotoxin poisoning, is thought to be responsible for thousands of deaths in Nigeria. However, the exact numbers will not be known owing to poor surveillance and reporting mechanisms. However, Odeyemi (2016) estimated that well over 35 million people (~20%) in Nigeria are affected by foodborne illnesses annually. The true economic and health impact of these illnesses is yet to be properly quantified.

Many African countries including Nigeria are becoming increasingly interested in regional and international trade, with demands to strengthen their Sanitary and Phytosanitary (SPS) capacity, and are consequently trying to address their national food safety issues. As a result, a common framework for the countries is being developed. International cooperation and technical support for African countries in areas of agriculture, food security and food safety is centred around the Comprehensive Africa Agriculture Development Programme (CAADP). In spite of such efforts, it is unlikely significant changes in Nigeria will be made over the next 5 years. This is reflected in the absence of a realistic budget set aside by successive governments to transform the food security situation in the country, including a detailed timebound, auditable, and accountable implementation strategy.

Over 70% of the food in Nigeria is produced in rural areas where farmers and traders often have not gone beyond secondary school education. The Nigerian government must therefore develop a practical and workable strategy to sensitize and educate such stakeholders on good hygiene practices. Achieving food safety begins with ensuring good agricultural practices in production at the farm level. Further, open markets and vendors with basic facilities should be in place. Many foodborne illnesses are well known to be preventable when adopting proper handling, processing, and storage methods for foods guided by HACCP principles. Therefore, the provision or accessibility of appropriate infrastructure to facilitate this such as clean water, power supply, good processing facilities, and physical market design, alongside regular basic HACCP and food handling training of food handlers and vendors should be made in order to significantly reduce the number of incidents of foodborne illnesses and deaths and support the national economy.

References

O. ODEYEMI, 2016. Public health implications of microbial food safety and foodborne diseases in developing countries, Food & Nutrition Research, 60:1, DOI: 10.3402/fnr.v60.29819

MAKUN , H. A., DUTTON, M. F., NJOBEH, P. B., MWANZA, M., AND A. Y. KABIRU, 2011. Natural multi-occurrence of mycotoxins in rice from Niger State, Nigeria. Mycotoxin Research, 27:97–104.

EGBUTA, M. A., WANZA, M. M., AND M. F., DUTTON, 2015. Evaluation of five major mycotoxins co-contaminating two cereal grains from Nigeria. International Journal of Biochemistry Research and Review, 6(4): 160-169.

Nigeria's agriculture promotion policy 2016-2020, 2016. Building on the successes of the ATA, closing key gaps. Policy and Strategy Document.

Expert Report: Expert mission on TAIEX Workshop on Integrated Pest Management and Maximum Residue Levels of Pesticides. REF: AGR 61394. 21-23 March 2016.

Insect Pests and Fungal Pathogens in Maize Stored in Ghana

James K. Danso[1], Enoch A. Osekre[1], George P. Opit[2], Naomi Manu[1], Pail R. Armstrong[3], Frank H. Arthur[3]*, James F. Campbell[3], George N. Mbata[4], Samuel G. McNeill[5]

[1]Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
[2]Oklahoma State University, Stillwater, OK, USA
[3]USDA, Agricultural Research Service, Center for Grain and Animal Health Research, 1515 College Avenue, Manhattan, KS, USA
[4]Fort Valley State University, Fort Valley, Georgia, USA
[5]University of Kentucky, Princeton, KY, USA
*Corresponding author Email: frank.arthur@ars.usda.gov
DOI 10.5073/jka.2018.463.008

Abstract

Insect infestations and mycotoxin contamination contribute to postharvest degradation and crop loss in sub-Saharan Africa, including maize stored in Ghana. Surveys were conducted to assess the prevalence of insect pests and fungal pathogens in stored maize from the major and minor cropping seasons (September to December and January to April, respectively) that was stored on-farm and in retail markets in Ghana. Results show differences between the major and minor storage seasons for on-farm sites and retail markets. The presence of internal feeders such as *Sitophilus zeamais* (Motschulsky) was positivly correlated with insect-damaged kernels and percentage weight loss. Levels of aflatoxin were generally greater than the established threshold of 15 ppb early in the major crop storage season, while fumonisins were generally lower than threshold levels of 4.0 ppm in on-farm sites and in the retail markets.

Keywords: maize, storage, management, insects, mycotoxins

Introduction

Stored-product insects are a major threat to food security in sub-Saharan Africa, with loss estimates due to insects and associated mycotoxins ranging as high as 70%, depending on the specific commodity, storage site, and management strategies (Hell and Mutegi, 2011; Affognon et al., 2015; Kumar and Kalita, 2017). Major insect pests include the larger grain borer, *Prostephanus truncatus* (Horn), maize weevil, *Sitophilus zeamais* (Motschulsky), lesser grain borer, *Rhyzopertha dominica* (Fauvel), and Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Darfour and Resentrater, 2016). Interactions between insect infestations and subsequent prevalence of mycotoxins are known to occur (Lamboni and Hell, 2009). Many African countries have set tolerances for mycotoxins; for example, the allowable limits for aflatoxin and fumonisin in Ghana are 15 ppb and 4.0 ppm, respectively (Ghana Standards Authority, 2013). In 2015 to 2016, surveys were conducted by the Department of Crop and Soil Sciences of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, to assess insect pest populations and mycotoxin content of maize stored on-farm and in commercial markets. The United States Agency for International Development (USAID), through the U.S. Government's Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHLIL) funded this work conducted in Ghana.

On-farm sites

The survey of on-farm sites was conducted in the Middle Belt crop production region of Ghana, which is the primary grain-producing region of the country. Complete details of this survey are described in Danso et al. (2017). In this study, a total of 51 farm sites were sampled from three separate geographic areas within the Middle Belt of Ghana: Ejura, Sekyedumase, and Amantin. Sampling was conducted on maize on stalks just before harvest, maize piled on the ground as unshelled cobs pending threshing (shelling), or maize shelled and then stored for distribution to grain markets. For the field sampling and sampling from ground piles, maize cobs were collected from different areas within the piles, then dehusked and mixed into 500-g replicate lots, and the kernels stored for subsequent analysis and processing. Sampling for the third category, dried maize, was done by collecting 2-kg samples, then sub-dividing and mixing into 500-g lots as described for the first two categories. For each sample, temperature, moisture content, and relative humidity (r.h.)

were assessed using a John Deere moisture meter (Armstrong et al., 2017). Samples were sieved to collect live insects. Separate subsamples were taken to analyze for aflatoxin and fumonisin, using a standard Romer Labs test kit (romerlabs.com). Complete data analyses are given in Danso et al. (2017) and Armstrong et al. (2017), and will be summarized here in general terms.

Data for each species were summed over the entire year and analyzed first by Chi-Square analysis (SAS Institute) to determine differences between the three sites at each geographic area, and then summed by the months associated with major season storage (September to December) and with minor season storage (January to April) to determine differences between storage season. The predominant species collected were *S. zeamais* and *S. cerealella*, with ground piles as the site where most were found (Table 1) in the respective geographic areas. The other species in order of abundance were *Carpophilus dimidiatus*, *Cathartus quadricollis*, *Cryptolestes ferrugineus*, and *Tribolium castaneum*, with ground piles again being the site where most *C. dimidiatus* and *C. quadricollis* were found (Table 1). *Cryptolestes ferrugineus* and *T. castaneum* were the least prevalent species (Table 1).

Table 1. Total numbers of *S. zeamais* (SZ), *S. cerealella* (SC), *C. dimidiatus* (CD). *C. quadricollis* (CQ), *C. ferrugineus* (CF), and *T. castaneum* (TC) collected from three types of on-farm areas where maize was stored after harvest (Field, Ground Piles, and Post-drying) in Ejura, Sekyedumase, and Amantin during September to April. Sum totals within columns followed by different lower-case letters are significantly different (Chi Square, $P < 0.05$).

Location	Site	SZ	SC	CD	CQ	CF	TC
Ejura	Field	85b	71b	37b	48c	7a	0a
	Ground pile	200a	128a	76a	126a	9a	8a
	Post-Drying	181a	35c	26b	70b	15a	8a
Sekyedumase	Field	69b	48b	52a	40b	2a	0a
	Ground pile	149a	76a	70a	75a	6a	2a
	Post-Drying	141a	25c	63a	41b	10a	4a
Amantin	Field	112c	86b	17b	59a	6a	7a
	Ground pile	236a	125a	46a	76a	9a	13a
	Post-Drying	189b	58c	49a	65a	9a	6a

More *S. zeamais* were collected in the minor season compared to the major season in all three locations, but the only difference for *S. cerealella* occurred in Amantin (Table 2). More *C. dimidiatus* were collected from the major season compared to the minor season, while differences were mixed or not significant for the other four species (Table 2). Temperatures in all locations and sampling sites ranged from about 27.0 to 34.5°C during the period of the experiment. Moisture content was more variable, but in general ranged between 15 and 27% during the major season, and declined from September to December, with the low moisture content levels predominantly in the post-drying samples (as expected) (Danso et al., 2017). MC in the minor season ranged from about 9 to 17%, with less variation between sites, but MC was usually lowest in the post-dried samples. Neither temperature nor moisture content were correlated with the insect populations ($P < 0.05$). Numbers of *S. zeamais* were positively correlated with percentage of IDK and with kernel weight loss ($P < 0.05$). This was the primary species contributing to IDK and weight loss, as it is an internal feeder.

Average aflatoxin levels at all three locations were well above the tolerance level of 15 ppb during the major season, but ranged between 0.6 and 3.6 ppb during the minor season (Table 3). Fumonisin levels were below the tolerance level of 4 ppm.

Market Sites

The survey of market retail sites was also done in the Middle Belt of Ghana, in the geographic regions of Ejura, Techiman, and Amantin. The maize that was sampled was bagged mixed-variety white maize. Samples were taken monthly from September to April by randomly selecting 100-kg polypropylene or jute bags, inserting a 1.2-m grain probe into the bag (Seedboro, Chicago, IL, USA), and withdrawing a sample of approximately 350 g. Three samples were taken from the bag, mixed, and 500 g weighed out for sampling for insects. In selected months, a second 500-g sample was collected for mycotoxin analysis, as described above. The maize was sampled from the same market location, but not from the same bags each time as this was an active retail market. Maize was also sampled for temperature, moisture content, and r. h. Collection procedures, sample preparation, and methodology for collecting insects, is the same as described above. More detailed descriptions of methodology are found in Danso et al. (2018), along with complete depictions of the results. Data from this study are re-analyzed and summarized here to present important findings from the market survey.

Table 2. Total numbers of *S. zeamais* (SZ), *S. cerealella* (SC), *C. dimidiatus* (CD). *C. quadricollis* (CQ), *C. ferrugineus* (CF), and *T. castaneum* (TC) collected in Ejura, Sekyedumase, and Amantin during the Major and Minor seasons (data for the three sites combined). Sum totals within columns followed by different lower-case letters are significantly different (Chi Square, $P < 0.05$).

Location	Season	SZ	SC	CD	CQ	CF	TC
Ejura	Major	117b	111a	97a	95b	10a	1b
	Minor	349a	123a	42b	148a	21a	15a
Sekyedumase	Major	109b	73a	106a	72a	13a	2a
	Minor	250a	76a	79b	84a	5a	4a
Amantin	Major	121b	54b	94a	85b	7a	2b
	Minor	416a	215a	18b	115a	17a	24a

Table 3. Average aflatoxin values (ppb, means ± SE) during the major and minor seasons in Ejura, Techiman, and Amantin. Data from Danso et al. 2017. All comparisons by season were significant ($P < 0.05$, SAS, Tukey's Honestly Significant Difference Test).

	Major Season	Minor Season
Ejura	39.2 ± 9.1a	3.2 ± 0.1b
Sekyedumase	24.8 ± 0.8a	3.6 ± 3.6b
Amantin	23.4 ± 4.0a	3.6 ± 0.2b

There were six predominant stored-product insect species collected from the market samples: *S. zeamais*, *C. ferrugineus*, *C. quadricollis*, *S. cerealella*, *T. castaneum*, and *C. dimidiatus*. Data for each species were summed over the entire year and analyzed first by Chi-Square analysis (SAS Institute) to determine differences between markets, and then summed by the months associated with major season storage (September to December) and with minor season storage (January to April) to determine differences between storage season. The order of species abundance, in terms of total numbers, is arranged from left to right in Table 4, with *S. zeamais* as the predominant species. Varying levels of these six species were found in all markets, with no consistent differences between markets (Table 4).

Table 4. Total numbers of *S. zeamais* (SZ), *C. ferrugineus* (CF), *C. quadricollis* (CQ), *S. cerealella* (SC), *T. castaneum* (TC), and *C. dimidiatus* (CD) collected from three different maize markets in Ghana during September to April. Sum totals within columns followed by different lower-case letters are significantly different (Chi Square, $P < 0.05$).

Market	SZ	CQ	SC	TC	CF	CD
Ejura	816b	192a	112c	121a	100b	80a
Techiman	960a	139b	180a	125a	67c	37b
Amantin	930a	116b	207a	85b	144a	62a

Data were then summarized to compare total numbers during the major versus the minor season. For 14 out of the 18 comparisons (6 species x 3 markets), there were more insects collected during the major versus the minor season, and only one instance where there were more collected during the minor versus major season (*C. quadricollis* in the Amantin market) (Table 5).

Table 5. Total numbers of *S. zeamais* (SZ), *C. ferrugineus* (CF), *C. quadricollis* (CQ), *S. cerealella* (SC), *T. castaneum* (TC), and *C. dimidiatus* (CD) collected from each market during the major season vs the minor season. Sum totals within columns for each market followed by different lower-case letters are significantly different (Chi Square, $P < 0.05$).

Market	Season	CF	SZ	CQ	SC	TC	CD
Ejura	Major	91a	702a	113a	90a	77a	77a
	Minor	8b	116b	73b	22b	43b	3b
Techiman	Major	60a	786a	82a	80a	58a	31a
	Minor	8b	174b	57b	100a	67a	6b
Amantin	Major	136a	811a	28b	140a	49a	58a
	Minor	7b	119b	88a	67b	36a	5b

Again, temperature combined for all markets during the storage months was about 27 to 32°C, well within favorable limits for insect population development. Moisture content combined for all markets ranged from a high of approximately 15% in September to a low of about 9% in December, then began to increase until April. However, most of the *S. zeamais* collected during the major season storage were collected in November and December (see Danso et al., 2018), the months with the lowest MC. There was no correlation between temperature or MC and insect pest populations ($P < 0.05$). Average aflatoxin levels at all three market sites were far above the tolerance level of 15 ppb during the major season, but less than 4 ppb during the minor season (Table 6). Fumonisin levels were below the tolerance level of 4 ppm.

Table 6. Average aflatoxin values (ppb, means ± SE) during the major and minor seasons in markets in Ejura, Techiman, and Amantin. Data from Danso et al. 2018. All comparisons by season were significant ($P < 0.05$, SAS, Tukey's Honestly Significant Difference Test).

	Major Season	Minor Season
Ejura	66.2 ± 14.6a	3.4 ± 0.4b
Techiman	58.9 ± 14.2a	2.9 ± 0.2b
Amantin	28.0 ± 8.7a	3.1 ± 0.2b

Conclusions

Temperature was generally within 27 to 32°C during these studies, which is within the optimum range for development of the collected species (Howe, 1965; Fields, 1992), and hence was not correlated with the insect populations. The predominant stored-product insect collected in the on-farm and market sites was *S. zeamais*, but it was surprising that no *P. truncatus* were collected given the extensive presence of this species in stored maize, particularly cob-stored maize, in western Africa. Few *R. dominica* were collected as well, and this species is also listed as one of the main storage pests in Africa. More *S. zeamais* were collected during the minor season compared to the major season in the on-farm sites, but the reverse was true for the market sites. During the minor season, the maize is left on stalks for long periods to dry, in contrast to the major season, which is a possible explanation for the greater incidence of S. zeamais during the minor season. The greater infestation in the market sites during the major season versus the minor season may be because the maize in the market sites could have already been infested when the maize was brought to those sites. In addition to the seemingly greater insect populations in maize with high MC, drying of newly-harvested maize is also essential to reduce fungal contamination. Results show improved storage management, which includes integrated pest management strategies for drying and storing maize, may be necessary to limit economic losses and ensure food security.

Acknowledgements

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. The US Department of Agriculture is an equal opportunity provider and